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Performance of Agronomic Crop Varieties in Alaska 1978–2012

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Feed barley growing at the Matanuska Experiment Farm in Palmer August 7, 2014. Agronomic crop variety performance trials and crop development and adaptation research have been a part of the Agricultural & Forestry Experiment Station's work in Alaska since it was first established in the territory in 1898. These varieties were all bred and developed in Alaska. From left to right: Plot 1 = Otal, Plot 2 = Wooding, Plot 3 = Lidal, Plot 4 = Datal (just off the edge). A fifth plot to the far right is growing Weal (see page 17 for more on feed barley).

—Photo by Robert M. Van Veldhuizen

SCHOOL OF NATURAL RESOURCES AND EXTENSION
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Introduction

There is no such thing as the perfect crop variety for Alaska. Some varieties are adapted to a wide range of climatic and geographic locations, while others are more specific in their adaptation. The change in elevation of a few hundred feet or a move of a few miles can have a considerable effect on the performance of any variety. Also, cultural practices such as tillage, fertilizer rates, planting date, seeding rate, pest control, and a multitude of other factors can influence crop yields. This is especially noticeable in northern environments such as Alaska. For example, date of planting studies done by F.J. Wooding (1973) and C.W. Knight (1989) determined that any date after the middle of May for planting an agronomic crop such as barley in interior Alaska can result in delayed maturity, low yields, and low quality grain, even for the best adapted varieties for Alaska.

Another problem in northern environments is photoperiod, or the length of sunlight and darkness in one 24-hour day. Soybeans, for example, will germinate and grow well in Alaska, but do not flower until there is about 10 hours of daily darkness. This does not occur until mid-August, which does not give the plant time to develop and reach maturity before the first killing frost. Less obvious, but of equal importance, are many winter grains, such as winter wheat and winter rye. These are typically planted in late summer to early fall (mid-August), producing a small rosette of vegetative growth that builds up root reserves and go dormant in the winter. Then the next spring the plants produce a seed head, growing similarly to spring grains that are harvested in the fall.

Testing winter rye varieties at the Agricultural and Forestry Experiment Station (AFES) Matanuska Experiment Farm in Palmer, L.J. Klebesadel (1969) proved that long daylength caused nonadapted varieties to grow more rapidly as seedlings. This resulted in a low buildup of root reserves and, consequently, a low winter survival rate. Klebesadel (1971) also determined that covering perennial grass varieties to simulate a dark period in the fall would increase winter survival and thus forage yields the next season. Of course this is impractical on a large scale, but it illustrates the importance of variety testing and selection in the northern environment.

Agronomic crop variety testing has been conducted in Alaska ever since Russians established agricultural villages in the early 1800s to support the activities of the Russian American Company. Ninilchik is the only remaining settlement of those original villages founded as agricultural stations. After Alaska became a district of the United States, the USDA established a number of Alaska Agricultural Experiment Stations (AAES) to continue the evaluation and cultural development of agronomic crops, at Sitka (1898–1932), Kodiak (1989–1925), Kenai (1898–1908), Rampart (1900–1925), Copper Center (1903–1908), Fairbanks (1906–present), and Matanuska (1917–present). Of these stations, Rampart on the Yukon River was the main location for testing and breeding agronomic crops at the beginning of the 20th century. Similar to those at the early Russian American Company agricultural stations, many of the varieties tested were of Russian and Finnish origins. It was there that G.W. Gasser successfully bred the first agronomic crop for Alaska, 'Trapmar' (Rampart spelled backwards), a hooded, six-row, hulless spring forage barley released in 1920 (Wooding 1979a). Since then, crop breeding programs from around the circumpolar north have developed new varieties to improve yields, disease resistance, fertilizer use efficiency, and overall crop quality. As this work continues in Alaska, agronomists and other growers test varieties of traditional and nontraditional crops to determine which is best adapted to any particular climatic, soil, and geographic location within the state.

The performance of new varieties is evaluated against the known performance of standard varieties. These standard varieties are ones that have consistently performed at a given geographic location over several years. Characteristics that are evaluated against those of the standard varieties are seed and in some cases forage or biomass yield (pounds/acre and bushels/acre), plant growth characteristics (percent lodging and plant height), quality (test weight in pounds/bushel), and maturity (growing degree days and planting date to 50% mature). Growing degree days (GDD) are calculated from the average daily temperature minus a standard low temperature at which there can be no continued crop growth. That low temperature point for crops in this report is the freezing point of water, 32°F. The GDD calculation for each day is then added to the preceding GDD value to determine the cumulative value over a given period. This cumulative value is then used to determine the needed heat units for a particular crop or variety to reach a specific physiological growth stage. The time required for any variety to reach a specific physiologic growth stage can vary greatly from one year to another and from one location to another. This time frame, however, is correlated to the number of warm days or heat units received during each growing season. As an example, the typical number of days from planting to 50% physiological maturity growth stage is around 85 days for barley grown in the interior of Alaska. This is about 2,400 GDD. In a warm year, that number of days to 50% maturity might be only 80 days and in a cool year as much as 100 days, or a 20-day difference. However, the number of GDD for both years would be very close to the same 2,400 GDD as the average.

Maturity in grain or other seed is when it is physiologically mature, and is a precise term typically used by agronomists. In other words, the mature seed can germinate and grow, given the right conditions. However, at this point in the growth cycle the moisture content of the seed is still very high (30% or so). The seed is still soft enough that a farmer can perform a pinch test and still leave a dent in the kernel with the thumbnail. This is not the ripe stage. Ripeness refers to when enough moisture has been lost so that the seed can be harvested with minimal damage and it can be handled, cleaned, and stored. Ripe moisture levels are around 12–20%. The pinch test at this point will not leave a dent in the kernel. The term "ripe" is used by both agronomists and growers to signify that point when the seed can be safely harvested. Both terms are heard more often in Alaska because many tested varieties will reach a level of significant maturity but will not reach ripeness because of the short growing season and the lack of enough growing degree days. Finally, when the grain is mature, ripe, and ready for harvest, it should be, as part of a three-step process, ready for storage or sale: 1) the grain has to reach a level of physiological maturity, 2) the moisture levels need to be reduced to an acceptable level of ripeness, and 3) the grain is now ready for harvest, cleaning, and storage.

Other characteristics that are often evaluated are the seed and/or biomass nutritional qualities as an animal feed or for human food. This would include a measure of crude protein (percent nitrogen) as well as other major nutrients such as percent phosphorus (percent P) and potassium (percent K). The data presented in this publication from these measures are averages across all the years of testing of each crop or variety. As such, the data are intended to be used as a guide for potential yields, days to maturity, or crop quality at each of the test locations. These data are presented here without statistical analyses.

New varieties with a wide range of characteristics are selected for testing, with emphasis on early maturity because of Alaska's short growing season. Secondary characteristics that are used to select varieties for testing are the reported high yield and quality, because these characteristics reduce input costs and increase value of the final product for the producer. As a result, older varieties are constantly being replaced with newer varieties that have proven to be better adapted to a particular geographic location. The current recommended varieties are described in detail within each subsection. Evaluations of experimental breeding lines from plant breeders are not presented here unless those lines eventually were released as a specific cultivar.

The recommended varieties within each subsection are those varieties that have consistently performed well over time for a particular location. They are high-yielding, high-quality, early-maturing varieties for which certified seed is generally available. Lack of successful maturity and yield for a specific variety or crop indicates that it is not well adapted to the climatic or geographic location in which it was tested. However, just because there was a crop failure of a specific variety does not mean that it might not be able to be successfully grown somewhere within the state. The old Alaska adage "If you don't like the weather here, wait five minutes or move five miles" holds true for the production of crops as well. Therefore, the reader is not discouraged from trying any of the crops or varieties not recommended. However, the probability of success in attempting to produce those crops or varieties will likely be low. Any producer will most likely have to become his or her own processor and marketer as well because there are very few large-scale commercial processing facilities in Alaska set up to accept niche crops. There are, however, many small-scale flour mills and oil presses that could be set up on-farm for local processing and marketing by the producer.

This publication is not a crop production manual. Its main purpose is to provide basic information on small grain and oilseed variety testing, along with information on successful cultural practices identified by research conducted from 1978 through 2012. Crops are grouped into general sections based on the agronomic characteristics of the plant:

- True cereal grain crops, which are annual grasses that form seed heads. The seeds are then eaten whole or processed into flours.
- Pseudo-cereal crops, which are annual broad-leaved plants where the seed is treated similarly to cereal grains.
- Pulse crops, which are annual legumes with seed that is harvested dry at maturity (from the Latin *puls,* meaning porridge).
- Edible and industrial oilseed crops, which are annual broad-leaved plants with seeds high in extractable oils.
- Tuber-producing crops, which are annual broad-leaved plants that form edible tubers below ground (note that potatoes are not a part of this publication).

Within each of the general agronomic crop sections, specific crops are presented in separate subsections with general cultural information on fertilization, tillage, planting, pest control, harvest, and storage, followed by tables listing yields, maturity, and quality for all known varieties tested at each location within the state. In each subsection there is also a list, description, and seed source for all recommended varieties. Because many different crops may have similar cultural requirements, the information will tend to be repetitive among sections and subsections, but each crop can be reviewed separately from others. The crops in each subsection are not listed alphabetically, but rather in order of potential for consistently producing a successful crop in at least one location within the state. There have been many previous publications that describe grain and oilseed variety testing in Alaska during this period. Most important was the "Performance of Cereal Crops in the Tanana River Valley of Alaska" series by F.J. Wooding and others that was published from 1979 to 1986. Information on barley, oat, and wheat varieties presented in those publications is not repeated here, except as the list of varieties. Summarized here are reports on grain and oilseed varieties tested during that period but unreported due to such factors as poor crop performance, extreme weather conditions, and budget reductions. All small grain, oilseed, and alternative crop variety trials done after 1986 are also summarized in this publication.

With the recent release of 'Sunshine' hulless barley by the plant breeding program at the AFES Matanuska Experiment Farm, there has been an increased interest in growing grains and oilseeds in a small-scale garden setting for personal use in Alaska. Even though this publication is intended more for large-scale agronomic crop production, the same principles can apply to grow a high-yield, high-quality crop successfully on a small scale. The same information on soil fertility, seeding rates, weed and insect control, diseases, harvesting, and cleaning methods will apply on a few square feet just as well as on many acres (one acre equals 43,560 square feet). For more information on growing grains on a small scale in Alaska the reader is referred to the publication, "Growing Small Grains in Your Garden," by B. Van Veldhuizen (AFES Circular 135, published 2010), which is available online through the publications link of the School of Natural Resources and Extension (SNRE) at www.uaf.edu/snre/research/publications/.

There are a number of issues that must be considered after choosing any particular crop for production. The first of these is soil fertility. Proper fertilization is important in the production of a high-yielding and high-quality grain crop. It is very important to use a soil test to determine which plant nutrients are limiting and how to correct for those deficiencies. Soil testing should be done in the fall in the field in which next year's crop will be grown. Work with your local Cooperative Extension Service agricultural agent to take soil samples for available nutrient analysis and interpretation of the results (there will be a fee charged for the analysis at a commercial laboratory). In general, all soils should receive a complete mix of nitrogen, phosphorus, potassium, sulfur, and boron.

The plant nutrition sources can be either a commercial chemical mineral fertilizer blend, or an organic type such as fish meal, liquid fish emulsion, or composted manures. Complete chemical mineral fertilizer blends typically available in Alaska usually consist of one or more of the following: ammonium sulfate, urea, monoammonuim phosphate, triple superphosphate, potassium chloride (muriate of potash), or potassium sulfate (sulfate of potash). Regardless of the source, each fertilizer material should have the chemical analysis of %N-%P_2O_5-%K_2O (and in some cases %S or %Cl) on the label.

The nutrient concentrations in chemical mineral fertilizers are usually higher than in organic fertilizer sources. The concentrations in organic fertilizers will vary depending on the source of the organic nutrients. These organic nutrients may not always be available as quickly as those from chemical mineral fertilizers. Chemical fertilizers are more readily available, usually as soon as they are dissolved in the soil water.

All nutrients from organic matter only become available through a biochemical process called mineralization that soil microorganisms facilitate. Recent studies on fish wastes as nitrogen sources for barley by M. Zhang and others (2010) and cattle manure as nitrogen sources for oats by M. Zhang and others (2006) indicated that there was potentially a long-term residual nutrient effect when these organic wastes were applied at the recommended rates for nitrogen. However, there are still questions about how fast all nutrients (not just N) will become available and how efficient different crops are at recovering those nutrients, especially in the colder soils typical in Alaska.

Nutrient concentrations and availability from composts will vary considerably depending on the source and quantity of the raw materials that go into the pile. If using commercial composts, be sure to read the label or have your own on-farm compost tested through your local agricultural Extension agent. All types of fertilizer sources (chemical and organic) can be broadcast and incorporated with spring tillage but only portions of mineral blends can be banded next to or with the seed at planting. The plant nutrient ratios of N, P_2O_5, K_2O, and S suggested in this publication are based on research that use chemical mineral fertilizer blends available in Alaska. These will provide the needed nutrients during the time frame required for optimal plant growth. However, the reader is not discouraged from trying any organic source that is available in the quantities necessary to supply the required nutrients in the time frame needed by growing plants. Regardless of the fertilizer source, the recommended application rate should be determined from the soil test results. Actual percentages of each fertilizer material required as well as the rate of application vary with the soil test results.

Specific nutrient recommendations (in lbs/acre) are not generally presented in this publication for a number of reasons. First, soil types (texture, pH, organic matter content, nutrient content, etc.) as well as the growing environment (temperatures, precipitation, evaporation rates, etc.) vary greatly between all locations in the state. As an example, sandy loam soils in a low-precipitation location such as the Delta Junction area would have a lower available nitrogen content, thus requiring a higher nitrogen fertilization rate, compared with silt loam soils in a high-precipitation location like the Palmer area. Compounding this problem is that the soils in the Palmer area are moderate in available aluminum (allophane soil). This aluminum lowers the soil pH and bonds with phosphorus, making it unavailable for plant use and requiring a higher phosphorus fertilization rate.

Second is the cropping history of each of the fields where the following year's crop will be grown. For example, a grain crop following a heavily fertilized crop like potatoes in the rotation wouldn't need as much plant nutrients (low fertilizer rate) as the same crop following a fallow year where no plants were grown (medium rate), which wouldn't need as much as the same crop grown continuously (high rate), which wouldn't need as much as the same crop grown in newly cleared ground with high organic matter content (very high rate).

Third is the type of soil test performed to determine the amount of available nutrients. As an example, there are 3 different types of soil tests that can be used to determine the amount of potentially available phosphorus (P) in soils. Olsen's test is used to determine available phosphorus in alkaline soils (pH >7) where phosphorus is bound to calcium to form unavailable calcium phosphates, which occurs in soils at the Fairbanks location. The Bray-1 test is used to determine available phosphorus in neutral to acidic soils (pH <7) where phosphorus is bound to iron or aluminum to form unavailable iron and aluminum phosphates, which occurs in soils at the Delta Junction and Palmer locations. The Mehlich-3 test is also used on neutral to acid soils but has a stronger extractant chemistry to get more of the measurable phosphorus as well as many other nutrients such as potassium (K), calcium (Ca), magnesium (Mg), copper (Cu), zinc (Zn), iron (Fe), and manganese (Mn). Each of these 3 tests will have very different concentrations of phosphorus (in ppm) for the range of very low (unavailable P) to very high (available P), which then require different interpretations for fertilization recommendations. G.J. Michaelson and C.L. Ping (1989) and G.J. Michaelson and others (1991) have resolved this problem to use the Mehlich-3 test as the standard soil test method for all Alaska soil nutrient recommendations except for nitrogen (N). However, the same soil tested in any lab outside of Alaska might not have the same recommendations. Therefore, it is very important to contact and work with your local agricultural Extension agent for more information on soils, soil nutrition and testing, and plant-specific nutrition requirements, or visit their website at www.uaf.edu/ces/ (see Appendix 1 for addresses and contact information).

The second issue is the source of the seed. Use of certified seed is strongly recommended. In recent years, feed barley that was contaminated with wild oats (*Avena fatua* L.) has been used to plant the following year's crop. This strain of wild oats has become resistant to herbicides and is now a serious weed problem in many fields in Alaska. Certified seed has strict limits on maximum content of weed seeds and diseased kernels, and must meet a minimum percent germination. This helps to ensure good germination and emergence and reduces weed and disease infestations. The standards for certified seed (blue tag on the seed bag) as outlined by the Alaska Seed Growers Association (1985) are as follows:

- Minimum of 96% pure seed
- Maximum of 14% kernel moisture
- Maximum of 2% inert matter (chaff, dirt, etc.)
- Maximum of 0.25% other crops
- Maximum of 0.20% other varieties of the same crop
- 0% diseased (toxic) kernels (*Fusarium* blight, ergot, etc.)
- 0% objectionable weed seeds
- 0.05% other weed seeds
- Minimum of 85% germination

Use of certified seed along with the agronomic practice of including a year of summer fallow before planting can potentially reduce or eliminate the use of pesticides (as well as lower the amount of needed nutrients). A year of summer fallow involves a number of mechanical tillages to cut back on the amount of weeds by allowing weed and volunteer crop seed to germinate and grow for a short time (usually before flowering) before incorporation back into the soil. This also cuts back on the amount of crop residues, reducing the amount of diseases and detrimental fungal populations. Also, without plants or plant residues present, harmful insect populations are reduced. All of this reduces or potentially eliminates the need to apply herbicides, fungicides, or insecticides during the year the crop is grown.

This publication includes the use of chemical control measures as an effective tool within integrated pest management strategies (IPM) for agronomic crop production. Integrated pest management is a more balanced approach to pest control that involves action to anticipate pest outbreaks in order to limit potential economic or aesthetic damage. It requires accurate pest identification, measurement of population levels, assessment of differing levels of damage (economic and aesthetic), and knowledge of all different pest management strategies or tactics, of which one tool is the use of pesticides. However, not all pesticides are registered for use in Alaska and some niche crops don't have any registered pesticides for any use. Also, studies by C.W. Knight and C.E. Lewis (1981), J.S. Conn and C.W. Knight (1984), J.S. Conn (1990), and S. Seefeldt (2011) indicate that some herbicides are persistent in the cold soils that occur in Alaska. In temperate climates these herbicides are quickly broken down by sunlight or through biochemical degradation by soil microorganisms. If they are not broken down, then the effects could carry over in the following year's crop with potential yield or seed quality reductions. With this in mind, IPM should be the first line of defense against pest infestations. Work with your local Cooperative Extension Service IPM pest scout. More information on IPM can be obtained at the program's website at www.uaf.edu/ces/ipm/ (see Appendix 1 for addresses and contact information).

All general use and restricted use pesticides are regulated by the U.S. Environmental Protection Agency (EPA) through the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and the Federal Food, Drug, and Cosmetic Act (FFDCA), as amended by the Food Quality Protection Act (FQPA). As defined under this legislation, the label on the pesticide product is a legal document. Uses inconsistent with product labeling are prohibited and against the law. As such, a pesticide may be applied to control a pest not specified on the label as long as it is applied to a crop or a site that is specified on the label. For example, this means that an EPA-registered insecticide can be used to control cutworms in canola only if the crop, canola, is specified on the label. The pest, cutworms, doesn't need to be specified on the label, although it would be better if it did as this would improve the chances of effective control. Also, the label will specify all methods and frequency of application, concentrations, and any allowed tank mixes with other pesticides or fertilizers. There will also be a very important section on every label called Agricultural Use Requirements that applies to all agricultural workers and pesticide handlers. The worker protection standard (WPS) stipulates that all pesticide workers and handlers receive pesticide safety training as well as a list of all personal protective equipment that must be worn when handling or working with the pesticide. Therefore, if any pesticide use is recommended by IPM, remember always to read the label and follow the directions on mixing, application, and disposal. More information on all EPA-registered pesticides and pesticide labels can be obtained at the EPA website, www.epa.gov/pesticides/.

General-use pesticides can be bought and used by the general public without special permits. They are lower in toxicity and have lower potential to cause harm to humans or the environment. There are many general use pesticides that are registered by the EPA. The remainder are the restricted-use pesticides (RUP). These can only be sold and used by a certified applicator. If the use of an RUP is warranted from IPM then the applicator, who would most likely be the farmer or producer who is growing the crop, needs to be licensed and certified in the proper category. For most situations where the farmer or producer is working on their own farms this would be category 3–Private Agricultural Pest Control. Pesticide applicator licensing and training is done by the Department of Environmental Conservation under the Pesticide Control Program. Alaska statute, Title 18 – Environmental Conservation, Chapter 90 – Pesticide Control covers the state definitions and requirements for pesticide applications. More information is on the DEC website, http://dec.alaska.gov/commish/regulations/index.htm or with the local DEC Environmental Health Officer (see Appendix 1 for addresses and contact information). Pesticide training programs are run by the local Cooperative Extension Service office. For more information, contact your local agricultural Extension agent. Work with your local Cooperative Extension Service IPM pest scout to determine the most effective control measure, including non-chemical controls like summer fallow.

A third issue to consider is the type of crop that is being brought into Alaska and its potential to become an invasive weed. For example, white and yellow sweet clover (*Melilotus alba* and *Melilotus officinalis*) and bird vetch (*Vicia cracca*) were brought into Alaska as potential legume forage crops. They have since rapidly expanded beyond their cultivated range and encroached upon the edges of the wilderness in many of the more developed areas of the state. Less obvious is the oilseed borage crop, purple viper bugloss (*Echium plantagineum* (L)). It is native to western and southern Europe and northern Africa. Since its introduction to North America as a potential oilseed crop, it has escaped cultivation and become an invasive weed in much of the southern United States. It grows best in temperate climatic zones so the potential for it becoming an invasive weed in Alaska is most likely limited to the Interior. This could potentially cause it to be included in the list of invasive and noxious plants for Alaska, perhaps limiting its potential as an oilseed crop. For more information on invasive weeds in Alaska contact your local Cooperative Extension Service IPM pest scout or visit the Committee for Noxious and Invasive Plants Management for Alaska (CNIPM) website at www.uaf.edu/ces/cnipm. The regulations for import of seed into Alaska are covered under Alaska statute Title 11, Administrative Code, Chapter 34, Plant Health and Quarantine, administered by the state Division of Agriculture, Department of Natural Resources. This includes the very important seed inspection phytosanitary certificate that must accompany every seed lot imported into Alaska from outside of the United States. More information on seed lot inspections can be found on line at the website, http://plants.alaska.gov/pdf/SOA-seed-regs.pdf or with the local office of the state Division of Agriculture or the Alaska Seed Growers Association (see Appendix 1 for addresses and contact information).

The final issue for consideration is to determine the cost/benefit of producing the crop. This publication is not intended to provide a cost/benefit analysis for production of any crop or product, only to provide the agricultural requirements to grow each agronomic crop. However, the reader must be aware of the costs of production (seed, fertilizer, fuel, equipment, etc.) to produce a high-yielding, high-value crop, along with, as mentioned above, the likelihood of being one's own processor and marketer into the bargain.

Test Site Characteristics

Fairbanks Area Test Site Characteristics

The Fairbanks test site is located on the lower fields of the Agricultural and Forestry Experiment Station (AFES) Fairbanks Experiment Farm on West Tanana Drive of the University of Alaska Fairbanks campus. The elevation of this test site is approximately 500 feet. Agronomic crop variety evaluations have been conducted here since the establishment of the Fairbanks Experiment Farm in 1906. This is a Tanana mucky silt loam (D. Mulligan 2004) that has been conventionally farmed for about 80 years.

All crops were planted into soil that had been summer fallowed the previous season. Also, large quantities of animal manures have been added to the fields over the years, which has made the soil quite uniform with high levels of available nitrogen, phosphorus, and potassium. There is a perched water table above the permafrost at about 27 feet deep and the main water table is located about 65 feet deep. This is an alluvial soil in the Tanana River floodplain. As a result, there is a high concentration of calcium carbonate and calcium sulfate salts dissolved in the groundwater. These salts are brought to the surface by soil capillary rise due to the evaporation rate being greater than the precipitation of the area. These salts make the soil slightly alkaline to neutral in acidity (pH). This soil has a pH range of about 7.0-7.5.

It is at this location since the early 1990s where selections of open-pollinated oilseed varieties that are better adapted to Alaska growing conditions have been made. These selections were tested against known oilseed varieties at the Fairbanks, Delta Junction, and Palmer sites over a number of years for early maturity, high yields, and quality. This has resulted in the eventual unofficial release in 2008 of 'Midnight Sun-flower', a dwarf open-pollinated oilseed sunflower. Continued research into the selection and cultural practices of an open-pollinated Polish canola are ongoing.

The average date of planting for Fairbanks for the years 1978-2012 was May 12. As mentioned previously, date of planting and fertilizer rate studies conducted by F.J. Wooding (1973) and C.W. Knight (1989) determined that late May to early June planting dates may result in delayed maturity and reduced yields and test weights. On the other hand, it is important not to work this soil too early when it is still too wet, because a hard surface crust can result, impeding emergence. Also, soil temperatures in early May are around 40°F. Wet soils tend to be even colder. This causes delayed and uneven germination, resulting in poor stands. Preparing the seedbed as soon as the soil has dried out enough to work without forming clods results in better maturity and higher yields.

Coauthor Mingchu Zhang driving a tractor while Robert Van Veldhuizen operates a cone seeder at the Fairbanks Experiment Farm, spring 2009

For the Fairbanks area, the average total precipitation for the month of May for the years 1978-2012 was only 0.59 inches, with most of that falling in the last half of the month (Fig. 1). This means that most of the soil moisture needed for successful seed germination and seedling establishment comes from spring snowmelt or residual moisture from the previous year. It becomes important therefore to have a rough soil surface, or leave last season's stubble standing throughout the winter to trap snow and reduce spring runoff. This allows for greater water infiltration into the soil profile before seedbed preparation.

A packer pulled behind the tillage implement helps to seal in soil moisture, and a drill equipped with press wheels also helps conserve moisture. Another method for conserving soil moisture and nutrients is to include a year of mechanical summer fallow in the field rotation. Summer fallow helps incorporate the previous season's stubble, straw, and this year's weeds, speeding the breakdown and decomposition of organic matter. This decomposing organic matter binds the soil particles together to increase tilth, moisture retention, and nutrient availability. The only drawback is that there will not be any standing stubble left to trap snowmelt. Also, in areas prone to high winds over the winter, significant soil erosion can occur unless the soil surface is left in a rough condition from the last tillage, with many ridges and furrows to trap blowing snow and soil particles.

The average cumulative number of GDD for the month of May in the Fairbanks area was 525 (degrees F) (Fig. 2). This is sufficient for germination and emergence of most cool-season small grains and oilseeds. Planting and germination are delayed in a cool, wet May because soil conditions are too cold and wet for early tillage. This happened in the 1992 season, which had only 306 cumulative GDD and a total precipitation of 1.15 inches. That year, planting was delayed until May 28.

Estimates of germination uniformity were taken by determining the number of plants by counting the number of seed leaves, from germinated seed, emerging from the soil within a measured distance in each drill strip. Under average soil and weather conditions, 50% emergence usually occurs 7 to 10 days after planting. For the 1992 season, 50% emergence occurred about 10 days after planting on June 7. In contrast, planting can occur on the average date or earlier during a warm dry spring, but there may be a delay in germination due to insufficient soil moisture. This occurred during the 1981 season, which had 655 cumulative GDD and only 0.40 inch of total precipitation. Planting for that year was on May 12, but 50% emergence did not occur until 14 days after planting on May 26. Average June rainfall for the study period was 1.78 inches with the precipitation events evenly scattered throughout the whole month (Fig. 1).

Average cumulative GDD to the end of June was 1,345 (Fig. 2). Among years, June does not appear to be as variable in GDD as May. For example, the 1992 season continued its cool, wet trend with only 1,118 cumulative GDD and 2.69 inches of total precipitation. In comparison, the 1981 season had 1,370 cumulative GDD with an above-average total precipitation of 2.84 inches. By the last week of June through the first week in July, grain varieties usually have heads fully emerged from the flag leaf. The seed begins to fill as nutrients are translocated. Average time to 50% headed for the study period was July 4 with 1,474 cumulative

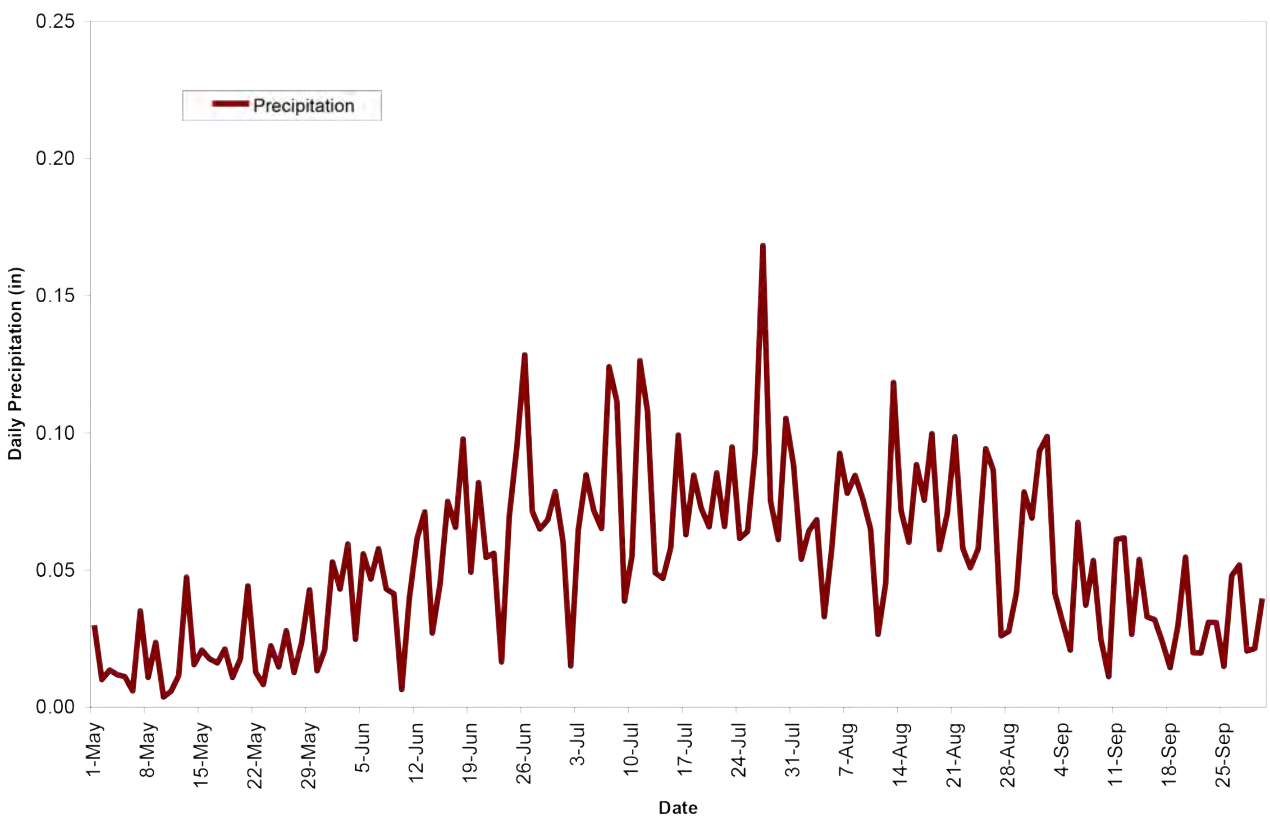


Figure 1. Average daily growing season precipitation for the Fairbanks area, 1978–2012.

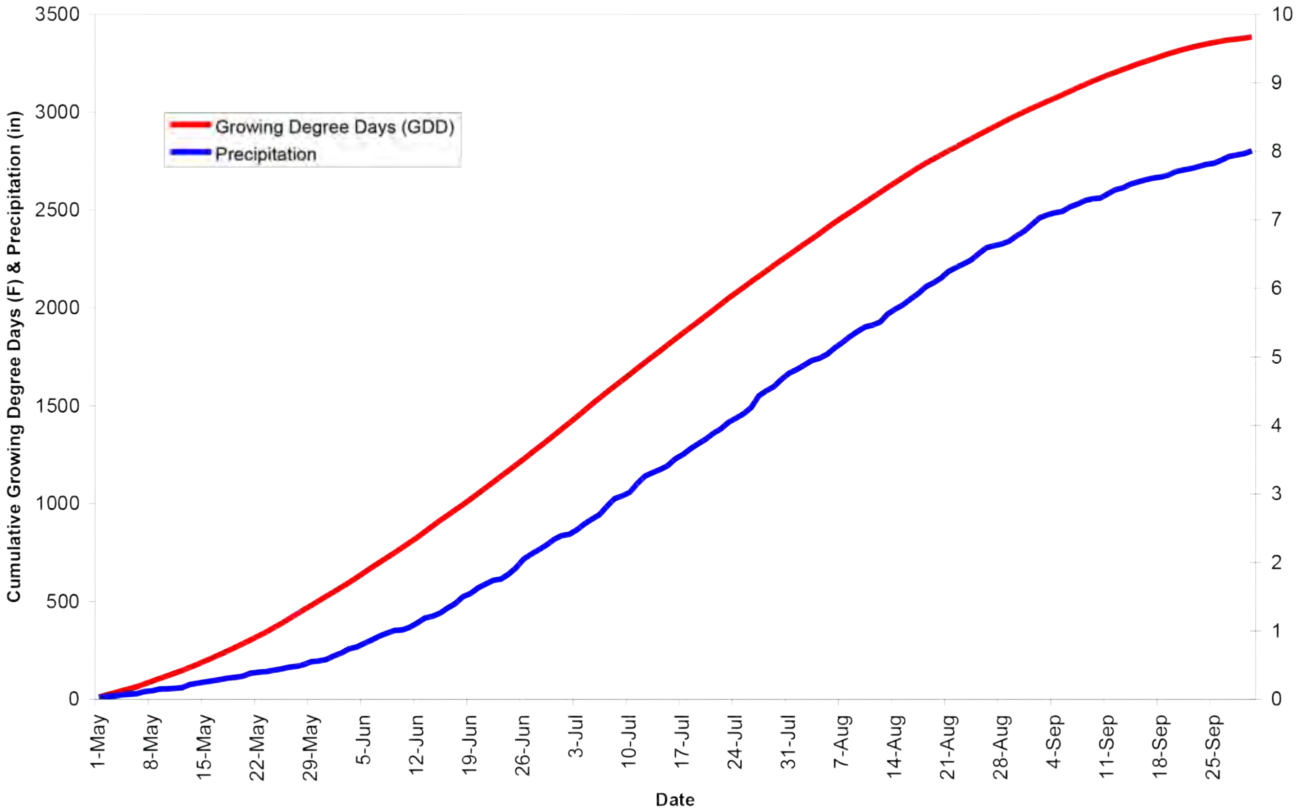


Figure 2. Average cumulative growing degree days and precipitation for the Fairbanks area, 1978-2012.

GDD. Even years that had a delay in germination and emergence; reached the 50% headed physiologic growth stage by this time. For example, the average 50% heading for 1992 occurred on July 5 with 1,290 cumulative GDD; the average 50% heading for the 1981 season occurred on July 7 with 1,526 cumulative GDD.

July and August are the rainiest months for the study area. The average total precipitation was 2.41 inches for July and 2.06 inches for August (Fig. 1). By the end of July, an average of 2,268 cumulative GDD had accumulated and at the end of August 2,998 cumulative GDD (Fig. 2). The accumulation of GDD for this period is relatively low because the average daily temperature is decreasing.

Compared with the previous months, by the end of August there is even less variation between years in GDD. For example, the 1992 season's cool, wet trend continued, with only 2,820 cumulative GDD and 2.34 inches total precipitation, while the 1981 season had 2,786 cumulative GDD and below-average total precipitation of 1.47 inches.

By late July to early August, most crops have reached the 50% maturity physiologic growth stage. This is when the seed is mature enough to germinate but not yet ripe enough for harvest. Heavy precipitation events accompanied with high wind during this period can cause severe lodging of tall, weak-stemmed varieties. (Lodging is the bending or breaking of grain stems that puts the seed heads near the ground, making harvest difficult.)

The average time to 50% maturity for the Fairbanks area was August 4 with 2,377 cumulative GDD. The average 50% maturity for 1992 occurred on August 2 with 2,138 cumulative GDD. By contrast, the 1981 season was cooler in late July and early August. These cooler temperatures caused most grain to reach 50% maturity 2 weeks later than average, on August 18 with a higher than average 2,520 cumulative GDD.

September's average total precipitation for this period (1978-2012) was 1.16 inches, with the greatest portion falling during the first half of the month (Fig. 1). An average of 3,381 cumulative GDD occurred in September (Fig. 2).

During late August to early September, the seed is ripening and losing moisture. Harvest can be scheduled when the seed has reached ripeness and has low moisture content. Individual precipitation events can delay harvest, but care must be taken not to delay too long because a precipitation event near the end of the month can be a wet, heavy snow that causes excessive lodging and makes harvest impossible. Late August to early September is also when the first killing frosts can occur (temperatures below the freezing point of water). With late maturing varieties or those that produce an abundance of late tillers, this can result in green, high-moisture seed at harvest. Green seed can be removed at harvest by increasing the airflow through the combine or by precleaning before drying grain. This can result in lower total yields.

The last month of the 1992 season had only 2,955 cumulative GDD and total precipitation of 0.01 inches. To add to the season's difficulties, there was a killing frost on September 10, significantly reducing total yields. The 1981 season had a near-normal 3,123 cumulative GDD and a total precipitation of 1.11 inches for September. There was an early killing frost on August 17 of that season, but temperatures warmed up after that, which helped speed ripening and harvest. Total yields were higher than average for that season.

Eielson Area Test Site Characteristics

The Eielson test site was located on a private farm in the Eielson Agricultural Project, 6 miles south and 2 miles west of North Pole. The elevation of this test site is approximately 540 feet. The soil is an Eielson fine sandy loam (D. Mulligan 2004) that had been conventionally farmed for about 10 years before variety trial evaluations were begun. Trials were conducted at this location from 1993-2001. Eielson soil is usually 10 to 40 inches of fine sandy loam over sands and gravels, although that depth is highly variable; sand and gravels may be near or even at the surface.

Tillage practices at this site were identical to those at the Fairbanks site. All crops were planted into soil that had been summer fallowed the previous season. This recently cleared soil still contains large amounts of organic matter in the form of woody material and moss. This type of organic matter is more resistant to decomposition than grain straw, adding to soil variability. This soil is very low in available nitrogen and phosphorus, but has moderate potassium levels. Like the Fairbanks site, this alluvial soil is in the Tanana River floodplain. The distance from the river is less than a mile, and the elevational difference from the river is only a few feet. The water table is about 5 feet deep. The groundwater contains a high concentration of calcium carbonate and calcium sulfate salts that are brought to the surface by capillary rise. These salts make the soil slightly alkaline to neutral in acidity with a pH range of about 7.0-7.5.

The Eielson Agricultural Project was started in the mid-1980s. Small grain, oilseed, and alternative crop variety evaluations were begun in 1993 to determine the performance characteristics of crops for the area. Even though this soil is sandier than the silt loam soil at the Fairbanks site, the low elevation in relation to the Tanana River and seasonally frozen soil result in large areas of standing water in the fields in early May. This resulted in an average planting date of May

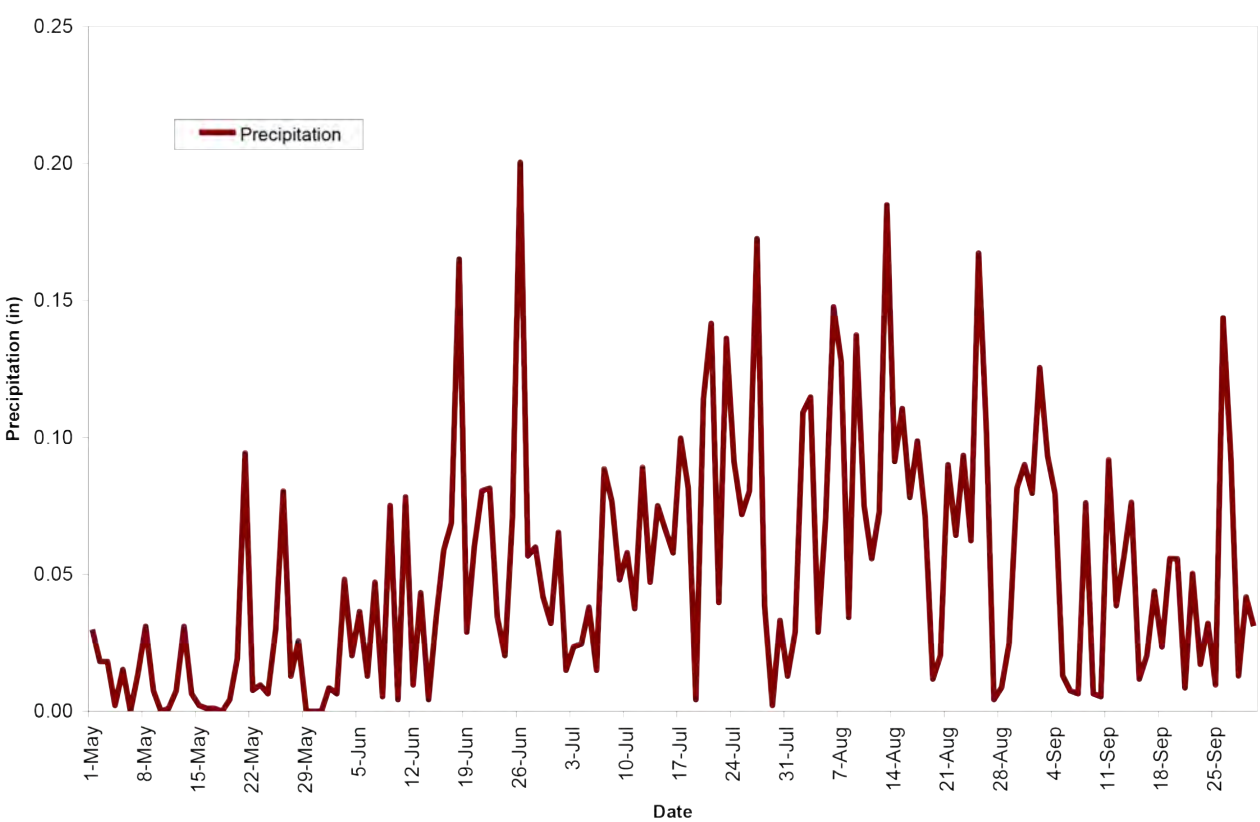


Figure 3. Average daily growing season precipitation for the Eielson area, 1993-2001.

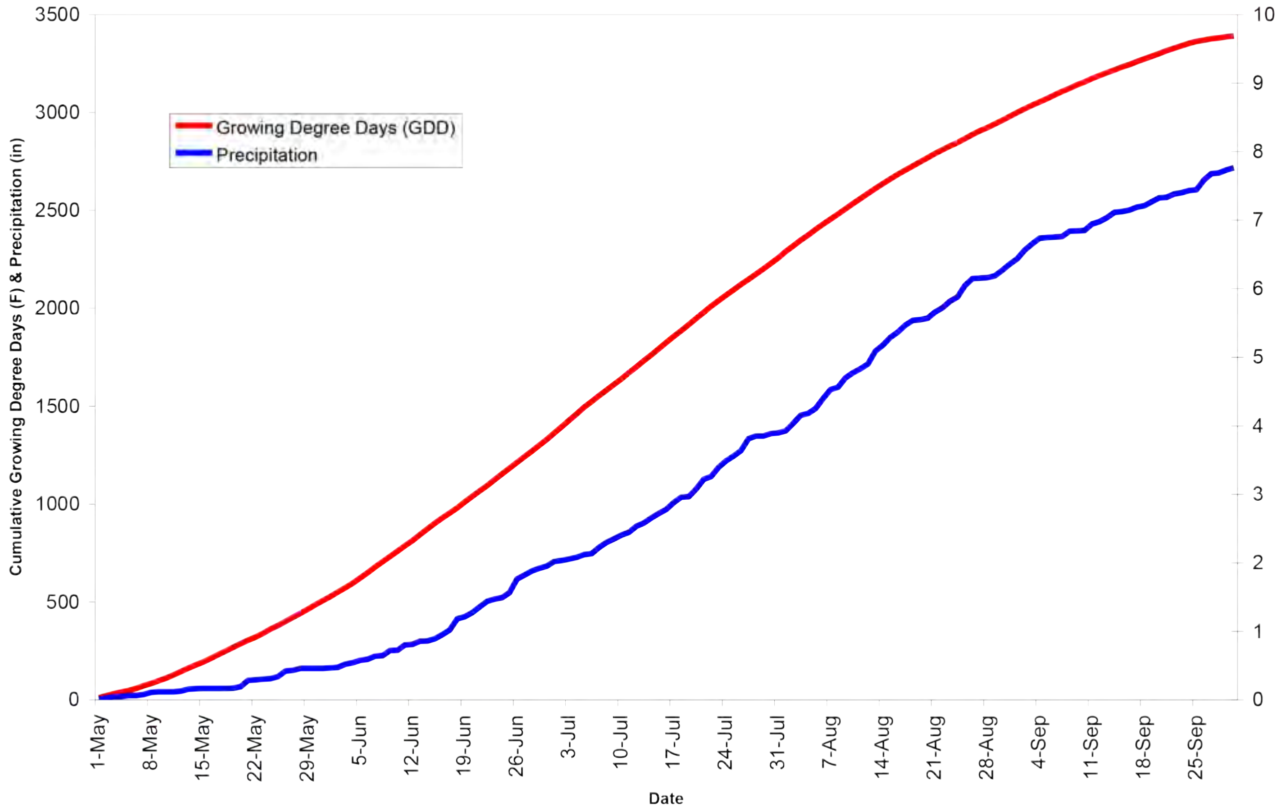


Figure 4. Average cumulative growing degree days and precipitation for the Eielson area, 1993–2001.

12 for the years 1993-2001, which is the same average date as the Fairbanks area. Uneven topography in this area causes marked differences in soil moisture during the growing season. The sandier texture allows the higher portions of a field to dry out quickly, while the lower portions remain wet. This uneven soil characteristic translates into uneven germination and emergence. Field leveling would greatly reduce this tendency. As with the Fairbanks site, preparing the seedbed as soon as the soil has dried out enough to work without forming clods results in better germination, earlier maturity, and higher yields.

The Eielson Agricultural Project is only 20 miles southeast of the Fairbanks site, and weather patterns are similar. The average total precipitation for the month of May for this area (1993-2001) was 0.66 inch, with most of that falling in the last two-thirds of the month (Fig. 3). Average cumulative GDD for May was 505 (degrees F) (Fig. 4). Conservation of soil moisture is important because the soils are sandy and tend to lose moisture rapidly. Soil moisture conservation practices similar to those employed at Fairbanks site should be followed here as well. Because of the variability in soil organic matter and moisture, germination and emergence was spotty, sometimes extending into June. In most years, this variability in germination resulted in uneven ripening in the field at harvest.

The average total precipitation for June (1.71 inches) was similar to the Fairbanks site, with precipitation events scattered throughout the month (Fig. 3). Average cumulative GDD for the end of June (1,323) were also similar (Fig. 4). Although germination and emergence were uneven, the crops still reached 50% headed physiologic growth stage at close to the same time as the Fairbanks site. Average time to 50% headed for the study period was July 7 with 1,546 cumulative GDD. One result of the uneven emergence was an increased number of late tillers. Where gaps in the plant canopy due to the lack of emergence allowed increased sunlight to reach the base of the small grain plants, tillering was stimulated.

July and August were also rainy months for the Eielson area, with an average total precipitation of 2.31 inches for July and 1.97 inches for August (Fig. 3). The number of average cumulative GDD for the end of July at this site was 2,249, with 2,973 for August (Fig. 4). These values are similar to those at Fairbanks for this period. The average 50% maturity physiologic growth stage was reached at this site on August 10 with 2,515 cumulative GDD. However, due to the large number of late tillers that formed, a large portion of the crop was still green, not physiologically mature, and did not mature before the first killing frost. Lower nitrogen levels at this site also tended to result in shorter than normal plant heights. Low nitrogen coupled with moderate levels of potassium resulted in low incidences of lodging.

Average total precipitation for September was 1.08 inches distributed throughout the month (Fig. 3), and average cumulative GDD at the end of this month were 3,353 (Fig. 4). As in July and August, both of these values are similar to the long-term averages for Fairbanks. Due to the uneven soil conditions, spotty germination and emergence, and abundance of late tillers, crops were late maturing and still had high moisture content late into September. Over time, with continued tillage and cropping, the soils in the Eielson area should become more uniform. This should reduce incidence of spotty germination and emergence, as well as the number of late tillers, producing a more uniform, evenly maturing grain crop. With the lower precipitation level, an evenly maturing grain crop would be ripe and ready to harvest sooner than at the Fairbanks site.

Delta Junction Area Test Site Characteristics

There were a number of short-term test sites within the Delta Junction area. Before the 1978 growing season and through the 1981 season, research plots were located on a private farm off of Remington Road, 2 miles north and 8 miles east of Delta Junction. The elevation of this test site is approximately 1,125 feet. The soil in this area is a Gerstle-Moosehead complex (T. Pink 2008) that before 1978 had been conventionally farmed for about 20 years. Gerstle-Moosehead complex soils are deep (4 to 5 feet) silt and very fine sandy loams over sands and gravels. Because of the long-term history of conventional farming practices, this soil is quite uniform, with high levels of good-quality organic matter that speeds up decomposition and nutrient release. There are also moderate levels of available nitrogen and potassium in this soil and low levels of available phosphorus. This is an alluvial soil in the floodplain of the Clearwater River, which is a spring-fed tributary of the Tanana River. The water table is about 60 feet. The pH range is slightly acidic at about 5.5-6.5.

From 1994-1996 a field pea study was conducted on a private farm in the Tanana Loop area, 5 miles north and 4 miles east from Delta Junction. The elevation of this test site is approximately 1,050 feet. The soil in this area is a Salchaket very fine sandy loam similar in characteristics to the Tanana mucky silt loam described for the Fairbanks site. The main difference with Salchaket soil is that there isn't any permafrost in the soil profile. This is also an alluvial soil in the Tanana River floodplain. It was conventionally farmed for about 15 years with annual applications of dairy manures before studies were conducted. The site tested relatively high in available nitrogen, phosphorus, and potassium, but because of the uneven application of animal wastes the field was not uniform. The water table in the area is about 30 feet. The groundwater contains a high concentration of calcium carbonate and calcium sulfate salts that are brought to the surface by capillary rise. The pH range of the soil is about 6.2-6.8 due to the presence of these salts within the soil profile.

Studies to determine the importance of irrigation were conducted from 1998-2000 on 2 private farms off of Sawmill Creek Road and Rapeseed Way in the Delta I Agricultural Project, 19 miles southeast from Delta Junction. The elevation of the first test site off of Sawmill Creek Road is approximately 1,170 feet. The soil in this area is a Nenana silt loam (T. Pink 2008) that had been cleared and conventionally farmed for about 15 years before irrigation studies were conducted. Nenana soils are shallow silt loams over sand and gravels, and fairly acidic, with a pH range of about 5.1-5.5. The second irrigation study site, off of Rapeseed Way, is located only 5 miles north from the first site. The elevation is approximately 1,100 feet. The soil in this area is a Moosehead silt loam (D. Swanson 2001) that had also been cleared and conventionally farmed for about 15 years before irrigation studies were conducted. Moosehead soils are similar to Salchaket soils, except that they are much deeper (3 to 5 feet) to gravelly sands and are located on terraces above the active floodplain of the Tanana River, with a pH range of about 5.4-6.0. Neither soil contains high levels of organic matter and they are rather dry. They lack uniformity because high ridges tend to be sandy and dry, while other areas are stony. Both soils are low in available nitrogen and moderate in available phosphorus and potassium. The depth of the water table is about 100 feet. The fairly acidic pH (5.1-6.0) limits the availability of phosphorus through fixation of the phosphate ion with free iron and aluminum ions. It is recommended that phosphorus fertilizers be banded with the seed to compensate for this.

From 1981 to the present, the largest portion of variety testing was done at the UAF Agricultural and Forestry Experiment Station Delta Field Research Site at mile 1,408 of the Alaska Highway, 14 miles southeast from Delta Junction. The elevation of this test site is approximately 1,220 feet. This location is the original test clearing site for the Delta I Agricultural Project. Until 1990 all variety testing was done on a Sawmill Creek silt loam soil. (T. Pink 2008). This silt loam soil is very deep (more than 6 feet) to gravelly coarse calcareous sands formed from alluvial fans from the Granite Mountains to the south. As a result, it has many irregular deposits of coarse gravels from the many intermittent streams that flow out of the mountains. This soil has a pH range of about 5.1-5.5. It was cleared in 1978 and put into production with conventional farming practices in 1979. Tillage practices on this site were identical to those at the Fairbanks and Eielson sites. Similar to the Eielson site, the soil still contained large amounts of woody and moss organic matter. The variability of soil organic matter coupled with the thin, sandy texture of the soil resulted in a variable and non-uniform study site. The soil tends to be dry, is low in available nitrogen, and has moderate availability of phosphorus and potassium. The depth to the water table is about 150 feet.

After 1990, the variety testing area was moved about 1 mile north to another site on the same farm (with the same elevation) with Gerstle-Moosehead complex deep (4 to 5 feet) silt and very fine sandy loam soils (T. Pink 2008). This area was also cleared in 1978 and conventionally farmed. By 1990, when the variety testing plots were moved there, most of the woody organic material had been removed or broken down and decomposed. However, due to the variability in soil depth and the thin, sandy texture of the soil, the new site is still not uniform. This soil is low in available nitrogen and moderate in available phosphorus and potassium. Tillage practices on this site were identical to those done on the Sawmill Creek silt loam. The soil tends to be dry because of the sandy texture, which does not hold water well. This, along with lower nitrogen and moderate potassium levels, tended to produce shorter than normal plant heights, resulting in low incidences of lodging and early maturity, which produces low yields with correspondingly low test weights. The depth to the water table is about 120 feet. Irrigation studies were begun at this site in 2011 to explore the management of soil moisture with available plant nutrients on crop yield and quality.

In the Delta Junction area, high winter winds can blow snow off of fields that lack stubble or sufficient soil roughness to trap the snow. Since crops rely on spring snowmelt to provide sufficient soil moisture for germination, it is important to leave standing stubble after harvest, or to leave the soil surface rough after fallowing to trap the snow and keep it from blowing off. Because the soils of the Delta Junction area tend to be coarser in texture than soils at the other sites, it is even more important to conserve soil moisture during seedbed preparation and planting. As in the Fairbanks area, a packer pulled behind the tillage implement helps to seal in soil moisture. A drill equipped with press wheels can also help conserve moisture. Leaving standing stubble in the fall or leaving a rough soil surface with fallow tillage provides the added benefit of reducing soil erosion over the fall and winter months by reducing wind force and anchoring the soil against movement. This is especially important with fine-textured silt loams, which are easily moved by wind erosion. Since many of the soils in the Delta Junction area are thin layers of silt loam over sands and gravels, any loss can be significant.

Because of the higher elevation of the Delta Junction area compared with the Fairbanks and Eielson sites (1,200 vs. 500 feet) there are fewer GDD over a typical growing season. Spring planting in May is usually later than in Fairbanks because of cooler, wetter conditions. The average date of planting for the Delta Junction area in the years 1978-2012 was May 14. The first killing frost usually occurs near the end of August to the first of September. With this shortened growing season, planting as soon as equipment can get into the fields to work the seedbed results in better maturity and higher yields.

A fairly large distance separates the Delta Junction test sites. It is almost 40 miles from the farthest north test site near the Tanana River to the farthest south test site near the Granite Mountains. This large variation in distance and topography leads to a large variation in weather conditions at each site. However, not all test sites were run all years during the 1978-2012 period. Most of the variety evaluation and testing was performed at the UAF Agricultural and Forestry Experiment Station's Delta Field Research Site at mile 1,408 of the Alaska Highway. Weather data information presented here is from the official FAA observatory at the Delta airport, about midway between all the test sites.

For the Delta Junction area, the average total precipitation for the month of May was 0.90 inches, with most of that falling in the last half of the month (Fig. 5). Average cumulative GDD for this month were 481 (degrees F) (Fig. 6). Compared with the Fairbanks and Eielson areas, the Delta Junction area is generally drier and cooler during May. The lower precipitation and cooler temperatures often result in poor germination and delayed or spotty emergence. Therefore, ensuring adequate soil moisture during seedbed preparation is very important in this area. Even with proper precautions to slow down soil moisture loss, average 50% emergence does not occur until 12-14 days after planting.

June precipitation averaged 2.19 inches with precipitation events scattered evenly throughout the month (Fig. 5). The average cumulative GDD figure was 1,249 (Fig. 6). As in the Fairbanks and Eielson areas, the end of June to the first of July is the time when most varieties reach the 50% headed physiologic growth stage. Compared with the Fairbanks site, the cooler temperatures in the Delta Junction area caused a slight lag time of 3 to 4 days in the average time to reach 50% maturity. Average time to 50% headed for the study period was July 8 with 1,474 cumulative GDD. During this time, as at the Eielson site, uneven emergence resulted in increased emergence of late tillers.

July and August are also the rainy months for the Delta Junction area, with an average total precipitation of 2.49 inches in July and 1.86 inches for August (Fig. 5). At the Delta Junction site, the average cumulative GDD figures for the Delta Junction site were 2,114 for the end of July and 2,809 for the end of August (Fig. 6). The combination of sandier soils, lower precipitation, cooler temperatures,

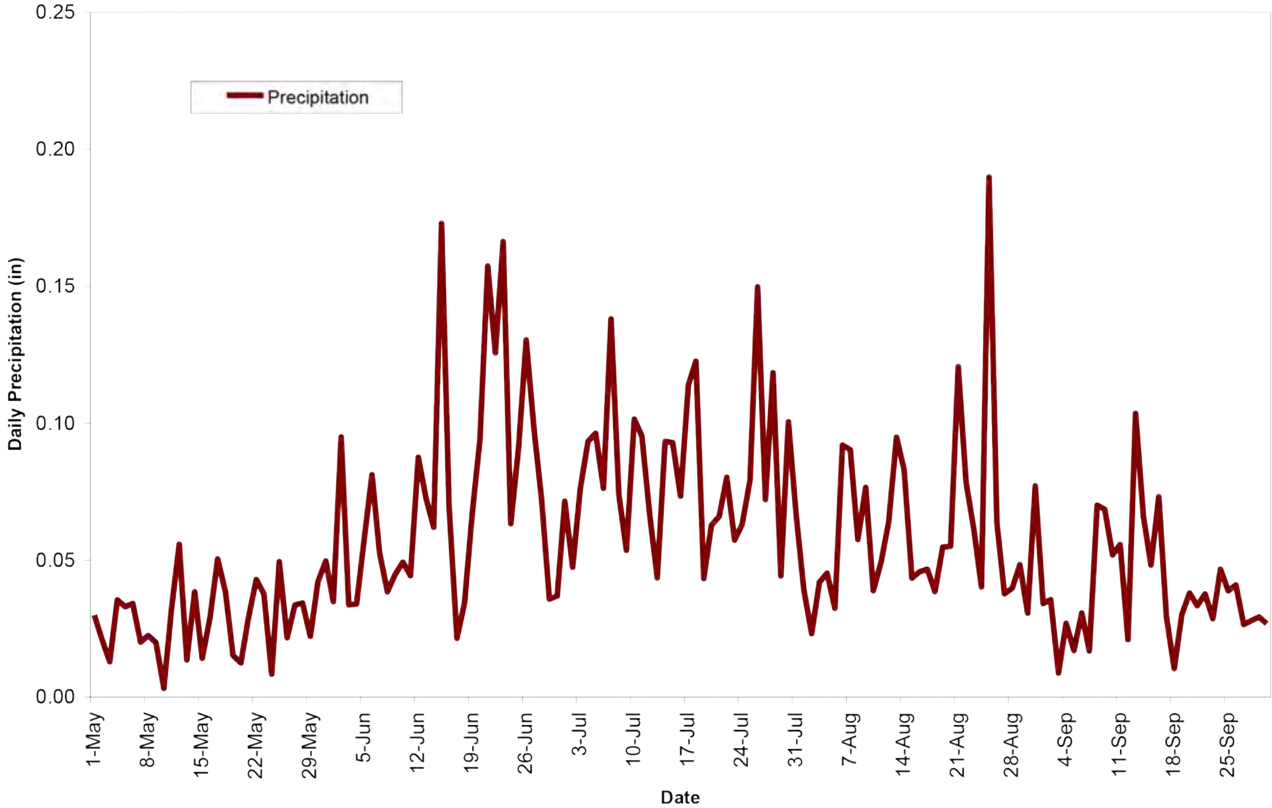


Figure 5. Average daily growing season precipitation for the Delta Junction area, 1978-2012.

poor germination, and spotty emergence can lead to an abundance of green tillers at this time. This can delay the 50% physiologic maturity growth stage by 1 to 2 weeks compared to the Fairbanks and Eielson areas. In the Delta Junction area, mid- to late August is usually when most crops reach the 50% physiologic maturity growth stage; the average time to 50% maturity is August 14 with 2,467 cumulative GDD.

Average total precipitation for September was 1.14 inches (Fig. 5), and the average cumulative GDD figure was 3,163 (Fig. 6). With average precipitation events scattered throughout the month of September, it is difficult to have low seed moisture, which usually means that grain drying before storage is required. There can be an early killing frost at any time between late August through September, which can result in lower than average yields. Yields can also be reduced because of the high amount of immature tillers present at the time of a killing frost.

Palmer Area Test Site Characteristics

The Palmer test site is on Georgeson Road, 7 miles southwest of Palmer, on the upper bench of the UAF Agricultural and Forestry Experiment Station's Matanuska Experiment Farm. The site elevation is approximately 200 feet. Agronomic crop variety evaluations have been conducted here since the establishment of the Matanuska Experiment Farm in 1917. The soil is a Knik silt loam (M.H. Clark and D.R. Kautz 1998) that has been conventionally farmed for about 70 years, during which large quantities of animal manures have been added to the fields. This has made the soil quite uniform, with high levels of available nitrogen and potassium. This is also a moderate allophane soil, which means that it contains moderate levels of available aluminum. Because the aluminum bonds with soil phosphates, making the phosphorus unavailable, it is recommended that phosphorus fertilizers be banded with the seed to compensate. Knik soils are shallow silt loams over sands and gravels at average depths of 1 to 3 feet. The gravels in this area are glacially deposited. The water table is about 150 feet deep. The pH range of this soil is slightly acidic at 5.0-6.0.

As in the Delta Junction area, high winter winds can occur in the Palmer area, so it is important to leave standing stubble after harvest or a rough soil surface after fallowing to trap the snow that is vital to early season soil moisture. Similar to the Fairbanks and Delta Junction areas, a packer pulled behind the tillage implement and a drill equipped with press wheels helps conserve moisture. The standing stubble from the fall or a rough soil surface from fallow tillage reduces soil erosion over the fall and winter months by reducing the the wind force and anchoring the soil against movement. This is especially important with fine-

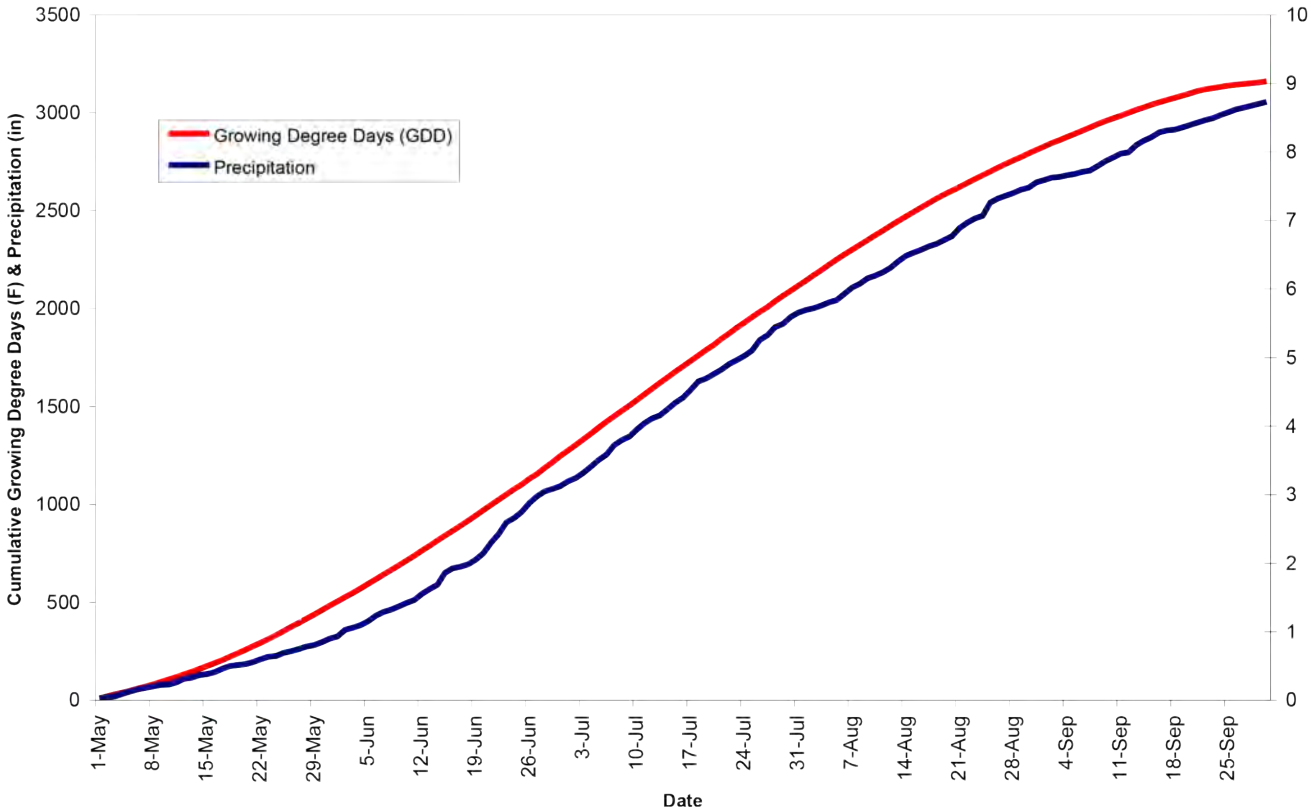


Figure 6. Average cumulative growing degree days and precipitation for the Delta Junction area, 1978-2012.

textured silt loams that are easily moved by wind erosion. Because the Knik soils of the Palmer area are thin layers (<.8 inch) of silt loam over sands and gravels, any soil loss can be significant.

Since the early 1950s, the Matanuska Experiment Farm has been the location of all of the small grain plant breeding programs. Experimental breeding lines developed by the U.S. Department of Agriculture-Agricultural Research Service (USDA-ARS) plant breeder, R. Taylor, were tested against the standard varieties at the Palmer, Fairbanks, and Delta Junction sites for a number of years. This resulted in the eventual joint USDA-ARS/ AFES release of 'Lidal' feed barley (1972), 'Weal' hooded barley (1978), 'Otal' feed barley (1981), 'Datal' feed barley (1981), and 'Thual' hulless barley (1981). Also released during this period were 'Toral' oat (1977), 'Ceal' oat (1978), 'Gasser' hard red spring wheat (1953), 'Ingal' hard red spring wheat (1981), 'Nogal' hard red spring wheat (1981), 'Vidal' hard red spring wheat (1981), and 'Berbral' winter rye (1981). Variety testing and evaluation was also done at this site primarily to determine plant breeding material. Beginning in the late 1980s with the hiring of a new AFES plant breeder, S. Dofing, small grain variety evaluations were conducted at the Palmer, Fairbanks, and Delta Junction sites with an emphasis on determining the genetic diversity of small grains from around the circumpolar north. Information from the genetic diversity study led to crossing existing

Left: Frank J. Wooding, plant breeder, after whom a feed barley was named in 2006; and right, George W. Gasser, one of the earliest plant breeders in Alaska, after whom a hard red spring wheat variety was named in 1953.

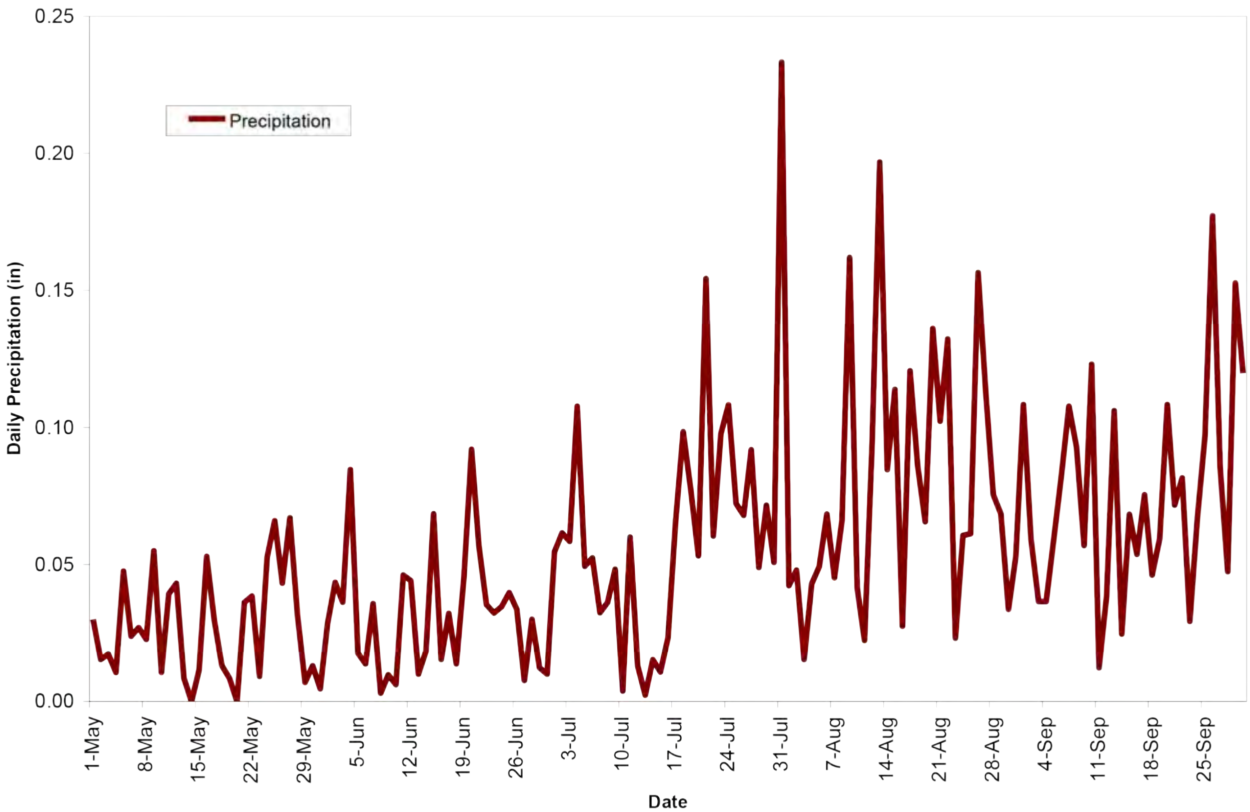


Figure 7. Average daily growing season precipitation for the Palmer area, 1989-2012.

Alaska barley varieties with new northern European barley strains for improved vigor, yield, and quality. This resulted in the eventual AFES release of 'Finaska' feed barley (2001), 'Wooding' feed barley (2006), and 'Sunshine' hulless barley (2009). Due to budget reductions, the plant breeding position has since been eliminated. The data presented in this publication for the Palmer location is therefore limited to the 1989-2012 period.

Average planting date for this period was May 16. Average total May precipitation for this test site was .82 inch (Fig. 7). Generally, the first week of the month is drier than the remaining 3 weeks. The average cumulative GDD figure for the month of May was 510 (degrees F) (Fig. 8). This is about the same as the Fairbanks, Eielson, and Delta Junction areas. The uniformity of the soil and sufficient soil moisture ensures that uniform germination and emergence occurs 7 to 10 days after planting. As at the other sites, any variation from the average soil moisture or soil temperatures due to drier or colder conditions can delay germination and emergence.

June's total precipitation, 1.00 inch, fell mostly in a few heavy showers (Fig. 7). Most of the month is normally dry. The average number of cumulative GDD to the end of June was 1,220 (Fig. 8). The end of June to the first of July is still when most varieties reached the 50% headed physiologic growth stage, even though

Left: Roscoe L. Taylor, plant breeder with the USDA Agricultural Research Service (now eliminated in Alaska). Right: Steven M. Dofing, plant breeder with the Alaska Agricultural & Forestry Experiment Station (the position was eliminated in 1999 so the data for Palmer only goes to 2012).

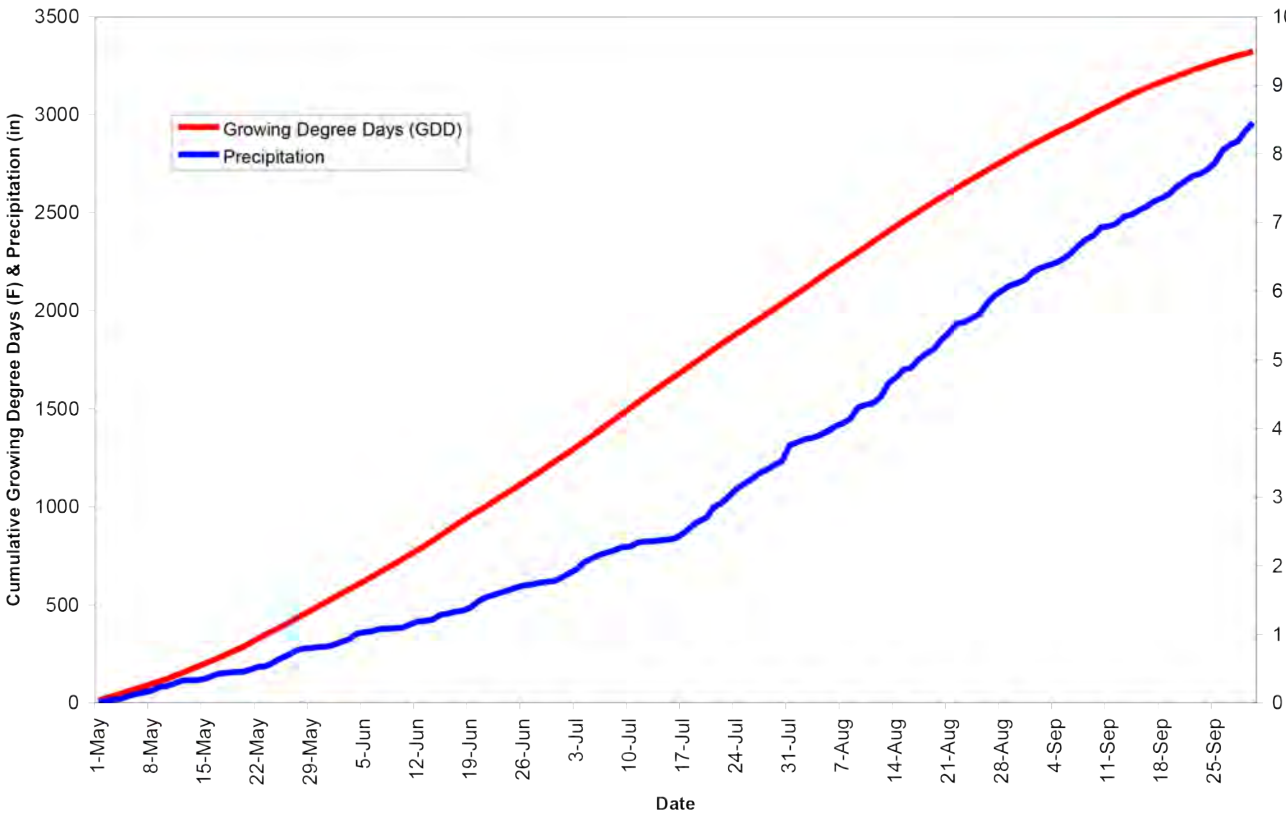


Figure 8. Average cumulative growing degree days and precipitation for the Palmer area, 1989–2012.

temperatures for this area are cooler than those of the Fairbanks, Eielson, and Delta Junction areas. Compared to Fairbanks, there is a slight lag time of 3 to 4 days, which is similar to the Delta Junction site. Average time to 50% headed for the study period was July 7 with 1,401 cumulative GDD. Even in years with delayed germination and emergence, crops reached the 50% headed physiologic growth stage during this period.

Precipitation at the Palmer site during July and August is generally greater than May and June, but unlike the Fairbanks, Eielson, and Delta Junction sites, these months are not the rainy season. The month of July received an average of 1.93 inches and August received 2.43 inches, with precipitation events scattered evenly throughout each month (Fig. 7). The end of July had 2,046 cumulative GDD and the end of August had 2,807 cumulative GDD (Fig. 8). As with the other sites, this is the period when most varieties reach the 50% maturity physiologic growth stage, although at Palmer this point is reached 2 to 3 days later than at Fairbanks. Cool and wet conditions can cause the 50% maturity dates for some late-maturing varieties to occur as much as a week later than in the Fairbanks area. The average time to 50% maturity for the Palmer area was August 7 with 2,228 cumulative GDD. High levels of available nitrogen coupled with high precipitation resulted in tall plant heights during this period. In weak-stemmed varieties, occasional high winds in August can cause serious lodging.

Average total precipitation for Septem-ber was 2.51 inches (Fig. 7). The average cumulative GDD number was 3,309 (Fig. 8). Even though this month has much more total precipitation than any other month during the growing season, most of this precipitation comes in individual storm events. This allows time between storms for grain ripening and harvest. Unlike the Fairbanks, Eielson, and Delta Junction sites, there may not be a killing frost until much later in the month.

Depending on the amount and severity of lodging, as well as variety characteristics, many green tillers can occur this late in the growing season. Because there are not enough GDD to mature these tillers in September, grain from them is high in moisture at harvest. This reduces both the yield and test weights of the crop.

Barley

Barley Performance Trials—Spring Feed Barley

Barley is the most important true cereal grain crop grown in Alaska, and is well adapted to the state's long day length and short growing season. Although it is used primarily as an animal feed, some types, such as malting and hulless varieties, could fill fast-growing niche markets for human consumption. There are 2 common species of barley that are differentiated by the shape of the seed heads. Six-rowed barley (*Hordeum vulgare* L.) has a long, round-shaped seed head with kernels forming 6 rows evenly around all sides. Two-rowed barley (*Hordeum distichum* L.) has a flat seed head with kernels forming 2 rows on opposite sides. Most barley varieties have a long awn attached to the hull surrounding the kernel. The awns of some varieties are smooth, but most are rough or bearded. These rough awns are barbed in one direction, a holdover genetic trait from wild barley that may have helped to ensure seed dispersal by animals. Unfortunately, the rough awns can work into the soft tissues around animals' mouths, nostrils, and eyes, causing potentially serious infections. If left on grain or found in straw, these rough awns make the crop undesirable for use as feed or bedding. When most varieties of barley are ripe (the kernel can't be dented with a thumbnail) and harvested at proper moisture conditions, these awns break off during the harvesting process. Except for hulless varieties, the fibrous hull remains on the kernel.

Heads of 2-row barley (left) and 6-row barley (right)

Most barley varieties grown in Alaska have been the 6-row types, which usually mature earlier and are more uniform at harvest than the 2-row types. Early-maturing 6-row barley varieties usually produce 3 to 4 tillers per plant. Each tiller is an additional stem with its own seed head, which normally reaches maturity and ripens to increase yields at harvest. Two-row varieties, which mature later, often produce many tillers, even late into the growing season (late July to early August). These late tillers may be immature at harvest when the main head is ripe. They also tie up plant nutrients important in filling and ripening seed, and at harvest produce wet plant material mixed with the ripe seed, increasing drying costs.

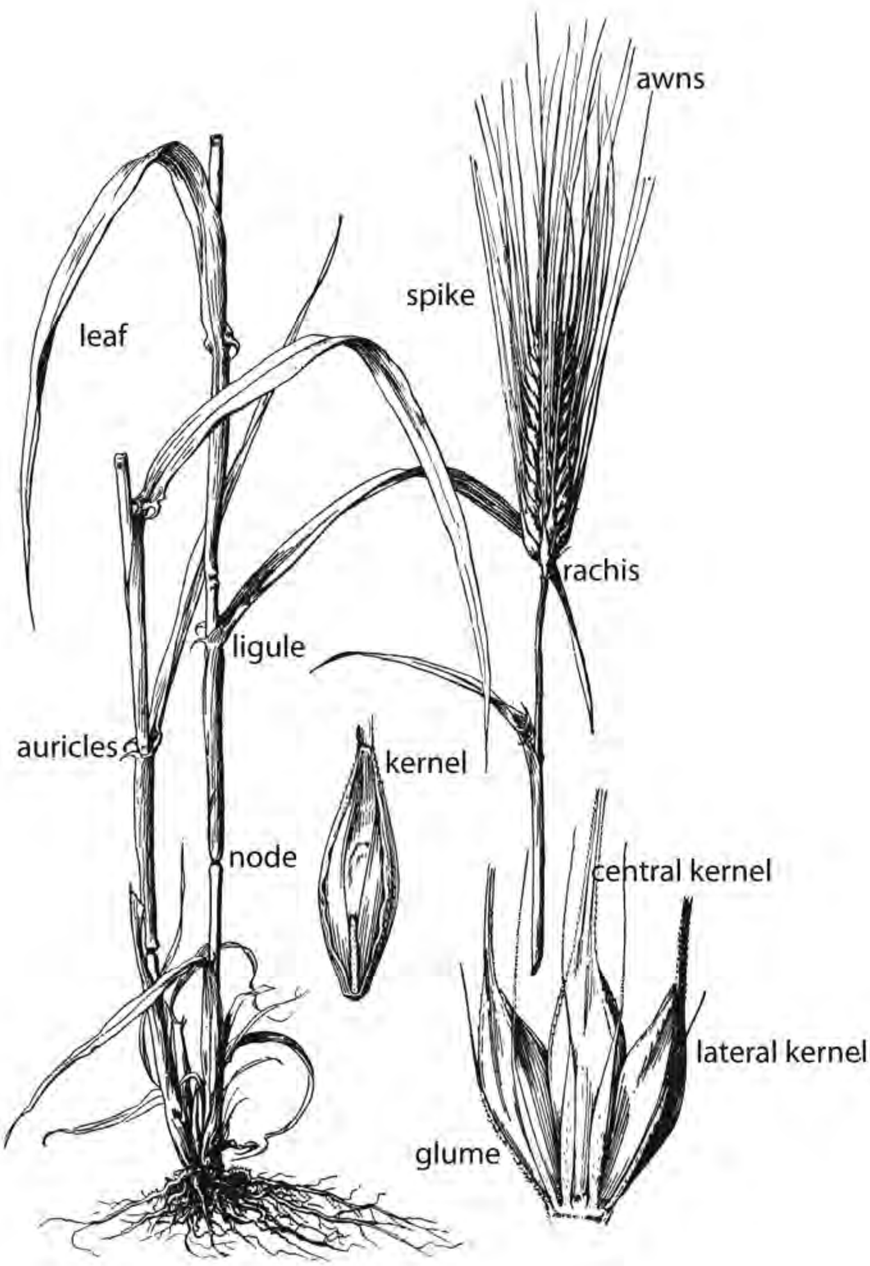
Besides plant variety, a number of other factors can contribute to the formation of tillers: plant genetics, plant population density, soil fertility, the amount of light penetrating the canopy, etc. If the grain has lodged and fallen over due to high levels of nitrogen fertilizer, weak stems, or a strong wind or rainstorm late in the season, then more light can reach the plant base. This light and any extra moisture (from a rainstorm, for example) stimulates tiller formation. Proper fertilization and planting rates can help reduce this.

According to D.C. Church (1979), the crude protein content of barley ranges from 11% to 15% and crude fiber from 5-7%, with a total dry matter content of 80% to 90%. Six-row barley varieties usually contain higher levels of protein and lower levels of carbohydrates compared to the 2-row varieties. Although high protein content is an advantage in animal feed, barley is usually used as an energy source, added mainly for the carbohydrate content that comes from the 50% to 60% starch contained in the endosperm of the seed. Supplemental proteins are then added to the feed from such sources as soybean meal, canola meal, fishmeal, etc. This makes barley a high-fiber, high-energy, very palatable feed for ruminants and horses. Because the high fiber content of hulled barley varieties is difficult to digest by monogastrics like swine and poultry, hulless barley is more suitable as a high-energy feed. Hulless barley has a 1 to 2 percent higher level of nutrients and crude protein than hulled barley.

Date of planting and fertilizer rate studies conducted by F.J. Wooding (1973) and C.W. Knight (1989) determined that combining late planting dates with high nitrogen fertilization produces barley that is higher in protein. However, total yields and grain quality measures such as fiber content and test weights were significantly reduced. Two-row barley varieties often contain lower levels of protein and higher levels of carbohydrates. This is important in the malting industry, where low protein levels prevent cloudy precipitates and high carbohydrate levels are needed for conversion into alcohol. Two-row varieties that produce protein levels unsuitable for malting make excellent animal feed. For animal feed, the grain is usually ground or rolled and fed with the hull attached.

Because proper fertilization is important for producing high yields of high-quality barley, soil should be tested to determine which plant nutrients are limiting and how to correct for those deficiencies. Test soil in the fall on the field in which next year's crop will be grown. In general, all soils should receive a complete mix of nitrogen, phosphorus, potassium, sulfur, and boron. Complete fertilizer blends consisting of ammonium sulfate, urea, monoammonuim phosphate, triple superphosphate, potassium chloride or potassium sulfate, and sodium borate work well in the soil conditions described previously. If ammonium sulfate is not available, a substitution of potassium sulfate for potassium chloride would work to provide the needed sulfur. Continuing soil nutrition and fertilizer rate studies by M. Zhang (2011), B. Van Veldhuizen (2010), and M. Lene (2011) in the Delta Junction area indicate that, with dryland farming practices, soils that have existing moderate to high levels of available nitrogen, phosphorus, and potassium should have a complete fertilizer blend consisting of the following ratio: 3:2:1:0.5 of N, P_2O_5, K_2O, and S. These studies also suggest that, with irrigated farming practices, the ratio should be reduced to about 1.5:1:0.5:0.25. This is possibly due to an increase in the amount of the available forms of soil nutrients due to maintaining the soil moisture levels close to the maximum soil moisture holding capacity during the growing season. Regardless of which farming practice is used, actual percentages of each material and application rates vary according to specific soil test results. The fertilizer can be broadcast and incorporated with spring tillage, or portions of it can be banded at planting.

Nitrogen is important in the production of the amino acids, nucleic acids, and many enzymes that make up the protein concentration of the plant. Nitrogen is also a major portion of the



Labeled diagram of a barley plant

growth and reproduction process. At maturity, the highest concentrations of nitrogen compounds will be in the seed. It is usually the most limiting plant nutrient in Alaska soils, requiring higher application rates to supply plant nutrition needs. Pure nitrogen fertilizers should be broadcast applied or banded a short distance away from the seed, especially at high rates, and should never be banded with the seed. Most forms, like urea, are hygroscopic and draw soil water away from the seed. This hinders germination and "burns" the seedlings. A general rule is not to place with the seed any more than 15 to 20 pounds per acre of nitrogen (as monoammonium phosphate for example). It is better to band these fertilizers 1 inch below and 1 inch to the side of the seed row. Newly cleared soils are usually low in available nitrogen, and so application rates should be increased to compensate for this. When a lot of plant residue (stubble and straw) is to be tilled in with the fertilizer, extra nitrogen should be applied to compensate for the microbial decomposition that competes with the crop for the available nitrogen. An extra 25 pounds of nitrogen per acre should be applied for each 2,000 pounds per acre of dry crop residue incorporated during spring tillage. Summer fallowed fields require less nitrogen than fields planted the previous year. This is especially true if the previous crop was a heavily fertilized one, such as potatoes. It is easy to apply too high a nitrogen rate as many phosphorus carriers also contain nitrogen. Too high of a nitrogen application—especially under irrigation—causes excessive plant heights, which leads to lodging problems, late tillers, delayed maturity, and reduced yields.

Phosphorus is important in plant cell energy transfer through such materials as adenosine diphosphate (ADP) and adenosine triphosphate (ATP) needed for cell reproduction. It is also important for conversion of sugars into starch and cellulose. At maturity, the highest concentrations of phosphorus compounds will be in the seed. It is usually the second-most limiting plant nutrient in Alaska soils. Where possible, phosphorus fertilizers should be banded with the seed. Many soils in Alaska have a low pH and high levels of free iron or aluminum ions. These conditions tend to fix phosphorus and make it unavailable for plant use. Banding a phosphorus fertilizer such as monoammonium phosphate with the seed allows the plant quick access and reduces overall soil fixation of phosphorus. If the fertilizer material is broadcast, application rates for phosphorus should be 20% to 25% higher.

Potassium is important in the formation of carbohydrates and proteins in the plant. Proper potassium levels help reduce the incidence of plant lodging by increasing straw strength. Potassium fertilizers should be broadcast-applied with the nitrogen. As with nitrogen, banding potassium, like potassium chloride, with the seed causes serious salt problems, leading to poor germination and seedling damage. Most soils in Alaska have moderate levels of potassium and good crop yields may be obtained without addition of this nutrient. Therefore, cropping systems where straw and stubble are added back to the soil, or where summer fallow is utilized, may be adequate to sustain yields over a long time. However, when all plant residues are removed or continuous cropping has occurred, about 3 times the amount of potassium is lost, so an increase in the potassium rate is needed.

Sulfur is deficient in many Alaska soils. Lack of sufficient sulfur decreases total yields and reduces overall grain quality. This is especially noticeable on older fields that have been in continuous production for 5 or more years. On summer fallow land, the crop response to sulfur is not as strong. Fertilizer blends containing ammonium sulfate or potassium sulfate should provide sufficient levels of sulfur when blended for nitrogen or potassium. Soils in the Tanana River floodplain are not deficient in sulfur due to the high concentration of calcium carbonate and calcium sulfate salts dissolved in the groundwater. These salts are brought into the root zone by capillary rise because the evaporation rate is greater than precipitation.

The micronutrient boron also is deficient in many Alaska soils. Studies by F.J. Wooding (1985) found that application rates of 0.5 to 1.0 pounds per acre of actual boron can increase yields by 10% to 15% and improve disease resistance. Care must be taken in applying boron, because too high a rate can produce toxic levels in the soil. Barley is especially sensitive to high boron levels. Rates higher than 2 to 3 pounds per acre can cause toxicity symptoms: small light brown spots near the edges of the upper leaves of barley. This can produce lower overall total yields than the 0.5 to 1.0 pounds per acre rates.

As previously mentioned, tillage practices that conserve the most soil moisture should be used. Broadcast fertilizer should be applied to the soil surface before tillage and incorporated along with any plant residues from the previous year. A packer should be pulled behind the tillage implement to form a weak crust on the surface. This helps to slow the soil moisture evaporation rate and keeps moisture within the root zone. Also, a drill equipped with press wheels helps to keep soil moisture in next to the seeds. Avoid tillage and soil packing when conditions are too wet, because this causes the soil to develop a hard crust that impedes emergence. This is especially true if the crop is to be irrigated. The soil should be irrigated sufficiently to bring the soil moisture levels to close to the maximum water-holding capacity before tillage. It is very important not to irrigate above the maximum water-holding capacity before tillage and planting, as this could cause a soil crust to form on the surface that can impede seedling emergence, reduce plant density, and lower seed yields.

Use of certified seed is strongly recommended. In recent years, feed barley that was contaminated with wild oats (*Avena fatua* L.) has been used to plant the following year's crop. This strain of wild oats has become resistant to herbicides and is now a serious weed problem in many fields in Alaska. Certified seed has strict limits on maximum content of weed seeds and diseased kernels and must meet a minimum percent germination. This helps ensure good germination and emergence and reduces weed and disease infestations. Heavy seeding rates of 90 to 100 pounds per acre of pure live seed are important to help reduce late tillering and ensure uniform ripening. Barley should be planted at a depth of 1.5 to 2.5 inches so it is in contact with moist soil. Deeper seeding slows emergence, produces thin stands, and reduces yields.

Irrigation should begin again after the crop has reached about 50% emergence to avoid any problems with emergence from too hard of a crust on the surface. Thereafter, a good range of irrigation plus precipitation is around 0.5 to 1.0 inch per week. Irrigation should continue until the crop has reached the 50% headed growth stage. Preliminary results from irrigation studies by B. Van Veldhuizen and M. Zhang (2011) in the Delta Junction area suggest that additional irrigation after this growth stage doesn't increase yields or seed quality enough to warrant the added expense of irrigation.

Pest control practices for high-quality, high-yielding barley is also important. Using IPM techniques, assess each field for all pests (weeds, diseases, and insects) and plan control measures accordingly. Identification of potential pests before they become a serious problem is the first step in producing good crops. There are many excellent published identification and control guides for common crop weeds, insects, and diseases. The Meister Publishing Company's series, "Weed Control Manual" and "Insect and Disease Control Guide" are good examples. Consult the local area Cooperative Extension Service IPM pest scout for more information (see Appendix 1 for addresses and contact information).

Weed control for this study was a combination of mechanical and chemical summer fallow to reduce the number and species of weeds for the following year and an application of a post-emergence herbicide when needed as determined through IPM practices. Common annual broad-leaved weeds in Alaska fields are chickweed (*Stellaria media* L.), corn spurry (*Spergula arvensis* L.), hawksbeard (*Crepis tectorum* L.), lambsquarter (*Chenopodium album* L.), Pennsylvania smartweed (*Polygonum pensylvanicum* L.), knotweed (*Polygonum aviculare*), shepherd's purse (*Capsella bursa-pastoris* (L.) Medic.), tansy mustard (*Descurainia sophioides* Fisch.), and wild buckwheat or field bindweed (*Polygonum convolvlus* L.). If weed populations have been determined through IPM practices to be high

Barley in the early (left) and late (right) boot stage enough to cause a potential loss in yield or quality of the crop, then the application of herbicides may be warranted. Good results for control of these broad-leaved weeds can be obtained using a tank mix of broadleaf-selective herbicides, Bromoxynil, MCPA, Diglycolamine, or a 2,4-D amine, all of which are labeled for use on barley. These herbicides must be applied after the barley has reached the 3-leaf stage (4 to 6 inches tall), but before it reaches the boot stage, and when the weeds are small and free from drought stress. The higher application rates can injure the crop, leading to increased tillering and reduced yields if the weather conditions are hot and dry for 2 weeks after application. If a choice of herbicides is available, it is best to use the one that causes the least stress to the crop and has the lowest impact on the environment.

Common grassy weeds are bluejoint reed grass (*Calamogrostis canadensis* (Michx.) Beauv.), foxtail barley (*Hordeum jubatum* L.), quackgrass (*Agropyron repens* (L.) Beauv.), and wild oats (*Avena fatua* L.). Best control of grassy weeds is a combination of mechanical and chemical summer fallow. To eliminate grassy weeds with chemical fallow, a broad-spectrum nonselective post-emergence herbicide such as glyphosate (Roundup) was used. Studies conducted by C.W. Knight and C.E. Lewis (1981), J.S. Conn and C.W. Knight (1984), J.S. Conn (1990), and S. Seefeldt (2011) have determined that in cold soils some herbicides can be persistent and take many years to break down, resulting in potential detrimental effects on subsequent rotational crops. Always remember to read the pesticide label and follow the directions on mixing, application, and disposal.

Net blotch (*Pyrenophorea teres*), spot blotch (*Cochliobolus sativus*), and barley scald (*Rhynchosporium secalis*) are the most prevalent fungal diseases found on barley in Alaska. All of these diseases produce brown spots on the leaves. Net blotch has light brown blotches of irregular size and shape with dark brown net-like patterns within. Spot blotch has round or oblong spots that later combine to form irregular brown stripes. Barley scald has water-soaked lesions that later appear scalded. Photosynthetic ability of these spotted leaves is reduced, which reduces yields. All of these diseases develop in the cool, moist environmental conditions that often exist in Alaska just before and during the 50% maturity growth stage. Because these diseases overwinter on plant residues, they are most prevalent in barley after barley rotations. If infection levels are high, yield and grain quality reductions can be significant. To reduce disease in following seasons, a year of summer fallow or another crop in the rotation is recommended.

Other fungal diseases such as barley stripe mosaic (*Pyrenophora graminea*), loose smut (*Ustilago nuda*),

Left: Barley smut. Right: loose smut.

and covered smut (*Ustilago hordei*) have also been found in Alaska. Although not as prevalent as net blotch, spot blotch, and scald, a 1.0% infection of barley stripe can cause a 0.75% reduction in yield. Stripe causes long white or yellow stripes along the leaves that later run together and turn brown. The plants are stunted and the seed heads may not emerge. Loose smut forms loose, powdery dark brown spore masses covered by a grey paper-like membrane in place of the seed head and earlier than normal heads. They will show up right after boot stage through the 50% heading growth stage. The membrane will rupture in a slight breeze or rain shower and these fungal spores are then blown around the field to infect the forming seed on the rest of the crop. At harvest, only a bare stem is left where the seed head should be. Heavily infected fields will have reduced yields as well as infected seed for the following year. Covered smut is less common in Alaska. It is similar in appearance to loose smut but the membrane remains intact until harvest and ruptures during threshing. The spores are then dispersed to the rest of the crop to infect healthy seed. Both loose and covered smut-infected seed is considered nontoxic and can be fed to humans and animals. These diseases are seed-borne and can be controlled with a seed treatment. To prevent disease infections due to seed-borne fungal attacks, seed should be treated with a seed protectant such as carboxin (Vitavax). Certified seed often comes pretreated. This treated seed will include a colored dye (red, pink, or purple) to differentiate it from untreated seed so that it isn't used as feed.

Barley stripe mosaic, showing the yellow and pale green leaves.

Many different species of Fusarium fungi (*Fusarium graminearum* and others) that cause Fusarium blight have been found on barley. They are easily identified by the pinkish color of the fungal mass on diseased kernels. They form on seed heads during seasons of high precipitation and can increase in storage if moisture and temperature levels are higher than optimum. Fusarium molds may reduce yields and can produce mycotoxins. If infected barley is used for feed, it can cause unpalatibity and may be toxic to animals, especially swine. Because this disease overwinters on plant residues, it is most prevalent in barley after barley rotations. A year of summer fallow or another crop in the rotation is recommended to reduce the level of disease in following years.

There are 2 important viral diseases of barley: barley stripe mosaic virus (BSMV) and barley yellow dwarf virus (BYDV). Both cause stunted plants. Stripe mosaic causes light green or yellow leaves, while yellow dwarf causes bright golden yellow leaves. These viruses are both seed-borne, and the only control is to plant clean seed or resistant varieties. Yellow dwarf can be transmitted from plant to plant by several species of aphids (family Aphididae). This can become especially problematic during years of heavy aphid infestation. However, most aphid population booms occur late in the barley-growing season so yellow dwarf is not a serious disease problem. The symptoms of stripe mosaic differ from fungal barley stripe: a barley plant with stripe mosaic remains light green or yellow; it turns brown with fungal barley stripe.

Other than aphids, the most serious insect pests for barley are grasshoppers, including the lesser migratory grasshopper (*Melanoplus sanguinipes* Fabricias), the northern grasshopper (*Melanoplus borealis* Fieber), and the clear-winged grasshopper (*Camnula pellucida* Scudder). Grasshoppers in Alaska usually have a 2-year growth cycle, becoming pests every other year. Weather, soil conditions, and previous cropping practices can affect the cycle and extend the time between infestations. Although tillage practices such as summer fallow destroy eggs in the soil, any eggs laid in fence rows, ditches, or nearby untilled fields may overwinter, hatch, and emerge as nymphs in June. Young grasshoppers start moving into grain fields when the plants are at the 3- to 5-leaf stage. Heavy infestations at this time can severely defoliate the crop. Grasshoppers can damage the crop at any plant growth stage by eating leaves or even the green awns after heading has occurred. This reduces yields by reducing the plants' ability to photosynthesize. If insect population levels and damage have been determined to be too high through IPM practices, then the application of an insecticide may be warranted. Insecticide sprays or baits can help to control heavy infestations if applied at the nymph growth stage. Always remember to read the pesticide label to be sure the crop is specified and follow the directions on mixing, application, and disposal. Contact your local Cooperative Extension Service IPM pest scout for more information on pest control (see Appendix 1 for addresses and contact information).

Migratory waterfowl can inflict heavy crop damage in both the spring and the fall. In spring, early germinating barley varieties such as the malting cultivars are especially susceptible to predation. Because malting barley is genetically adapted to germinate early and uniformly for malt production, it is the first of the barley varieties to emerge in the spring after planting. Large flocks of returning migratory waterfowl can cause serious damage to these varieties merely by walking down the row and pecking out each newly emerged plant. In some years of our research, many small plots were completely wiped out. In the fall, migrating waterfowl often prefer the hulless barley varieties. If the grain is significantly lodged, damage can increase dramatically. Otherwise, they usually work the edges of fields where they have a large field of vision. Propane scare cannons, designed to swivel in different directions and go off at uneven time intervals, seem to work best at keeping birds out of fields. Check with and inform the neighbors before setting up cannons.

Large ungulates like moose and bison can also cause serious damage to the crop. A single moose or a cow and calf pair usually don't cause much damage to large fields, but can wipe out small-scale plots over the summer. They usually are attracted to newly emerging plants and will keep coming back to graze until 50% maturity when the awns start to develop the stiff barbs. In the Delta Junction area, bison congregate in large herds that don't usually cause serious damage until their fall migrations north of the Alaska Highway. This migration occurs during the time when the grain is mature, ripe, and ready for harvest. They will not only eat large portions of the crop, but a large herd walking through or bedding down in the field can flatten the crop into the ground making harvest impossible. It is illegal to harass wildlife in Alaska so the only control is to erect large (6 feet or higher), stout, highly visible fencing that can direct the animals around the fields. For more information on wildlife control in agricultural fields, contact the local office of the Alaska Department of Fish and Game.

If the crop grown is intended for sale as seed for future planting, the fields should be inspected before harvest to insure that the highest quality crop is being grown in order to meet the standards for certified seed (blue tag on the seed bag). The fields should be planted in clean ground and not in ground in which the same crop that is being certified was planted the previous year. There can be only 1 plant out of 1,000 of another barley variety as well as 1 plant out of 2,000 that is an inseparable crop like wheat or rye seed, and there must be no objectionable weeds (prohibited or restricted noxious weeds). The seed lots after harvest should also be inspected to meet the certified seed standards. These standards as outlined by the Alaska Seed Growers Association (1985) are as follows:

- Minimum of 96% pure seed
- Maximum of 14% kernel moisture
- Maximum of 2% inert matter (chaff, dirt, etc.)
- Maximum of 0.25% other crops
- Maximum of 0.20% other barley varieties
- 0% diseased (toxic) kernels (Fusarium blight, ergot)
- 0% objectionable weed seeds
- 0.05% other weed seeds
- Minimum of 85% germination

For more information about field and seed lot inspections, contact the local office of the state Division of Agriculture, Department of Natural Resources or the Alaska Seed Growers Association (see Appendix 1 for addresses and contact information).

Barley stops growing when it reaches the hard dough stage. The heads are light yellow in color and the kernels can't be dented when pressed with a thumbnail. The typical moisture content of the grain at this stage is 25% to 35%. Barley can be harvested at this moisture content, but artificial drying is required and a significant loss of germination ability can occur. Continued ripening reduces moisture in the seed heads. Barley must be around 14% moisture for safe, long-term storage. Moisture content higher than 14% can result in the grain germinating or molding; significantly lower moisture content can result in embryo damage, reducing germination ability. Both situations reduce the quality of the stored grain. Grain harvested before or at the hard dough stage has a fair amount of green, high-moisture heads. This underdeveloped grain is low in yield, test weights, starch content, and market value.

It is important then to harvest barley at the optimum grain moisture content and degree of ripeness. No field is completely uniform in ripeness, so timing of combine harvest is usually set around weather events, with supplemental grain drying after harvest. If such conditions as weather and field uniformity are right, standing barley dries faster and suffers less damage from moisture. Swathers are often used in fields having significant amounts of green tillers or weeds that would raise grain moisture content at harvest. The swather windrows the grain on stubble that is about one-third the total height of the grain. The excess moisture dries off in about 7 to 10 days after swathing in cool moist conditions and in 3 to 4 days in hot dry weather. The windrows are then picked up with a combine that has a pick-up attachment.

Care must be taken in swathing or combining to prevent or reduce losses from improper cutting height, shattering, crinkling, and weathering. If the cutter bar is too high, then short-stemmed heads fall to the ground and do not get picked up by the combine. Light windrows also have a tendency to settle into the stubble, where the grain may start to sprout. Head shatter, or loss of the grain due to physical contact, occurs on overripe barley. Some varieties are more susceptible to this than others, and 6-row varieties are more susceptible than 2-row varieties. Crinkling is when the heads bend over and "nod" towards the ground. Such stems may break soon after maturity, especially in damp weather. In weathering, or sun bleaching, the grain swells when damp and does not shrink after drying. These kernels are less dense and thus have a lower test weight, although other quality measurements are unaffected.

Combine settings should be adjusted so that the concave clearance and cylinder speed produces the highest amount of clean seed. Awns should be completely broken off of the kernels without cracking the kernels. To reduce the incidence of peeling or skinning the hull, augers should be run full, or if not full, then at slower speeds. When the hull is peeled the embryo becomes exposed and thus subject to potential damage during handling. Any damage to the embryo lowers the seed's germination ability. Every time grain is handled, more damage to the kernels occurs. This is less important when grain is grown for animal feed than when grown for seed. The highest quality barley brings the highest price.

Although it's best to try to leave the barley standing in the field until the optimum 14% moisture level is reached, and then direct combine or swath the grain, weather and field conditions do not always cooperate, so the crop is often harvested at higher moisture levels. There are 2 things that should be done to optimize moisture levels and prevent damage to seed after threshing. First, clean the seed. Removing weed seeds and other plant material with high moisture content makes the drying process much easier and cheaper and improves overall crop quality. Second, provide supplemental drying. If the outside air has low humidity, forcing it through the seed removes a lot of moisture. If the outside air has high humidity, heat must be applied when aerating the seed to draw moisture away. Care must be taken not to provide too much heat during the drying or storage process, because this can literally cook the seed, damaging the embryo and severely reducing germination ability. Heat-damaged kernels exhibit a dark brown or black discoloration on either the basal or awn end of the kernel, or both. Heat damage is not as significant in barley grown only for feed.

In Alaska there is a strong market for barley as a supplement for animal feed. The fibrous hull on all feed and forage barley remains on the kernel. For animal feed, the grain is usually ground or rolled and fed with the hull attached. However, before hulled barley can be consumed by humans and other nonruminants, the outer hull must be first removed through a dehulling process. This consists of an abrasion wheel inside a large spinning closed container which sands off the outer fibrous hull. The lighter hulls are then blown off and the dehulled kernels are collected. The bran and germ are still part of the kernel so dehulled barley is considered whole grain. The bran can be removed in an additional process called pearling. This takes dehulled barley and removes the outer bran (and portions of the germ) through a steam and polishing process. Loss of the bran and germ also reduces the amount of nutrients in pearled barley. The market for barley straw for bedding is limited because it contains the rough awns removed from the seed during harvest. In livestock, awns can penetrate soft tissues around eyes, mouth, nose, and ears, causing irritation and possibly infection. There is also a small seed production industry to provide local farmers with certified seed.

Recommended Variety Descriptions for Spring Feed Barley

Note: See Appendix 1 for the addresses of seed suppliers.

'Albright' is an early-maturing, tall, stiff-strawed, rough-awned, 6-row, high-yielding spring barley released in 1992 by Agriculture Canada in Beaverlodge, Alberta. Selected from 'Otal', it has many of the same characteristics, although 'Albright' is 1 to 2 days earlier in maturity, slightly taller, more uniform, and consistently produces higher test weights and yields than 'Otal'. Direct inquiries about seed sources to the SeCan Association, Agricore United, or the Alaska Farmers Coop elevator in Delta Junction.

'Datal' is an early-maturing, mid-tall, stiff-strawed, rough-awned, 6-row, high-yielding spring barley released in 1981 by the USDA-ARS plant breeding program at the Matanuska Experiment Farm. It is a cross between a 6-rowed Swedish cultivar, 'Edda', and an unnamed early-maturing 2-rowed selection from Sweden. 'Datal' is more susceptible to yield reductions from early-season drought conditions than 'Otal'. Direct inquiries about seed sources to the Alaska Seed Growers Association or the Alaska Plant Materials Center.

'Finaska' is an early-maturing, short, stiff-strawed, rough-awned, 6-row, high-yielding spring barley released in 2001 by the plant breeding program at the Matanuska Experiment Farm. It is a cross between two 6-rowed Finnish cultivars, 'JO 1632' and 'JO 1599'. 'Finaska' has better lodging resistance than 'Otal', but lower test weights.

Direct inquiries about seed sources to the Alaska Seed Growers Association or the Alaska Plant Materials Center.

'Lidal' is an early-maturing, mid-tall, stiff-strawed, rough-awned, 6-row, high-yielding spring barley released in 1972 by the USDA plant breeding program at the Matanuska Experiment Farm. It is a cross between a 6-rowed Swedish cultivar, 'Edda', and the early maturing 6-rowed cultivar 'Olli' from Finland. 'Lidal' has only a fair resistance to lodging and head shattering compared with

'Datal' spring feed barley growing at the Matanuska Experiment Farm, August 7, 2014

'Lidal' spring feed barley growing at the Matanuska Experiment Farm, August 7, 2014

'Finaska' barley at the Fairbanks Experiment Farm

'Otal' spring barley, a 6-row barley and the standard variety in this report against which other barleys were compared

'Otal'. 'Lidal' is a good-yielding variety for later planting dates (late May). Direct inquiries about seed sources to the Alaska Seed Growers Association or the Alaska Plant Materials Center.

'Otal' is an early-maturing, mid-tall, stiff-strawed, rough-awned, 6-row, high-yielding spring barley. It was released in 1981 by the USDA-ARS plant breeding program at the Matanuska Experiment Farm. It is a cross between a 6-rowed Finnish cultivar, 'Otra', and an unnamed early maturing 2-rowed selection from Sweden. In this report, 'Otal' performance is the standard against which all other varieties were compared. Direct inquiries about seed sources to the Alaska Seed Growers Association or the Alaska Plant Materials Center.

'Weal' is an early-maturing, tall, stiff-strawed, hooded, 6-row, high-yielding spring barley released in 1978 by the USDA-ARS plant breeding program at the Matanuska Experiment Farm. Because hooded barley awns are winged and hollow rather than rough and spiked, 'Weal' was developed primarily for use as a forage crop, although dry matter yields are slightly less than the best oat varieties. It is fairly resistant to lodging and can withstand high winds. 'Weal' is subject to yield reductions from early season drought conditions compared with 'Otal'. It also averages about 7 days later in maturity than 'Otal'. Direct inquiries about seed sources to the Alaska Seed Growers Association or the Alaska Plant Materials Center.

'Wooding' is an early-maturing, mid-tall, stiff-strawed, rough-awned, 6-row, high-yielding spring barley released in 2006 by the AFES plant breeding program at the Matanuska Experiment Farm. It is a cross between the early maturing 6-rowed Alaska cultivar 'Otal' and the 6-rowed Finnish cultivar 'JO 1632'. 'Wooding' is an improved variety over 'Finaska' with 1 day earlier maturity, better lodging resistance, and higher yields and test weights. Direct inquiries about seed sources to the Alaska Seed Growers Association or the Alaska Plant Materials Center.

'Weal' barley at the Fairbanks Experiment Farm

'Wooding' barley at the Fairbanks Experiment Farm

Barley Performance Trials — Winter Feed Barley

Winter feed barley, like spring feed barley, is either 6-rowed (*Hordeum vulgare* L.) or 2-rowed (*Hordeum distichum* L.). Fertilization rates, tillage practices, seeding depths, irrigation practices, weed and insect control, harvesting, cleaning, and storage are the same as for spring barley. Winter barley, like winter wheat and winter rye, is usually planted in late summer to early fall. To build up winter reserves, it usually requires as much as 2 more weeks of growth than other winter grains and so is planted earlier. It produces a small, low rosette of vegetative growth that builds up root reserves before winter dormancy. The next spring it assumes an upright growth form with a seed head similar in appearance to other annual grains. Winter barley will produce more tillers than other winter grains, but suffers from weak straw and significant lodging. In Alaska winter barley production is problematic. First, winter barley is adapted to more southern climates and is primarily grown no farther north than southern New York and the Great Lake states. Second, there is a 13-month growing season as opposed to the 3- to 4-month season for an annual grain crop. Also, winter barley, like all winter grains in Alaska, is susceptible to winter kill from freezing injury to the rosette, desiccation and freeze-drying of the rosette, and attacks of snowmold fungi, including white snowmold (*Sclerotinia borealis*) and pink snowmold (*Gerlachia nivalis*).

The cost in time of 13 months versus 3 or 4 months, the susceptibility to snowmolds, very late maturity, and the high probability of winter kill detracts from the economic viability of this crop in Alaska. Due to the lack of consistent success with other winter grains in Alaska, no winter barley varieties were tested during this period. Before this study, F.J. Wooding and others tested 2 varieties of winter barley ('Dicktoo' and 'Kearney') in the Fairbanks area with no success. Due to these cultural problems, no varieties of winter barley are generally recommended. However, just because there was a crop failure for this study does not mean that it might not be able to be successfully grown somewhere within the state. Therefore, the reader is not discouraged from trying any of the winter barley varieties not recommended, but the probability of success in attempting to produce these crops will likely be low.

Yields and Quality by Location for Feed Barley

Most agronomic crops, including barley, are bought and sold by weight, usually by the ton. On the other hand, storage facilities (truck beds, bins, elevators, etc.) are measured in units of volume, usually the bushel. Therefore, a standardized density measurement of weight per unit volume or test weight was developed to use as the legal unit for selling the crop. The standard test weight for clean, dry, and undamaged barley is 48 pounds per bushel. Test weights are taken at the grain elevator and used to determine crop quality. Low test weights can reflect the presence of foreign material, lack of maturity,

Bob Van Veldhuizen atop the plot combine at the Fairbanks Experiment Farm, harvesting 'Wooding' 6-row feed barley grown in a fish byproduct waste fertility study. Brian Jackson, then a graduate student, stands behind the machine.

high nitrogen fertilizer application, or severe drought during the growing season. Any low test weight reduces crop value. Test weights can differ between cultivars and can change within a single cultivar, depending on cultural practices, weather conditions, and location where grown. Test weight is used here as a measure of grain quality to determine maturity. Yields are expressed in pounds per acre and bushels per acre. Determine bushels per acre by dividing the yield of any specific cultivar by the standard test weight. Biomass yields are given, on a dry weight basis, for a few select varieties as a measure of straw or forage production. For feed varieties, this information was collected after seed harvest for straw bale production used as animal bedding. For forage varieties, this information was collected when the plants were at the soft dough stage.

Tables 1, 3, 5, 7, and 8 list barley yields and quality measurements for all test locations: Fairbanks, Eielson, Delta Junction, and Palmer. All sites in the Delta Junction area have been combined into either the Delta dryland site (Table 5) or, if grown under irrigation, the Delta irrigated site (Table 7). Each table also contains information on barley type (6-row, 2-row, hooded, etc.), the source or the location of where it was bred, and the years it was tested at each location. Maturity in this study was defined as when 50% of the heads for each plot were at the hard dough stage, or when the heads were a light yellow in color and the kernels did not dent when pressed with a thumbnail. Growing degree days (GDD) for average maturity were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. The low temperature point for barley in this report is the freezing point of water, 32°F. The GDD calculations for each day were then added to the preceding GDD value to determine the cumulative value to the date at which the specific variety had reached 50% maturity. All varieties were compared with 'Otal' spring feed barley as the standard variety. Yield as a percent of the standard variety 'Otal' was determined by dividing the average yield of each variety by the average yield of 'Otal'. Maturity vs. Std. (Standard Variety) is the number of days each variety reached 50% maturity either before or after the number of days that 'Otal' reached 50% maturity.

Tables 2, 4, 6, and 9 list the animal feed quality analyses of the seed and forage, on a dry weight basis, for select barley varieties for all test locations. They are presented here without statistical differences and solely for the reader's benefit. More detailed information and explanation about the industry standards for feed grade barley that follow can be obtained from J.H. Martin and others (1976). Detailed explanation of the feed analyses that follow as well as laboratory procedures can be obtained from J. Schroeder (1994) and G.J. Michaelson and others (1987). As with the yield tables, all sites in the Delta Junction area have been combined.

Percent crude protein is calculated from the total percent nitrogen analysis of the seed multiplied by a constant of 6.25. Crude protein is made up of amino acids, which are 16% nitrogen, as well as other, non-protein portions of the plant, and so percent crude protein is not a measure of true protein. Feed industry standards are set for a range of 11% and 15% crude protein. Values higher than 15% have a greater feed value, but are often an indicator of immature green seed with lower yields and test weights. Industry standards for forage barley are 9-14%. In a standard feed analysis, other major nutrient mineral concentrations commonly measured are percent phosphorus (%P), potassium (%K), and calcium (%Ca).

Percent total nonstructural carbohydrates (%TNC) is a measure of easily digestible carbohydrates (sucrose and fructose) that can be translocated and accumulated to other plant parts when the plant reaches physiological maturity. In this case, it is a measure of the sugars that have been translocated into the seed.

Percent neutral detergent fiber (%NDF) is a measure of the percentage of partially digestible plant material (lignin, hemicellulose, and cellulose). Lower levels of NDF usually result in a higher animal intake of the feed. It is also used to calculate the dry matter intake (DMI), where DMI = 120 ÷ %NDF. This value is later used to determine the relative feed value.

Percent acid detergent fiber (%ADF) is a measure of the highly indigestible plant material (lignin and cellulose). Higher levels of ADF usually indicate a low digestibility of the plant material. It is also used to calculate the digestible dry matter (DDM), where DDM = 88.9 - (0.779 x %ADF). This value is also later used to determine the relative feed value.

The percent in vitro dry matter digestibility (%IVDMD) is a laboratory simulation of plant material digestibility in cow rumen. A known weight of plant material is digested in a simulated rumen for a given period of time. After digestion is complete, the residue that is left is weighed and the difference is the estimated percentage of the plant material that is potentially digestible or a measure of potential metabolizable energy.

The relative feed value (RFV) is a unit-less index that combines the nutritional factors of the dry matter intake and the digestible dry matter of the plant material, where RFV = (DDM x DMI) ÷ 1.29. Plant material with an ADF of 41% and a NDF of 53% has a RFV of 100. All other plant material is compared to this value. Lower ADF and NDF values will cause the RFV to increase. The higher the RFV, the lower the overall quality of the feed.

Spring Hulless (Naked) Barley

There are both 2-row (*Hordeum distichum* L.) and 6-row (*Hordeum vulgare* L.) hulless barley varieties. In hulless barley varieties the outside hull detaches from the kernel when harvested, exposing the embryo and leaving a hulless or naked kernel. There are 2 types of hulless barley, normal and waxy. In normal hulless barley the ratio of amylose to amylopectin starch fractions is the same as that found in regular hulled barley (about 25% amylose and 75% amylopectin). In waxy barley there is a higher percentage of amylopectin starch and beta-glucans (95% to 100% amylopectin). Although both starches are polysaccharide glucose chains, amylopectin has a greater temperature stability range, making it better suited for industrial uses. In recent years there has been an increased interest in producing hulless barley, not only for diets of nonruminant animals that can't digest the fibrous hulls of hulled barley, but also for human consumption in items such as breakfast cereals, food thickeners, and health foods. Before hulled barley can be consumed by humans, the outer hull must be removed through an abrasion process called dehulling. This has the potential to also remove a portion of the outer bran and germ. The bran can be further removed in an additional process called pearling. This takes the dehulled barley and removes the outer bran and portions of the inner germ through a steam and polishing process. Loss of the bran and germ reduces the nutrient content of the seed. Because the hull is not attached to the kernels on hulless barley, dehulling and pearling is not needed. Hulless varieties sold to niche markets, such as for human consumption, bring higher prices.

In human, swine, and poultry diets, hulless barley has many advantages over hulled varieties. Hulless barley has a 1 to 2% higher level of nutrients and crude protein than hulled barley. B. Baik and S. Ullrich (2008) report that it can also regulate blood sugar levels for up to 10 hours after consumption compared to white or even whole-grain wheat, which has a similar glycemic index. In addition, there is improved digestibility and weight loss by increasing satiety (feeling full). All barley contains 8 essential amino acids so there is improved digestibility and available energy that is close to that of wheat. In poultry diets this is improved if enzymatic feed supplements are used. Regular hulless barley has higher beta-glucan content than hulled barley, which helps to lower LDL cholesterol levels. Waxy barley varieties, because of the higher beta-glucans, should never be used for poultry diets. If used in swine diets, enzymes should be added to improve digestibility. Hulless barley is also very low in gluten, making it a suitable substitute for wheat in human diets. Because hulless barley contains less fiber, its use results in less manure to handle. Also, the lack of an outer hull produces less fines and dust during handling. Fines in swine and poultry diets make them less acceptable.

Several factors have reduced the popularity of hulless barley: most varieties are late or very late maturing; they are lower yielding than hulled varieties; if there is no established niche market for the crop, it will sell at a price equal to that of regular feed barley; and finally, the exposed embryo can be damaged in handling, which can reduce the germination ability of any seed lot. It is not uncommon to have hulless barley seed lots with less than 90% germination. With a lower percent of pure live seed in any seed lot, a greater volume of seed is required to achieve the same stand density.

Fertilization, tillage practices, and seeding depths are the same as for regular hulled barley. The use of certified seed is very important in producing commercial food-grade hulless barley. Industry standards for food-grade hulless barley have very strict limits on the amount of foreign material and diseased kernels that can be in any seed lot. Avoid excessive nitrogen fertilization because most hulless varieties are late maturing and weak stemmed; too much nitrogen can delay maturity and induce lodging, especially if grown under irrigation. Because the hulls are loose on hulless varieties, any seed heads that lodge severely enough to touch the ground can quickly sprout while still in the head. When selecting a field to plant, check the cropping history and pick one where it is unlikely that volunteer hulled barley will germinate. A year of summer fallow before planting helps reduce the incidence of both volunteer barley and barley diseases transmitted by crop residues.

As mentioned previously, the exposed embryo can be damaged in handling, which reduces germination ability. Improved germination comes from seed lots where the combine operator did not set the combine to thresh all the hulls from the seed at harvest. Seeding rates similar to that of hulled barley are recommended (90 to 100 pounds per acre of pure live seed). However, hulless barley has smaller kernels than hulled barley, higher bushel weights, and flows faster through seeder metering systems, so seeding rates must be adjusted accordingly.

Pest control measures are the same as for regular hulled barley. If weed populations have been determined through IPM practices to be high enough to cause a potential loss in yield or quality of the crop, then the application of herbicides may be warranted. Best weed control is a combination of mechanical and chemical summer fallow to reduce the number and species of weeds for the following season and an application of a post-emergence herbicide when needed as determined through IPM practices. Good results for control of annual broadleaf weeds can be obtained using a tank mix of broadleaf-selective herbicides Bromoxynil, and MCPA, Diglycolamine, or 2,4-D amine, all of which are labeled for use on barley. These herbicides must be applied after the barley has reached the 3-leaf stage (4 to 6 inches tall), but before it reaches the boot stage, and when the weeds are small and free from drought stress. The higher application rates can injure the crop, leading to increased tillering and reduced yields if the weather conditions are hot and dry for 2 weeks after application. To eliminate grassy weeds with chemical fallow, a broad-spectrum, nonselective, post-emergence herbicide such as glyphosate (Roundup) can be used. Loose smut (*Ustilago nuda*) and Fusarium blight (*Fusarium graminearum* and others) are the biggest fungal disease problems on hulless barley. Commercial food-grade hulless barley can't contain any diseased kernels. Use of clean certified seed and a seed protectant such as carboxin (Vitavax) is recommended. This treated seed will include a colored dye (red, pink, or purple) to differentiate it from untreated seed so that it isn't used as animal feed or human food. Insect pests and their control is the same as for feed barley. If insect population levels and damage have been determined to be too high through IPM practices, then the application of an insecticide may be warranted. Always remember to read the pesticide label to be sure the crop is specified and follow the directions on mixing, application, and disposal. Contact your local Cooperative Extension Service for more information on pest control (see Appendix 1 for addresses and contact information). Because hulless barley is usually later maturing and susceptible to lodging, it may still be in the fields when waterfowl begin fall migration. With its higher nutrient content and easier digestibility it is a strong favorite for migrating waterfowl. Use of the propane scare cannons, designed to swivel in different directions and go off at uneven time intervals, is recommended. For more information on wildlife control in agricultural fields, contact the local office of the Alaska Department of Fish and Game.

The fields should be inspected before harvest to insure that the highest quality crop is being grown in order to meet the standards set for commercial food-grade hulless barley. These standards are identical to the Alaska state foundation seed requirements (white tag) from the Alaska Seed Growers Association (1985). The fields should be planted in clean ground and not in ground in which the same crop that is being certified was planted the previous year. There can be only 1 plant out of 3,000 of another barley variety as well as 1 plant out of 10,000 that is an inseparable crop (for example, another grain crop in barley), and there must be no objectionable weeds (prohibited or restricted noxious weeds). The seed lots after harvest should also be inspected to meet the foundation seed standards. These standards are as follows:

- Minimum of 96% pure seed
- Maximum of 5% hulled kernels
- Maximum of 4% damaged kernels
- Maximum of 14.5% kernel moisture
- Maximum of 2% inert matter (chaff, dirt, etc.)
- Maximum of 0.06% other crops
- Maximum of 0.05% other barley varieties
- 0% diseased (toxic) kernels (Fusarium blight, ergot)
- 0% objectionable weed seeds
- 0.01% other weed seeds
- Minimum of 85% germination

It must be stressed that this inspection is only for foundation seed and not the final inspection that needs to be done before milling or sale to the public. Fields where seed is grown for sale for planting in future years should also be inspected. The standards for all seed grade lots as certified seed (blue tag) are the same as for feed barley. For more information about field and seed lot inspections, contact the local office of the state Division of Agriculture, Department of Natural Resources or the Alaska Seed Growers Association (see Appendix 1 for addresses and contact information).

Like hulled barley, hulless varieties stop growing at the hard dough stage and can be harvested using the same methods. However, 14.8% or lower moisture is considered good for safe, long-term storage conditions. For the commercial human food industry, a reading of 14.5% or less moisture is required. The highest quality grain can be achieved when swathing or combining at the lowest moisture content.

For proper threshing and hull removal during combining, slow down the feeding rate by reducing the front concave opening and cylinder speed, and increase the airflow to improve hull removal. To reduce embryo damage, run augers at full capacity or slow them down. For commercial food-grade seed that can have only 4% cracked hulls, it is important to continually check for hulls left on the seed or cracked seeds and adjust combining methods accordingly. For seed grade, a higher percentage of hulls (not more than 15%) can be left on to reduce the possibility of embryo damage. Exceeding 15% results in a lower price paid to the producer. Commercial food grades must be at least 95% free of hulls, which is difficult to achieve when combining. It is better to leave a higher percentage on during harvest and remove the excess hulls during the handling processes with additional buffing before shipping to market. Commercial food-grade hulless barley can't contain any diseased kernels, and has a maximum amount of other crops or foreign material. On-farm cleaning and sizing of the seed lot to food grade standards before shipment results in higher prices paid to the producer. Clean-outs can be used on farm or sold as feed grade.

Currently in Alaska there is an increased interest in producing hulless barley for human consumption as whole grain and flour. However, there are no large-scale mills to produce food-grade flour and no elevators set up to accept these varieties. Although there are a number of small-scale on-farm mills, hulless barley is sold at present primarily as whole grain and flour in local health food markets. Hulless barley is also grown here for on-farm use as a supplement for animal feed. Similar to hulled barley, there is a limited market for hulless barley straw due to the rough awns that remain after harvest. There is also a small seed production industry to provide local farmers with certified seed.

All commercial food-grade grain products, which include whole kernel grain and processed flour, are regulated and inspected by state and federal agencies before sale to the public. In Alaska, the Department of Environmental Conservation regulates and inspects commercial food-grade grain products under the Food Safety and Sanitation Program - Food Processors. Alaska statutes, Title 17 - Food and Drugs and Title 18 - Environmental Conservation, Chapter 31 - Alaska Food Code cover the state definitions and requirements to produce commercial food-grade grain products. More information can be obtained at the DEC website, http://dec.alaska.gov/commish/regulations/index.htm or contact the local DEC Environmental Health Officer (see appendix 1 for addresses and contact information).

Nationally, commercial food-grade grain products are regulated and inspected by the U.S. Food and Drug Administration (FDA) under the Good Manufacturing Practice (GMP) of Title 21 of the Federal Food, Drug and Cosmetic Act, part 110 - Sanitary conditions. More detailed information can be found in the USFDA publication, "Guide to Inspections of Grain Product Manufacturers," located at the FDA website, www.fda.gov/.

Recommended Variety Descriptions for Hulless Barley

Note: See Appendix 1 for the addresses of seed suppliers.

'Falcon' is an early-maturing, short, stiff-strawed, rough-awned, 6-row, naked-kerneled, spring barley released in 1992 by Alberta Agriculture Food and Rural Development in Lacombe. It is about equal in maturity with 'Thual' and 1 to 5 days later than 'Otal' feed barley. Seed yields are lower than 'Otal' but higher yielding than 'Thual'. Its stiff straw has high lodging resistance. It is susceptible to loose smut and Fusarium blight, which can be controlled with seed treatments. This variety is protected by Canadian plant breeders' rights. Producers may save seed for their own use on their own farms, but sale or transfer of seed is prohibited without written permission and a payment of royalities to the breeder. Direct inquiries about seed sources to the SeCan Association or Progressive Seeds Ltd.

'Peregrine' is an early-maturing, short, stiff-strawed, rough-awned, 6-row, naked-kerneled, spring barley released in 1999 by Alberta Agriculture Food and Rural Development in Lacombe. It is about 1 to 2 days earlier in maturity than 'Thual' but 2 to 4 days later than 'Otal'. It is lower yielding than both 'Otal' and 'Thual' due to the smaller kernel size. Its stiff straw has high lodging resistance. It is susceptible to loose smut and Fusarium blight which can be controlled with seed treatments. This variety is protected by Canadian plant breeders' rights. Producers may save seed for their own use on their own farms, but sale or transfer of seed is prohibited without written permission and a payment of royalties to the breeder. Direct inquiries about seed sources to Progressive Seeds Ltd.

'Sunshine' is an early-maturing, mid-tall, stiff-strawed, rough-awned, 6-row, naked-kerneled spring barley released in 2009 by the AFES plant breeding program at the Matanuska Experiment Farm. It is a cross between the hulless Alaska cultivar 'Thual', and the hulled Finnish cultivar 'JO 1632'. 'Sunshine' is equal in maturity to 'Otal', but earlier in maturity than 'Thual'. It produces higher yields, and has greater lodging resistance compared to 'Thual'. It is susceptible to loose smut and Fusarium

'Sunshine' hulless barley, a 6-row type released in 2009 by the Alaska Agricultural & Forestry Experiment Station

blight, which can be controlled with seed treatments. Direct inquiries about seed sources to the AFES Fairbanks Experiment Farm or the Alaska Seed Growers Association.

'Thual' is an early-maturing, mid-tall, moderately stiff-strawed, rough-awned, 6-row, naked-kerneled spring barley released in 1981 by the USDA-ARS plant breeding program at the Matanuska Experiment Farm. It is a cross between the 6-rowed hulled Finnish cultivar 'Otra' and an unnamed hulless line from Ireland. 'Thual' is one of the first released hulless varieties to mature and produce yields comparable with hulled varieties such as 'Otal'. It is usually 3 days later in maturity and slightly lower in yields than 'Otal'. In most years, its moderate straw strength causes a higher percentage of lodging when compared with 'Otal'. Direct inquiries about seed sources to the Alaska Seed Growers Association or the Alaska Plant Materials Center.

Yields and Quality by Location for Hulless Barley

Like feed barley, hulless barley is bought and sold by weight. Standard test weights are used as the legal unit for crop sales. The standard test weight for clean, dry, and undamaged hulless barley is 60 pounds per bushel, similar to that of spring wheat. Higher prices are paid to the producer for hulless barley but only if it can meet the quality criteria mentioned previously. Other than test weights, additional samples should be taken on-farm to determine quality. Any seed lots not meeting commercial food grade for hulless barley should be used as feed grade. It is important then for the producer to clean and size all seed lots before delivery to any niche markets. Test weights can differ between cultivars and can change within a single cultivar depending on cultural practices, weather conditions, and location where grown. It is used here as a measure of grain quality to determine maturity. Yields are expressed here in pounds per acre and bushels per acre. Determine bushels per acre by dividing the yield of any specific cultivar by the standard test weight.

Tables 10, 12, 14, 16, and 17 list hulless barley yields and quality measurements for all test locations: Fairbanks, Eielson, Delta Junction, and Palmer. All sites in the Delta Junction area have been combined into either the Delta dryland site (Table 14) or if grown under irrigation, the Delta irrigated site (Table 16). Each table also contains information on barley type (6-row, 2-row, etc.), the source or the location of where it was bred, and the years it was tested at each location. Maturity in this study was defined as when 50% of the heads for each plot were at the hard dough stage, or when the heads were a light yellow in color and the kernels did not dent when pressed with a thumbnail. Growing degree days (GDD) for average maturity were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. The low temperature point for barley in this report is the freezing point of water, 32°F. The GDD calculations for each day were then added to the preceding GDD value to determine the cumulative value to the date at which the specific variety had reached 50% maturity. All varieties were compared with 'Otal' spring feed barley as the standard variety. Yield as a percent of the standard variety 'Otal' was determined by dividing the average yield of each variety by the average yield of 'Otal'. Maturity vs. Std. (Standard variety) are the number of days each variety reached 50% maturity either before or after the number of days that 'Otal' reached 50% maturity.

Tables 11, 13, and 15 list the commercial food-grade quality measurements of the seed for select hulless barley varieties for the Fairbanks, Eielson, and Delta Junction dryland sites, respectively. They are presented here without statistical differences and solely for the reader's benefit. More detailed information and explanation about the industry standards for food-grade hulless barley that follow can be obtained from B. Baik and S. Ullrich (2008). Analysis of the Alaska grown hulless barley presented here is from the authors in cooperation with K. Long and K. Trateng (2007) of the Alaska Cooperative Extension Service.

Similar to hulled barley, percent crude protein is calculated from the total percent nitrogen analysis of the seed multiplied by a constant of 6.25. It is made up of amino acids and other non-protein portions of the seed and thus is only a measure of crude protein and not true protein. Industry standards are set for a range between 10% to 17% crude protein, which is higher than that for hulled barley. Higher values have greater nutritional food value, but too high a value (>17%) is an indicator of immature green seed which makes a lower quality grade flour because it turns rancid quicker. Other major nutrient mineral concentrations commonly measured are percent phosphorus (%P) and potassium (%K).

Broken kernels are usually limited to less than 15% for whole grain standards. Exposed endosperm on broken kernels can lead to spoilage and rancidity, lowering the grade of the flour.

Seed color for hulless barley can range from light yellow to dark brown, and even blue, purple, and black. Industry standards are a range of dark brown—medium brown—light brown, with acceptable seed color of medium to dark brown. The hardness of the kernel is an indicator of the ease of milling the seed into flour. Unless the bran on the outside of the kernel is removed through a pearling process before milling, this hard bran will contribute to the flour color. Hulless barley has a much harder bran than wheat and so has a uniform rating of "hard." The bran shatters during the milling process, leaving visible specks of the bran in the flour that are extremely difficult to screen out. The flour will appear darker in color compared to wheat flour. Like the seed color, industry standards are a range of dark brown to light brown with acceptable flour color of medium to light brown. Most consumers prefer lighter colored flour similar to wheat flour.

Related to the flour color is the percent polyphenol oxidase (%PPO). Polyphenols and other phenolic compounds tend to darken flour colors through oxidation so lower levels are better. Any barley grain contains greater amounts of the phenolic compounds than any other grain, which explains in part why products made from barley flour are darker in color compared to the same products made with wheat flour.

The percent amylose starch (amylopectin) is important in causing individual flour particles to stick together in processed products and affects the stability of these products during a freeze-thaw cycle. Also, amylopectin starches are difficult to digest, so the lower the amount the better. Waxy types are higher in this starch than normal hulless varieties, so industry standards range from 0% in some normal varieties to 45% in some waxy varieties.

The percent beta-glucan is what is responsible for lowering blood cholesterol and glucose levels. A large portion of these beta-glucans are found in the endosperm, which contributes to the kernel hardness of all hulless barley varieties. Industry standards range from 2% to 18%, and higher amounts are better.

Total dietary fiber consists of both soluble and insoluble fiber. In hulless barley this ranges from 11% to 34%, making this a high-fiber grain. High fiber has a satiety effect (feeling full) and speeds up the passage of food in the colon.

Spring Malting Barley

Like feed and hulless barley, there are both 2-row (*Hordeum distichum* L.) and 6-row (*Hordeum vulgare* L.) malting barley varieties. Almost any barley variety can be malted, but not every variety produces an acceptable malt. Malting barley varieties have high levels of alpha- and beta-amylase enzymes that help produce the necessary chemical changes needed to hydrolyze the starch in the endosperm of the seed into the fermentable malt sugars needed for high-quality beer. For these special characteristics, there are many differences among malting varieties, and the market sets the demand for specific ones. Large brewers have their own malting facilities that contract with malting barley producers to grow specific varieties. Although the local home brewer or microbrew facility may not have such a specific requirement, they demand a quality malt product. Check with local malting facilities for specific varieties grown in the area. In the malting and brewing niche markets, prices paid to the producer for high-quality malting barley are much higher than that for regular hulled varieties.

According to K. Panchuk and others (2000), there are several necessary characteristics for high-quality malting barley:

- A pure lot of an acceptable variety. Any contamination from other barley, even other malting barley varieties, results in rejection of the lot. It must also be free from other crops, insects, diseased heads, treated barley, and odor.
- Full and even maturity. Immature barley germinates slowly if at all. This is important because malting requires uniform, quick, and vigorous germination (95% or better and occurring within 3 days). Malt is actually barley that has been seeped in water to germinate it, grown 4 days, kilned dried, and cleaned to remove the rootlets—all with precise temperature and moisture controls. Anything that changes these procedures reduces malt product quality.
- The grain must be disease-free. Any fungal spores propagate along with the seed during the malting process, reducing malt quality. Also, loose smut spores carried through the malting process can affect the flavor of the beer.
- Anything else that may affect quick, even germination results in rejection of the seed lot. This includes frost or excessive heat damage, weathering and staining, and peeled or broken kernels. These are directly related to the producer's ability to grow a successful crop. Planting early with the correct variety to avoid frost, direct combining instead of leaving the grain in a swath to collect mold spores or sprout, and setting the concave and cylinder speed on the combine to reduce kernel damage produces a higher quality barley. Only 5% broken kernels are allowed in high-quality malting barley.
- Grain should be free from heat-damaged kernels. No desiccants and no extra-high heat can be used to reach the proper moisture of 13.5%. Any high heat may lower the germination ability and change the levels of the special enzymes needed to make high-quality malt.
- The barley must have plump, uniform kernels. Uniform kernels tend to germinate uniformly. Plump kernels contain more starch, which produces more malt extract, and in turn, more beer. Yield of malt extract is as important to a brewer as yield of grain is to the barley producer.
- Low to moderate protein concentration. Six-row malt barley must have 10.5% to 13.5% protein and 2-row malt barley 10.5% to 12.5% protein. High-protein barley is difficult to malt efficiently because it produces a low amount of malt extract and cloudy beer.

Fertilization, tillage practices, and seeding are identical with that of regular hulled and hulless barley. Similar to hulless barley, the use of certified seed is very important in producing commercial malting barley. Industry standards for malting barley have very strict limits on the amount of foreign material and diseased kernels that can be in any seed lot. Nitrogen fertilization requirements should be monitored closely, because with higher levels of nitrogen fertilizer, all malting varieties produce higher protein concentrations. The protein concentration and grain yields are determined by the amount of available nitrogen and precipitation during the growing season, all other things being equal. If total precipitation is high, protein concentration is generally low and vice versa, and low rainfall during the grain filling stage results in higher protein levels and fewer plump kernels. Because most malting varieties mature later than regular hulled feed barleys, it's likely that some immature seed will be harvested. Protein is more concentrated in immature seed, lowering malt quality. Overfertilization with nitrogen or a late planting date almost certainly results in an immature, high-protein barley unsuitable for malting. When selecting a field to plant, check the cropping history and pick one that does not have the likelihood of any volunteer barley or other crops coming up in the field. As with all barley crops, a year of summer fallow before planting helps to reduce the incidence of both volunteer barley and barley diseases transmitted by crop residues. Seeding rates are identical to that of regular barley (90 to 100 pounds per acre of pure live seed).

Pest control measures are the same as for regular hulled and hulless barley. If weed populations have been determined through IPM practices to be high enough to cause a potential loss in yield or quality of the crop, then the application of herbicides may be warranted. Best weed control is a combination of mechanical and chemical summer fallow to reduce the number and weed species for the following season and an application of a post-emergence herbicide when needed as determined through IPM practices. Good results for controlling annual broadleaf weeds can be obtained using a tank mix of Bromoxynil, MCPA, Diglycolamine, or a 2,4-D amine, all of which are labeled for use on barley. These herbicides must be applied after the barley has reached the 3-leaf stage (4 to 6 inches tall), but before it reaches the boot stage and when the weeds are small and free from drought stress. The higher application rates can injure the crop, leading to increased tillering and reduced yields if the weather conditions are hot and dry for 2 weeks after application. To eliminate grassy weeds with chemical fallow, a broad-spectrum, nonselective post-emergence herbicide such as glyphosate (Roundup) can be used. Malting barley can't contain any diseased kernels. Loose smut (*Ustilago nuda*) and Fusarium blight (*Fusarium graminearum* and others) are the biggest fungal disease problems occurring on the seed of malting barley. Use of clean certified seed and a seed protectant such as carboxin (Vitavax) is recommended. This treated seed will include a colored dye (red, pink, or purple) to differentiate it from untreated seed so that it isn't used as feed or directly in the malting process. Net blotch (*Pyrenophorea teres*), spot blotch (*Cochliobolus sativus*), and barley scald (*Rhynchosporium secalis*) on the leaves of malting barley reduces yields and kernel plumpness. These can be controlled by not planting malting barley in fields that had barley in the previous year. Insect pests and their control are the same as for feed barley. If insect population levels and damage have been determined to be too high through IPM practices, then the application of an insecticide may be warranted. Always remember to read the pesticide label to be sure the crop is specified and follow the directions on mixing, application, and disposal. Contact your local Cooperative Extension Service for more information on pest control (see Appendix 1 for addresses and contact information).

In the spring, early germinating malting barley varieties are especially susceptible to predation by returning migratory waterfowl. Large flocks of migratory waterfowl can cause serious damage to these varieties by walking down the row and pecking out each newly emerging plant. Use of the propane scare cannons, designed to swivel in different directions and go off at uneven time intervals, is recommended. For more information on wildlife control in agricultural fields, contact the local office of the Alaska Department of Fish and Game.

The malting industry wants plump, mature, even kernels. Also, it wants grain that is not artificially dried with high heat that reduces germination. Therefore, malting barley should be swathed or combined when the grain is at 13.5% moisture or less. Malting barley can be swathed at any time after it has reached the hard dough growth stage. Good, well-formed windrows cure in 3 or 4 days in hot, dry weather and in as much as a week in cool, wet weather. Because cool and wet conditions predominate at harvest time in Alaska, the swathed grain can weather and stain or fungal spores can spread in the windrow, reducing malt quality. In either swathing or direct combining, avoid green or weedy patches—the presence of immature seed or weed seed can cause the seed lot to be rejected. Studies conducted in Canada by K. Panchuk and others (2000) have determined that threshing at a moisture content of 16% or greater and then air drying significantly reduces germination. Therefore, do not direct combine or pick up windrows until the grain is below 16% moisture. If moisture is not at 13.5% after harvest, forced air drying with low heat is required.

In combining malting barley, increase the concave clearance, slow down the cylinder speed, and maintain low volumes in the return. This helps to reduce peeling of the hull and broken kernels. Maltsters want a bit of the awn left on the kernel. Awns of about 1/4 to 1/8 inch are acceptable. Continual checking for awns left on the seed or cracked seeds and adjusting combining methods is important. Run augers at full capacity or slow them down to reduce peeling. Remember that anything less than the acceptable quality standards for malting barley causes that seed lot to be rejected for malting. On-farm cleaning and sizing of the seed lot to malting grade standards before shipment results in higher prices paid to the producer. Clean-outs can be used on farm or sold as feed grade.

There are a number of microbreweries and home brewers throughout Alaska. To consistently produce a quality product, they require a consistent supply of quality malt. Currently, most of the malt used to produce beer in Alaska is imported. At the present, there are no malting facilities in Alaska large enough to supply the demand for quality malt and no elevators set up to accept malting varieties. There is an increasing market for locally produced malting barley in the state to supply a demand for an Alaska-grown microbrew product. However, any producer wishing to grow malting barley should only do so on contract with a local malting facility or microbrewery. Because most of the newer released malting varieties have been bred specifically for production under contract by major malting or brewing facilities, seed is often very difficult to obtain. However, many of the older varieties have since been released into the public domain. These varieties are still acceptable as top grades for malting barley and are more available to the general public.

Recommended Variety Descriptions for Malting Barley

Note: See Appendix 1 for the addresses of seed suppliers.

'Argyle' is a mid- to late-maturing, mid-tall, stiff-strawed, rough-awned, 6-row, high-yielding, high test weight, spring blue malt barley released in 1981 by the breeding program of the University of Manitoba in Winnipeg. 'Argyle' is much later maturing than 'Otal' feed barley with lower yields but much higher test weights. Because of its later maturity, there is a strong likelihood of immature seed at harvest. This variety is eligible for the top grades for 6-row malting barley. There is an established demand for this variety in North American markets. Direct inquiries about seed sources to the SeCan Association.

'B 1215' is a mid- to late-maturing, mid-tall, stiff-strawed, rough-awned, 2-row, mid-yielding, spring malt barley released in 1990 from the plant breeding program at Busch Agricultural Resources Inc. in Colorado. 'B 1215' is much later in maturity than 'Otal' feed barley and has lower yields. Because of its later maturity there is a strong likelihood of immature seed at harvest. It is shorter than the 2-row malt variety 'Harrington' and so has a greater lodging resistance. This variety is eligible for the top grades for 2-row malting barley. There is an established demand for this variety in North American markets. Direct inquiries about seed sources to Agricore United.

'B 1602' is a mid- to late-maturing, mid-tall, stiff-strawed, rough-awned, 6-row, high-yielding white spring malt barley released in 1989 from the plant breeding program at Busch Agricultural Resources Inc. in Colorado. 'B 1602' is much later in maturity than 'Otal' feed barley, but on good years yields better than 'Otal'. Because of its later maturity there is a strong likelihood of immature seed at harvest. This variety is eligible for the top grades for 6-row malting barley. There is an established demand for this variety in North American markets. Direct inquiries about seed sources to Agricore United or the Brewing and Malting Barley Research Institute.

'Harrington' is a mid to late maturing, mid-tall, stiff-strawed, rough-awned, 2-row, high-yielding spring malt barley released in 1981 from the plant breeding program at the University of Saskatchewan in Saskatoon. It is a cross between 'Klages' and 'Gazelle'/'Beltzes'/'Centennial'. 'Harrington' is much later in maturity than 'Otal' feed barley, but in good years yields about the same. Because of its later maturity, there is a strong likelihood of immature seed at harvest. This variety is eligible for the top grades for 2-row malting barley. There is an established demand for this variety in North American markets. Direct inquiries about seed sources to the SeCan Association.

Yields and Quality by Location for Malting Barley

Like feed barley, malting barley is bought and sold by weight. Standard test weights are used as the legal unit for crop sales. The standard test weight for clean, dry, and undamaged malting barley is 48 pounds per bushel like that of regular hulled barley. Higher prices are paid to the producer for malting barley, but only if it can meet the quality criteria mentioned previously. Other than test weights, additional samples should be taken to determine quality. Any seed lots not meeting malt quality for malting barley should be used as feed grade. It is important then for the producer to clean and size all seed lots before delivery to any niche markets. Test weight can differ between cultivars and can change within a single cultivar depending on cultural practices, weather conditions, and location where grown. It is used here as a measure of grain quality to determine maturity. Yields are expressed in pounds per acre and bushels per acre. Determine bushels per acre by dividing the yield of any specific cultivar by the standard test weight.

Tables 18, 21, 23, 26, and 27 list malting barley yields and quality measurements for all test locations: Fairbanks, Eielson, Delta Junction, and Palmer. All sites in the Delta Junction area have been combined into either the Delta dryland site (Table 23) or if grown under irrigation, the Delta irrigated site (Table 26). Each table also contains information on barley type (6-row, 2-row, etc.), the source or the location where it was bred, and the years it was tested at each location. Maturity in this study was defined as when 50% of the heads for each plot were at the hard dough stage, or when the heads were a light yellow in color and the kernels did not dent when pressed with a thumbnail. Growing degree days (GDD) for average maturity were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. The low temperature point for barley in this report is the freezing point of water, 32°F. The GDD calculations for each day were then added to the preceding GDD value to determine the cumulative value to the date at which the specific variety had reached 50% maturity. All varieties were compared with 'Otal' spring feed barley as the standard variety. Yield as a percent of the standard variety 'Otal' was determined by dividing the average yield of each variety by the average yield of 'Otal'. Maturity vs. Std. (Standard variety) is the number of days each variety reached 50% maturity, either before or after the number of days that 'Otal' reached 50% maturity.

Tables 19, 20, 22, 24, 25, 28, and 29 list the commercial malt quality measurements of the seed for select malting barley varieties for the Fairbanks, Eielson, Delta Junction dryland, and Palmer sites. They are presented here without statistical differences and solely for the reader's benefit. More detailed information and explanation about the industry standards for malting barley that follow can be obtained from the American Malting Barley Association (2005), the Brewing and Malting Barley Research Institute (2006), D. Miller (1995), and P. Schwarz and R. Horsley (2006). Analysis of Alaska-grown malting barley presented here is from S. Dofing and others (1991) and M. Van Veldhuizen and others (2007).

Malting barley standards are rather strict in order to produce a consistently high quality malt product. The final product is ranked for malt quality with the lower the ranking number equaling the better quality malt. Acceptable levels of malt quality are values of 5 or less for both 6-row and 2-row varieties. This ranking is determined from a number of standard measures of the barley before, during, and after malting. These measures include grain factors that relate to the amount and uniformity of malt production, and malt factors that relate to the amount of malt modification, the conversion of starches to malt sugars, the congress wort (malt extract), and malt enzymes.

Protein is needed for conversion of starches to fermentable malt sugars. Six-row malt barley must have 10.5-13.5% protein and 2-row malt barley 10.5-12.5% protein. Too high a protein content is often an indicator of immature seed. This will result in a thinner kernel with less starch to convert into malt sugars, producing a low amount of malt extract and a cloudy beer with lots of foam. It will also lead to lower germination rates and longer steeping times. Too low a protein content will not have enough of the enzymes needed to convert the starches into malt sugars. Also, lower protein levels (within the acceptable ranges) makes a sweeter malt whereas higher percent protein tends to have a bitter flavor. Other major nutrient mineral concentrations commonly measured are percent phosphorus (%P) and potassium (%K) as both are major nutrients for the yeast. Phosphorus binds with oxygen during malt modification, creating phosphates. These malt phosphates provide a weak acid buffer that help maintain the pH during the mashing process (conversion of starch to malt sugars). Too high potassium levels can inhibit enzyme reactions in the mash, creating a salty flavor. Acceptable levels for both %P and %K are 1.1% or less.

The percent plump kernels (>6/64 inch) and percent thin kernels (<5/64 inch) are an indicator of uniformity in the size of grain. The more uniform the grain, the more uniform the germination, and the more starch that can be converted to malt sugars in the kernels. Also, the more kernels that are on top of the 6/64-inch screen (the plump kernels) the more the grain that can potentially be converted into a malting product. Six-row malt barley must have 80% or greater plump kernels and less than 3% thin kernels. Two-row malt barley must have 90% or greater plump kernels and 3% thin kernels. There will be another measure of kernel plumpness after malting, which would indicate how well the kernels retained their size. The greater the percent loss, the lower the amount of converted sugars there will be for a quality malt. For 6-row barley there must be 60% or greater left on a 7/64-inch screen and for 2-row barley there must be greater than 70%.

Skinned and broken kernels will not germinate and produce a malt product, so the lower the percent the better. Industry standards are 5% or less broken kernels. Since most broken kernels will be a smaller size than whole kernels, they can be screened out before delivery to the malting facility. The hull covering the seed on malting barley is also very important because it protects the germinating grain during the malting process. Six-row varieties tend to have a higher hull content because they have thinner kernels, but this does vary with the growth environment. Higher hull content may mean that more oxidizable polyphenolic substances can end up in the wort that will react with the proteins, which can lead to a cloudy and bitter-flavored beer.

To get a quality malting product, the seed must have an adequate percent moisture of 12% to 14% that will allow the seed to germinate uniformly. Too high of a moisture content will cause the seed to rot in storage and too low will produce dead seed.

Germination energy is the germination percentage of 100 seeds in 4 milliliters (0.14 oz) of water at room temperature over a 72-hour period. The higher the percent germination, the more barley kernels that can be converted into malt. Industry standards for all types of malting barley are 98% or greater. This is important in the steeping process when the grain is soaked by sprinkling with a constant supply of fresh water and stirred to supply the needed oxygen levels to initiate germination. The steeping time will vary over a 2- to 3-day period. The grain is then germinated at a constant temperature of about 60°F and uniform moisture until the acrospires (shoots) are about 75-100% of the length of the kernels. This process, called malt modification, is when the enzymes break down the matrix surrounding the starch granules in the endosperm of the kernel, preparing the starch for conversion into fermentable malt sugars. The time required for malt modification will vary with variety but usually is between 4 and 5 days with 2-row barley taking longer.

After modification the germinated grain is then dried in a 2-step process. Step 1 is to lower the percent moisture on the grain to about 5%. This is done at a low temperature of around 100°F for a couple of days or until the 5% moisture goal is reached. The grain is then tumbled and re-cleaned to knock off and remove the acrospires and rootlets. Step 2 is the kilning process, where the temperatures are raised to any where between 180°F and 220°F for another day or two. The higher temperatures will produce a darker-roasted malt which will produce a darker-colored beer.

The protein content after malting should be slightly lower than the same measure before malting. This is the protein content of the malt sugars after malting that the yeasts will need to convert into energy and carbon dioxide. Six-row malt barley must have between 11.3% and 13.3% protein and 2-row malt barley between 10.8% and 12.9% protein.

Beta-glucans are long chains of glucose molecules that are joined together. During the germination process they are broken down into shorter chains by malt β-glucanase enzymes, becoming simple sugars. If they are not broken down, they can become gummy and increase the viscosity of the liquid malt. Six-row barley should contain 120 ppm or less β-glucan and 2-row barley 100 ppm or less.

The fine to coarse grind extract difference is an indicator of how well the malt has been modified. Basically the malt is ground fine and coarse and then tested to see if it has the same malting characteristics. The smaller the difference the better the malt quality. This also applies for malted flour quality used in baking. For all barley types the standard is less than 1.2% difference.

The percent soluble to total protein ratio is the amount of wort-soluble protein produced from the mashing process in relation to the total amount of protein in the malt after the malting process. Mashing is soaking the malt in hot water that starts the conversion of starches into fermentable sugars. The balance of soluble to total protein is important because this contributes to measures of beer quality like mouthfeel, foam, color, and flavor. Six-row barley should have a range of 42% to 47% and 2-row barley 40% to 47%. Values above or below these ranges are not considered acceptable.

The percent soluble protein of the congress wort is made up of various nitrogen compounds including peptides and amino acids. High levels of this type of protein (>5.5%) can lead to overdevelopment of color during wort boiling, filtration problems, and cloudy beer. Six-row barley is limited to a range of 5.2% to 5.7% and 2-row barley to 4.4% to 5.6% soluble protein.

The percent fine grind malt extract (expressed on a dry weight basis) is the yield of soluble material that can be obtained after the mashing process. This is important to large-scale brewers because this determines the amount of beer that can be produced from a given amount of malt. Two-row malting barley varieties will usually produce more malt extract than 6-row varieties. Therefore, 2-row barley should have 81% or greater malt extract and 6-row barley should have 79% or greater. This difference is not very great, so small-scale brewers are usually less concerned about this measure of the congress wort.

The wort color and clarity is a measure of the optical absorbance through a series of colored glass slides of the liquid wort. They are measured in ASBC (American Society of Brewing Chemists) units of degrees Lovibond. The lower the values, the clearer the wort, and eventually, the clearer the beer. Acceptable values for 6-row barley are 1.8 to 2.2 degrees Lovibond and 1.6 to 2.2 for 2-row barley.

Diastatic power is a measurement of the total enzymatic starch conversion potential of the malt. Malts with a higher diastatic power will convert starches faster and will also convert other starches not contained in the malt such as those found in the hull of the seed. Diastatic power is measured in units of degrees Lintner. Acceptable values for 6-row barley are 140 degrees Lintner or greater and 120 or greater for 2-row barley with most malting varieties falling within a range of 110 to 150 degrees Lintner.

Alpha-amylase enzymes dextrinize soluble starches, reduce mash viscosity, and increase the susceptibility of the breakdown of the starch from other enzymes, eventually converting the starch into fermentable malt sugars. Six-row barley usually has a higher level of α-amylase enzymes than 2-row barley. However, both types have a standard measure of 45 degree units (DU) or greater.

Table 1. Average yields and quality measurements for all feed barley varieties from test plots in the Fairbanks area.

Barley Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test wt. (lbs / bu)	Biomass Yield (lbs / acre)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
6-row feed, spring											
AC Albright	Alberta	13	4524	94	108	49	1706	53	26-Jul	-1	1955
AC Lacombe	Alberta	3	5892	123	103	46	N/D	27	5-Aug	9	2084
AC Stacey	Alberta	3	5249	109	91	46	N/D	22	6-Aug	10	2125
Agneta	Sweden	5	6008	125	104	47	N/D	18	1-Aug	5	2002
Arra	Finland	11	4338	90	100	46	N/D	31	29-Jul	2	2021
Arve	Finland	6	5769	120	100	47	N/D	14	31-Jul	4	1957
Azure	Idaho	2	3469	72	121	46	N/D	33	2-Aug	6	2316
Bamse	Sweden	3	6114	127	106	48	N/D	8	2-Aug	6	2016
Bere	Scotland	1	2698	56	79	36	N/D	95	30-Jul	3	2157
Bode	Norway	4	4027	84	69	44	N/D	28	1-Aug	5	1985
Brier	Saskatchewan	3	5625	117	97	45	N/D	50	8-Aug	12	2172
Cougbar	Washington	2	3542	74	124	46	N/D	44	2-Aug	6	2316
Datal	Alaska	12	3777	79	97	47	N/D	45	26-Jul	-1	1957
Edda	Sweden	3	5061	105	88	48	N/D	32	1-Aug	5	1982
Finaska	Alaska	14	3953	82	100	47	1316	18	25-Jul	-2	1925
Galt	Alberta	3	3819	80	139	47	N/D	35	31-Jul	4	2267
Heartland	Manitoba	1	2001	42	79	45	N/D	0	3-Aug	7	2323
Jackson	Alberta	3	3036	63	110	46	N/D	24	27-Jul	0	2153
Jokioinen 1599	Finland	4	6871	143	120	47	N/D	31	2-Aug	6	2014
Jokioinen 1632	Finland	5	4794	100	88	47	N/D	30	1-Aug	5	1955
Karin	Sweden	3	5498	115	95	46	N/D	8	31-Jul	4	1963
Lidal	Alaska	9	3970	83	89	48	N/D	29	26-Jul	-1	1920
Loviisa	Finland	5	5978	125	104	48	N/D	15	3-Aug	7	2040
Nobel	Alberta	2	3962	83	138	47	N/D	35	31-Jul	4	2278
Nordlys	Norway	4	4508	94	78	45	N/D	33	29-Jul	2	1904
Olli	Finland	4	4371	91	76	45	N/D	42	31-Jul	4	1969
Olsok	Norway	3	5014	104	86	48	N/D	25	31-Jul	4	1953
Otal	Alaska	26	3841	80	100	48	1113	35	27-Jul	0	1977
Otra	Finland	4	2266	47	83	41	N/D	54	27-Jul	0	2153
Pohto	Finland	4	5766	120	101	48	N/D	30	4-Aug	8	2053
Pokko	Finland	6	4572	95	115	45	N/D	17	31-Jul	4	2121
Ripa	Sweden	3	5744	120	99	48	N/D	17	2-Aug	6	2009
Steptoe	Washington	4	3930	82	119	44	N/D	62	1-Aug	5	2161
Svendal	Alaska	7	3152	66	96	47	N/D	14	26-Jul	-1	2035
Thule	Norway	3	6257	130	109	48	N/D	8	7-Aug	11	2140
Verner	Sweden	3	5368	112	93	49	N/D	3	4-Aug	8	2079
Wooding	Alaska	12	3783	79	107	48	1774	40	25-Jul	-2	1955

Table 1. Average yields and quality measurements for all feed barley varieties from test plots in the Fairbanks area, continued.

Barley Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test wt. (lbs / bu)	Biomass Yield (lbs / acre)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
6-row feed semi-dwarf, spring											
Duke	Saskatchewan	1	3321	69	131	44	N/D	0	1-Aug	5	2266
Eero 80	Finland	14	4441	93	114	46	N/D	28	4-Aug	8	2152
Kasota	Alberta	4	5356	112	101	47	N/D	13	3-Aug	7	2038
Stetson	Alberta	1	4775	99	96	40	N/D	0	11-Aug	15	2116
Winchester	Alberta	2	3373	70	117	46	N/D	70	2-Aug	6	2316
2-row feed, spring											
Abee	Alberta	2	4464	93	116	53	N/D	20	1-Aug	5	2115
Andre	Washington	1	2672	56	70	52	N/D	0	1-Aug	5	2115
Bonus	Sweden	2	2694	56	70	56	N/D	41	10-Aug	14	2356
Bowman	North Dakota	1	1584	33	41	47	N/D	0	13-Aug	17	2435
CDC Dolly	Alberta	1	6132	128	160	48	N/D	0	7-Aug	11	2279
Centennial	Alberta	1	4560	65	119	53	N/D	10	4-Aug	8	2197
Duece	Saskatchewan	3	4022	84	105	52	N/D	1	2-Aug	6	2142
Elrose	Saskatchewan	1	2832	59	73	50	N/D	40	1-Aug	5	2115
Fairfield	Alberta	3	4848	101	126	55	N/D	10	4-Aug	8	2197
Gallatin	Montana	2	3925	82	102	52	N/D	6	30-Jul	3	2060
HV #52	Washington	2	2832	59	74	46	N/D	0	31-Jul	4	2087
Lewis	Montana	2	4768	99	124	50	N/D	60	30-Jul	3	2060
Lud	England	2	5088	106	132	54	N/D	10	7-Aug	11	2279
Mari	Sewden	2	3648	76	95	55	N/D	23	6-Aug	10	2252
Norburt	Saskatchewan	1	3216	67	83	45	N/D	10	3-Aug	7	2169
Valier	Montana	1	3599	75	94	49	N/D	27	6-Aug	10	2252
2-row feed semi-dwarf, spring											
Icelandic	Iceland	2	3212	67	84	48	N/D	7	30-Jul	3	2060
6-row hooded forage, spring											
Trapmar^	Alaska	3	3086	64	80	46	N/D	40	11-Aug	15	2485
Weal	Alaska	28	3282	68	85	43	7874	35	26-Jul	-1	1947
2-row hooded forage, spring											
Haybet	Montana	2	3136	65	82	45	9910	45	4-Aug	8	2197
Hayes	Montana	2	3449	72	90	46	9245	9	3-Aug	7	2169
Weal Selection	Alaska	1	4128	86	107	44	N/D	10	29-Jul	2	2032
6-row feed, winter											
Dicktoo	Nebraska	1	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Kearney	Nebraska	1	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature.
º'Hyproly' and 'Hyproly Normal' are high protein varieties.
^'Trapmar' is also a hulless variety. N/D = No Data.
All varieties were compared with 'Otal' spring feed barley as the standard variety.

Table 2. Average quality measurements for select feed barley varieties from test plots in the Fairbanks area.

Barley Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)	Total Ca (%)	TNC (%)	NDF (%)	ADF (%)	IVDMD (%)	Relative Feed Value
Feed Industry Standards			**11-15%**	**0.3-0.5%**	**0.4-0.6%**	**0.05-0.1%**	**>35%**	**18-35%**	**5-9%**	**>80%**	**<218**
6-row feed, spring											
AC Albright	Alberta	13	14.17	0.28	0.46	0.04	38.50	26.19	5.86	80	299
Finaska	Alaska	14	14.96	0.30	0.42	0.03	36.40	27.79	5.31	81	284
Otal	Alaska	26	13.85	0.28	0.42	0.03	37.10	30.83	5.60	80	255
Svendal	Alaska	7	14.69	0.38	0.41	N/D	N/D	N/D	N/D	N/D	N/D
Wooding	Alaska	12	14.46	0.24	0.40	0.04	38.00	29.09	5.62	80	270
6-row feed semi-dwarf, spring											
Eero 80	Finland	12	13.69	0.32	0.46	N/D	N/D	N/D	N/D	N/D	N/D
Stetson	Alberta	1	14.31	0.36	0.35	N/D	N/D	N/D	N/D	N/D	N/D
Forage Industry Standards			**9-14%**	**0.3-0.5%**	**0.4-0.6%**	**0.05-0.09%**	**>20%**	**45-65%**	**25-35%**	**>60%**	**<144**
6-row hooded forage, spring											
Weal	Alaska	13	12.04	0.36	0.33	0.05	22.62	49.86	28.11	79	125
2-row hooded forage, spring											
Haybet	Montana	2	9.04	0.41	0.34	0.06	21.64	53.62	30.41	70	113
Hayes	Montana	2	9.90	0.42	0.35	0.06	22.38	49.64	28.42	63	126

Feed analysis done on mature, ripe seed only. Forage analysis done on whole plant biomass at soft dough stage. N/D = No Data. All varieties were compared with 'Otal' spring feed barley as the standard variety.

Table 3. Average yields and quality measurements for all feed barley varieties from test plots in the Eielson area.

Barley Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test wt. (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
6-row feed, spring										
Arra	Finland	1	1993	42	92	48	0	5-Aug	2	2388
Otal	Alaska	6	2179	45	100	46	0	3-Aug	0	2334
Pokko	Finland	1	1822	38	84	45	0	7-Aug	4	2444
Svendal	Alaska	3	2856	60	131	46	0	29-Jul	-5	2194
6-row feed semi-dwarf, spring										
Eero 80	Finland	4	2602	54	119	47	0	2-Aug	-1	2306
Stetson	Alberta	3	2504	52	115	39	0	13-Aug	10	2599

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. All varieties were compared with 'Otal' spring feed barley as the standard variety.

Table 4. Average quality measurements for select feed barley varieties from test plots in the Eielson area.

Barley Variety Name	Source	Years Tested	Crude Protein (%)	Total P %)	Total K (%)
Feed Industry Standards			11-15%	0.3-0.5%	0.4-0.6%
6-row feed, spring					
Otal	Alaska	6	11.13	0.37	0.45
Svendal	Alaska	3	12.50	0.39	0.52
6-row feed semi-dwarf, spring					
Eero 80	Finland	4	19.56	0.32	0.42
Stetson	Alberta	3	11.81	0.37	0.40

Feed analysis done on mature, ripe seed only. All varieties were compared with 'Otal' spring feed barley as the standard variety.

Dwarf Icelandic 2-row barley growing at the Fairbanks Experiment Farm.

Feed barley at heading stage, growing on the Fairbanks Experiment Farm summer 2010.

Table 5. Average yields and quality measurements for all feed barley varieties from test plots in the Delta Junction area, dryland site.

Barley Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test wt. (lbs/ bu)	Biomass Yield (lbs/acre)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
6-row feed, spring											
AC Albright	Alberta	12	2550	53	121	48	1246	1	31-Jul	-2	2046
AC Lacombe	Alberta	2	2047	43	70	42	N/D	0	31-Jul	-2	2019
AC Stacey	Alberta	1	2997	62	88	41	N/D	0	4-Aug	2	2169
Agneta	Sweden	2	2412	50	84	45	N/D	0	5-Aug	3	2166
Arra	Finland	8	2401	50	98	46	N/D	0	6-Aug	4	1973
Arve	Finland	3	2650	55	105	45	N/D	0	1-Aug	-1	1967
Azure	Idaho	2	3002	63	78	46	N/D	0	1-Sept	30	2501
Bamse	Sweden	1	3246	68	96	45	N/D	0	2-Aug	0	2098
Bode	Norway	1	2826	59	83	43	N/D	0	30-Jul	-3	1997
Brier	Saskatchewan	1	3110	65	92	41	N/D	0	2-Aug	0	2086
Cougbar	Washington	2	3231	67	84	48	N/D	0	1-Sept	30	2501
Datal	Alaska	11	2752	57	113	47	N/D	13	7-Aug	5	2084
Edda	Sweden	1	2681	56	79	46	N/D	0	31-Jul	-2	2027
Finaska	Alaska	14	2326	48	102	45	927	4	31-Jul	-2	2045
Galt	Alberta	3	3082	64	88	48	N/D	0	14-Aug	12	2204
Heartland	Manitoba	1	2029	42	73	47	N/D	0	29-Jul	-4	1873
Jackson	Alberta	3	3311	69	95	51	N/D	0	12-Aug	10	2138
Jokioinen 1599	Finland	3	2604	54	100	44	N/D	0	5-Aug	3	2093
Jokioinen 1632	Finland	5	2115	44	105	44	N/D	0	6-Aug	4	1785
Karin	Sweden	1	3074	64	91	44	N/D	0	3-Aug	1	2134
Lidal	Alaska	6	2419	50	102	45	N/D	10	1-Aug	-1	2126
Loviisa	Finland	2	3202	67	115	45	N/D	0	3-Aug	1	2024
Nobel	Alberta	2	3546	74	92	48	N/D	0	24-Aug	22	2401
Nordlys	Norway	1	2881	60	85	43	N/D	0	30-Jul	-3	2002
Olli	Finland	1	2844	59	84	44	N/D	0	31-Jul	-2	2027
Olsok	Norway	1	3243	68	96	48	N/D	0	29-Jul	-4	1962
Otal	Alaska	26	2361	49	100	46	1300	9	2-Aug	0	2073
Otra	Finland	3	3404	71	98	49	N/D	22	9-Aug	7	2086
Pohto	Finland	3	2845	59	110	45	N/D	0	3-Aug	1	2030
Pokko	Finland	5	3103	65	100	46	N/D	0	18-Aug	16	2156
Ripa	Sweden	2	2389	50	86	46	N/D	0	30-Jul	-3	2006
Steptoe	Washington	3	2878	60	81	43	N/D	1	18-Aug	16	2394
Svendal	Alaska	7	2464	51	94	48	N/D	3	2-Aug	0	2072
Thule	Norway	1	3520	73	104	44	N/D	0	5-Aug	3	2189
Verner	Sweden	2	2517	52	88	47	N/D	0	2-Aug	0	2080
Wooding	Alaska	10	2682	56	122	47	1626	11	2-Aug	0	2148
6-row feed semi-dwarf, spring											
Duke	Saskatchewan	1	2244	47	81	46	N/D	0	29-Jul	-4	1873
Eero 80	Finland	11	2564	53	116	46	N/D	0	9-Aug	7	2197
Kasota	Alberta	3	1848	38	77	41	N/D	0	3-Aug	1	1898

Table 5. Average yields and quality measurements for all feed barley varieties from test plots in the Delta Junction area, dryland site.

Stetson	Alberta	3	1414	29	77	41	N/D	0	2-Aug	0	2101
Winchester	Alberta	2	3338	70	86	50	N/D	0	24-Aug	22	2401
2-row feed, spring											
Andre	Washington	1	2204	46	79	49	N/D	0	1-Aug	-1	1940
CDC Dolly	Alberta	1	1808	38	84	39	N/D	0	10-Aug	8	2079
Duece	Saskatchewan	3	3373	70	96	52	N/D	0	16-Aug	14	2247
Gallatin	Montana	2	3569	74	93	55	N/D	0	25-Aug	23	2414
Lewis	Montana	2	3771	79	98	55	N/D	0	29-Aug	27	2448
Valier	Montana	1	2955	62	112	43	N/D	0	5-Aug	3	2013
2-row feed semi-dwarf, spring											
Icelandic	Iceland	1	3830	80	111	48	N/D	0	5-Aug	3	2142
6-row hooded forage, spring											
Weal	Alaska	10	2222	46	78	42	6645	14	7-Aug	5	2195
2-row hooded forage, spring											
Haybet	Montana	1	4085	85	144	42	5440	38	5-Aug	3	2195
Hayes	Montana	1	4566	95	161	43	6985	25	5-Aug	3	2195
Weal Selection	Alaska	1	3504	73	104	42	N/D	10	3-Aug	1	2090

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. N/D = No Data. All varieties were compared with 'Otal' spring feed barley as the standard variety

Table 6. Average quality measurements for select feed barley varieties from test plots in the Delta Junction area, dryland site.

Barley Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)	Total Ca (%)	TNC (%)	NDF (%)	ADF (%)	IVDMD (%)	Relative FeedValue
Feed Industry Standards			**11-15%**	**0.3-0.5%**	**0.4-0.6%**	**0.05-0.1%**	**>35%**	**18-35%**	**5-9%**	**>80%**	**<218**
6-row feed, spring											
AC Albright	Alberta	12	14.00	0.26	0.42	0.04	38.40	28.78	6.15	80	272
Finaska	Alaska	14	13.94	0.31	0.41	0.03	36.00	27.11	5.88	80	289
Otal	Alaska	26	14.25	0.28	0.45	0.03	37.10	30.35	5.84	80	259
Svendal	Alaska	7	15.06	0.27	0.37	N/D	N/D	N/D	N/D	N/D	N/D
Wooding	Alaska	10	14.63	0.22	0.41	0.03	36.30	34.31	6.67	79	227
6-row feed semi-dwarf, spring											
Eero 80	Finland	11	12.13	0.24	0.41	N/D	N/D	N/D	N/D	N/D	N/D
Stetson	Alberta	3	14.15	0.23	0.24	N/D	N/D	N/D	N/D	N/D	N/D
Forage Industry Standards			**9-14%**	**0.3-0.5%**	**0.4-0.6%**	**0.05-0.09%**	**>20%**	**45-65%**	**25-35%**	**>60%**	**<144**
6-row hooded forage, spring											
Weal	Alaska	10	12.48	0.25	0.36	0.05	21.35	51.63	34.12.	76	112
2-row hooded forage, spring											
Haybet	Montana	1	10.85	0.24	0.38	0.05	20.64	53.10	31.91	67	117
Hayes	Montana	1	11.75	0.29	0.37	0.05	20.11	54.39	31.10	68	111

Feed analysis done on mature, ripe seed only. Forage analysis done on whole plant biomass at soft dough stage. N/D = No Data. All varieties were compared with 'Otal' spring feed barley as the standard variety.

Table 7. Average yields and quality measurements for all feed barley varieties from test plots in the Delta Junction area, irrigated site.

Barley Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test wt. (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
6-row feed, spring										
AC Albright	Alberta	5	3284	68	109	48	3	8-Aug	2	2164
AC Lacombe	Alberta	2	4088	85	107	45	0	4-Aug	-2	2155
AC Stacey	Alberta	1	4734	99	118	43	0	6-Aug	0	2196
Agneta	Sweden	2	3718	77	98	48	0	31-Jul	-6	2017
Arra	Finland	3	3887	81	105	47	0	2-Aug	-4	2018
Arve	Finland	3	3628	76	99	46	0	4-Aug	-2	2057
Bamse	Sweden	1	3718	77	92	46	0	31-Jul	-6	2023
Bode	Norway	1	3520	73	89	44	0	30-Jul	-7	1989
Brier	Saskatchewan	1	4394	92	109	43	0	7-Aug	1	2243
Datal	Alaska	1	3387	71	84	48	0	1-Aug	-5	2069
Edda	Sweden	1	3582	75	89	46	0	4-Aug	-2	2148
Finaska	Alaska	2	4051	84	110	44	0	5-Aug	-1	2083
Jokioinen 1599	Finland	3	4151	86	112	46	0	9-Aug	3	2179
Jokioinen 1632	Finland	2	3793	79	102	45	0	2-Aug	-4	2007
Karin	Sweden	1	3275	68	81	44	0	31-Jul	-6	2022
Lidal	Alaska	1	3629	76	90	46	0	31-Jul	-6	2030
Loviisa	Finland	2	3966	83	107	46	0	5-Aug	-1	2087
Nordlys	Norway	1	3506	73	87	44	0	31-Jul	-6	2022
Olli	Finland	1	3605	75	90	45	0	30-Jul	-7	1982
Olsok	Norway	1	3914	82	97	46	0	2-Aug	-4	2085
Otal	Alaska	5	3042	63	100	49	7	6-Aug	0	2121
Pohto	Finland	3	4222	88	114	47	0	5-Aug	-1	2083
Pokko	Finland	1	4385	91	109	45	0	3-Aug	-3	2131
Ripa	Sweden	2	3574	74	94	48	0	29-Jul	-8	1966
Svendal	Alaska	2	3597	75	95	48	0	31-Jul	-6	2039
Thule	Norway	1	4035	84	100	45	0	5-Aug	-1	2186
Verner	Sweden	2	3552	74	93	50	0	4-Aug	-2	2138
Wooding	Alaska	2	2812	59	137	49	5	11-Aug	5	2248
6-row feed semi-dwarf, spring										
CDC Earl	Saskatchewan	1	4391	91	109	39	0	31-Jul	-6	2023
Eero 80	Finland	3	4158	87	112	46	0	7-Aug	1	2133
Kasota	Alberta	2	4136	86	109	48	0	1-Aug	-5	2064
Stetson	Alberta	2	3111	65	82	44	0	1-Aug	-5	2062
2-row feed, spring										
CDC Dolly	Alberta	2	3471	72	91	45	0	11-Aug	5	2204

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. All varieties were compared with 'Otal' spring feed barley as the standard variety.

Table 8. Average yields and quality measurements for all feed barley varieties from test plots in the Palmer area.

Barley Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test Wt. (lbs/bu)	Biomass Yield (lbs/acre)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
6-row feed, spring											
AC Albright	Alberta	13	3166	66	113	47	1351	34	2-Aug	-3	2104
AC Lacombe	Alberta	5	4042	84	95	47	N/D	18	17-Aug	12	2406
AC Stacey	Alberta	4	3630	76	86	45	N/D	48	18-Aug	13	2418
Advance	Washington	1	0	0	0	0	N/D	40	14-Aug	9	2179
Agneta	Sweden	6	4091	85	96	48	N/D	20	15-Aug	10	2351
Akka	Scotland	1	0	0	0	0	N/D	40	5-Aug	0	2255
Arra	Finland	6	3944	82	108	48	N/D	23	8-Aug	3	2174
Arve	Finland	6	4222	88	94	50	N/D	14	12-Aug	7	2174
Azure	Idaho	1	2987	62	92	50	N/D	0	28-Aug	23	2314
Bamse	Sweden	4	4342	90	101	49	N/D	18	15-Aug	10	2591
Bode	Norway	4	3980	82	90	46	N/D	17	11-Aug	6	2359
Brier	Saskatchewan	4	3645	76	86	45	N/D	33	21-Aug	16	2254
Brockilli	Finland	1	0	0	0	0	N/D	40	14-Aug	9	2179
Cougbar	Washington	1	3303	69	102	50	N/D	0	28-Aug	23	2498
Datal	Alaska	13	2869	60	99	48	N/D	50	11-Aug	6	2102
Edda	Sweden	3	3566	74	84	50	N/D	43	13-Aug	8	1709
Ershabet	Montana	1	0	0	0	0	N/D	40	21-Aug	16	1994
Etu	Scotland	1	0	0	0	0	N/D	40	1-Aug	-4	2121
Finaska	Alaska	16	2945	61	110	45	768	17	4-Aug	-1	1985
Flynn†	Minnesota	1	0	0	0	0	N/D	40	9-Aug	4	2449
Galt	Alberta	1	3476	72	107	51	N/D	0	21-Aug	16	1994
Gateway 63	Alberta	1	0	0	0	0	N/D	40	3-Aug	-2	2320
Gunilla	Sweden	1	0	0	0	0	N/D	40	12-Aug	7	2054
Hankkija 673	Finland	2	3229	67	114	48	N/D	40	3-Aug	-2	2320
Heartland	Manitoba	1	4512	94	159	45	N/D	20	13-Aug	8	2212
Iuzhnii	Russia	1	0	0	0	0	N/D	40	12-Aug	7	2591
Jackson	Alberta	2	3326	69	102	54	N/D	85	16-Aug	11	2418
Jokioinen 1465	Finland	2	2150	45	76	48	N/D	40	8-Aug	3	2174
Jokioinen 1474	Finland	2	2329	49	82	48	N/D	40	3-Aug	-2	2320
Jokioinen 1490	Finland	1	2630	55	93	48	N/D	40	5-Aug	0	2255
Jokioinen 1599	Finland	5	4544	95	103	46	N/D	9	19-Aug	14	2285
Jokioinen 1632	Finland	6	4312	90	114	47	N/D	17	9-Aug	4	2449
Karin	Sweden	6	3865	81	90	47	N/D	18	13-Aug	8	2212
Lidal	Alaska	11	2690	56	92	47	N/D	43	11-Aug	6	2088
Loviisa	Finland	4	4573	95	103	49	N/D	21	13-Aug	8	2114
Lyllpur	Pakistan	1	0	0	0	0	N/D	40	3-Aug	-2	2320
Nobel	Alberta	1	3243	68	100	51	N/D	0	28-Aug	23	2344
Nord	Norway	2	2614	55	92	48	N/D	40	3-Aug	-2	2320
Nordlys	Norway	4	3603	75	85	45	N/D	18	9-Aug	4	2891
Olli	Finland	4	3154	66	74	47	N/D	55	9-Aug	4	2217

Table 8. Average yields and quality measurements for all feed barley varieties from test plots in the Palmer area, continued.

Olsok	Norway	3	4496	94	105	51	N/D	13	11-Aug	6	2212
Otal	Alaska	25	2766	58	100	46	1098	29	5-Aug	0	2045
Otra	Finland	2	3581	75	110	47	N/D	75	12-Aug	7	2054
Paavo	Finland	1	0	0	0	0	N/D	40	10-Aug	5	2087
Pirkka	Finland	1	0	0	0	0	N/D	40	9-Aug	4	2891
Pohto	Finland	5	4739	99	106	49	N/D	19	14-Aug	9	2179
Pokko	Finland	4	4378	91	111	45	N/D	34	16-Aug	11	2387
Potra	Norway	3	2610	54	92	48	N/D	40	8-Aug	3	2174
Ripa	Sweden	6	3921	82	92	49	N/D	18	12-Aug	7	1570
Steptoe	Washington	2	2566	53	92	44	N/D	43	22-Aug	17	2291
Svendal	Alaska	1	3105	65	96	50	N/D	75	11-Aug	6	2388
Tammi	Finland	1	0	0	0	0	N/D	40	9-Aug	4	1914
Thule	Norway	3	3859	80	90	46	N/D	12	19-Aug	14	2148
Verner	Sweden	3	4405	92	103	51	N/D	13	16-Aug	11	2446
Wooding	Alaska	9	2200	46	120	46	1556	37	1-Aug	-4	1909
6-row feed semi-dwarf, spring											
Eero 80	Finland	8	4245	88	95	48	N/D	15	14-Aug	9	2373
Kasota	Alberta	4	3781	79	100	46	N/D	5	14-Aug	9	2316
Winchester	Alberta	1	2583	54	79	50	N/D	0	28-Aug	23	2591
2-row feed, spring											
CDC Dolly	Alberta	1	4881	102	95	48	N/D	25	9-Aug	4	1914
Bowman	North Dakota	1	0	0	0	0	N/D	40	5-Aug	0	2255
Duece	Saskatchewan	1	3296	69	101	56	N/D	0	28-Aug	23	2591
Gallatin	Montana	1	3617	75	111	55	N/D	0	29-Aug	24	2611
Lewis	Montana	1	4305	90	133	55	N/D	0	29-Aug	24	2611
Valier	Montana	1	1700	35	96	40	N/D	0	29-Jul	-7	1914
2-row feed semi-dwarf, spring											
Betzes	Montana	1	0	0	0	0	N/D	40	21-Aug	16	1994
6-row hooded forage, spring											
Trapmar^	Alaska	1	0	0	0	0	N/D	40	12-Aug	7	1570
Weal	Alaska	8	1982	41	100	40	5891	41	20-Aug	15	2395
2-row hooded, forage, spring											
Haybet	Montana	1	2093	44	150	46	7436	85	10-Aug	5	2069
Hayes	Montana	1	2436	51	174	47	7535	93	10-Aug	5	2038

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. N/D = No Data.

†'Flynn' is a smooth-awned variety.

^'Trapmar' is also a hulless variety. All varieties were compared with 'Otal' spring feed barley as the standard variety.

Table 9. Average quality measurements for select feed barley varieties from test plots in the Palmer area.

Barley Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)	Total Ca (%)	TNC (%)	NDF (%)	ADF (%)	IVDMV (%)	Relative Feed Value
Feed Industry Standards			11-15%	0.3-0.5%	0.4-0.6%	0.05-0.1%	>35%	18-35%	5-9%	>80%	<218
6-row feed, spring											
AC Albright	Alberta	13	16.52	0.26	0.44	0.05	34.60	30.58	6.71	79	255
Finaska	Alaska	16	15.62	0.28	0.46	0.06	35.10	29.67	6.46	79	263
Otal	Alaska	25	15.44	0.29	0.42	0.06	28.50	31.88	6.84	79	244
Wooding	Alaska	9	16.79	0.26	0.42	0.06	32.50	31.50	6.52	79	248
Forage Industry Standards			9-14%	0.3-0.5%	0.4-0.6%	0.05-0.09%	>20%	45-65%	25-35%	> 60%	< 144
6-row hooded forage, spring*											
Weal	Alaska	8	13.45	0.26	0.43	0.05	23.66	58.42	35.04	71	98
2-row hooded forage, spring*											
Haybet	Montana	1	11.81	0.22	0.44	0.06	22.25	59.42	29.94	65	103
Hayes	Montana	1	11.90	0.21	0.45	0.06	23.98	60.32	29.87	69	101

Feed analysis done on mature, ripe seed only. Forage analysis done on whole plant biomass at soft dough stage. All varieties were compared with 'Otal' spring feed barley as the standard variety.

Table 10. Average yields and quality measurements for all hulless barley variety test plots in the Fairbanks area.

Barley Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test Wt. (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
6-row hulless non-waxy, spring										
CDC Buck	Saskatchewan	3	3523	59	118	54	27	1-Aug	5	2166
CDC Silky	Saskatchewan	1	4002	67	140	51	7	5-Aug	9	2092
Peregrine	Alberta	4	2537	42	74	54	0	30-Jul	3	1985
Sunshine	Alaska	10	3069	51	85	57	33	22-Jul	-5	1907
Thual	Alaska	20	2911	49	80	56	68	27-Jul	0	2012
6-row hulless non-waxy, semi dwarf, spring										
Falcon	Alberta	7	3953	66	99	55	2	29-Jul	2	2055
6-row hulless, hooded non-waxy, spring										
Trapmar^	Alaska	3	3086	64	81	46	40	11-Aug	15	2116
2-row hulless non-waxy, spring										
CDC Dawn	Alberta	4	3574	60	104	56	12	4-Aug	8	2128
CDC Freedom	Alberta	2	3473	58	90	58	0	6-Aug	10	2238
CDC Richard	Saskatchewan	4	3136	52	109	60	47	5-Aug	9	2194
HB 3352	Alberta	4	3823	64	111	57	1	5-Aug	9	2156
HB 3433	Alberta	6	3959	66	108	55	1	3-Aug	7	1809
Phoenix	Alberta	4	3328	55	98	56	23	2-Aug	6	2094

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing.

^'Trapmar' is also a forage variety. All varieties were compared with 'Otal' spring feed barley as the standard variety.

Table 11. Average quality measurements for select hulless barley varieties from test plots in the Fairbanks area.

Barley Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)	Broken Kernels (%)	Seed Color (brown)	Flour Color (brown)	Polyphenol Oxidase (%)	Amlyose Starch (%)	β-glucan Enzyme (%)	Dietary Fiber (%)
Hulless Food Industry Standards			10-17%	0.2-0.4%	0.3-0.5%	<15%	medium	light	0.2-0.4%	0-45%	2-18%	11-34%
6-row hulless non-waxy, spring												
CDC Buck	Saskatchewan	3	13.94	0.35	0.36	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Peregrine	Alberta	4	11.94	0.36	0.44	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Sunshine	Alaska	10	13.69	0.41	0.48	12	dark	medium	0.17	22	5.60	15
Thual	Alaska	20	13.69	0.39	0.46	25	medium	light	0.17	23	5.50	15
6-row hulless non-waxy, semi dwarf, spring												
Falcon	Alberta	7	12.44	0.37	0.44	N/D	N/D	N/D	N/D	N/D	N/D	N/D
2-row hulless non-waxy, spring												
CDC Richard	Saskatchewan	4	13.88	0.32	0.39	N/D	N/D	N/D	N/D	N/D	N/D	N/D

N/D = No Data. All varieties were compared with 'Otal' spring feed barley as the standard variety.

Table 12. Average yields and quality measurements for all hulless barley variety test plots in the Eielson area.

Barley Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test wt. (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
6-row hulless non-waxy, spring										
CDC Buck	Saskatchewan	3	3135	144	54	0	2-Aug	-1	2306	3
Thual	Alaska	4	2423	111	54	0	4-Aug	1	2361	4
2-row hulless non-waxy, spring										
CDC Richard	Saskatchewan	3	3206	147	57	0	4-Aug	1	2361	3

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. All varieties were compared with 'Otal' spring feed barley as the standard variety.

Table 13. Average quality measurements for select hulless barley varieties from test plots in the Eielson area.

Barley Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)
Hulless Food Industry Standards			10-17%	0.2-0.4%	0.3-0.5%
6-row hulless non-waxy, spring					
CDC Buck	Saskatchewan	3	11.38	0.36	0.38
Thual	Alaska	4	12.25	0.37	0.44
2-row hulless non-waxy, spring					
CDC Richard	Saskatchewan	3	11.69	0.35	0.39

All varieties were compared with 'Otal' spring feed barley as the standard variety.

Table 14. Average yields and quality measurements for all hulless barley variety test plots in the Delta Junction area, dryland site.

Barley Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test wt. (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
6-row hulless non-waxy, spring										
CDC Buck	Saskatchewan	4	1779	30	134	52	0	11-Aug	9	2291
CDC Silky	Saskatchewan	1	2089	35	79	37	0	10-Aug	8	2004
Peregrine	Alberta	4	1837	31	76	56	0	3-Aug	1	2073
Sunshine	Alaska	10	2128	35	100	55	10	31-Jul	-2	2076
Thual	Alaska	23	1878	31	87	55	29	5-Aug	3	2127
6-row hulless non-waxy, semi dwarf, spring										
Falcon	Alberta	7	2320	39	92	50	1	6-Aug	4	2119
2-row hulless non-waxy, spring										
CDC Dawn	Alberta	4	2394	40	101	52	13	6-Aug	4	2161
CDC Freedom	Alberta	2	2470	41	79	53	0	7-Aug	5	2330
CDC Richard	Saskatchewan	4	1586	26	121	54	0	10-Aug	8	2291
HB 3352	Alberta	4	2896	48	126	56	0	7-Aug	5	2179
HB 3433	Alberta	6	2008	33	85	50	0	7-Aug	5	2132
Phoenix	Alberta	4	2359	39	103	54	3	5-Aug	3	2154

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. All varieties were compared with 'Otal' spring feed barley as the standard variety.

Table 15. Average quality measurements for select hulless barley varieties from test plots in the Delta Junction area, dryland site.

Barley Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)	Broken Kernels (%)	Seed Color (brown)	Flour Color (brown)	Polyphenol Oxidase (%)	Amlyose Starch (%)	β-glucan Enzyme (%)	Dietary Fiber (%)
Hulless Food Industry Standards			10-17%	0.2-0.4%	0.3-0.5%	<15%	medium	light	0.2-0.4%	0-45%	2-18%	11-34%
6-row hulless non-waxy, spring												
CDC Buck	Saskatchewan	4	13.38	0.27	0.35	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Peregrine	Alberta	4	11.00	0.27	0.41	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Sunshine	Alaska	10	11.88	0.29	0.39	14	dark	medium	0.19	20	5.50	16
Thual	Alaska	23	15.19	0.29	0.47	28	medium	light	0.15	19	5.50	17
6-row hulless non-waxy, semi dwarf, spring												
Falcon	Alberta	7	12.50	0.29	0.45	N/D	N/D	N/D	N/D	N/D	N/D	N/D
2-row hulless non-waxy, spring												
CDC Richard	Saskatchewan	4	14.63	0.28	0.46	N/D	N/D	N/D	N/D	N/D	N/D	N/D

N/D = No Data. All varieties were compared with 'Otal' spring feed barley as the standard variety.

Table 16. Average yields and quality measurements for all hulless barley variety test plots in the Delta Junction area, irrigated site.

Barley Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test wt. (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
6-row hulless non-waxy, spring										
CDC Silky	Saskatchewan	1	3091	52	77	51	0	7-Aug	1	2108
Sunshine	Alaska	2	1823	30	88	59	15	8-Aug	2	2192
Thual	Alaska	5	2209	37	75	56	32	7-Aug	1	2133
6-row hulless non-waxy, semi dwarf, spring										
Falcon	Alberta	2	2814	47	75	50	0	7-Aug	1	2033
2-row hulless non-waxy, spring										
HB 3433	Alberta	1	2805	47	81	46	0	12-Aug	6	2091

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. All varieties were compared with 'Otal' spring feed barley as the standard variety.

Table 17. Average yields and quality measurements for all hulless barley variety test plots in the Palmer area.

Barley Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test wt. (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
6-row hulless non-waxy, spring										
CDC Silky	Saskatchewan	1	1262	21	71	49	0	17-Aug	12	1965
Peregrine	Alberta	4	1764	29	90	50	26	17-Aug	12	1889
Sunshine	Alaska	9	1809	30	95	55	50	1-Aug	-4	1904
Thual	Alaska	13	1973	33	88	55	52	4-Aug	-1	1981
6-row hulless non-waxy, semi dwarf, spring										
Falcon	Alberta	6	2066	34	86	49	37	14-Aug	9	1933
6-row hulless, hooded non-waxy, spring										
Trapmar^	Alaska	1	0	0	0	0	40	12-Aug	7	1570
2-row hulless non-waxy, spring										
CDC Dawn	Alberta	4	1789	30	93	52	62	3-Aug	3	1943
CDC Freedom	Alberta	2	1511	25	83	59	62	3-Aug	3	2098
CDC Richard	Saskatchewan	1	1614	27	91	50	0	19-Aug	11	1928
HB 3352	Alberta	4	2575	43	142	55	40	3-Aug	3	1942
HB 3433	Alberta	6	2677	45	118	55	27	10-Aug	5	1995
Phoenix	Alberta	4	2010	33	105	54	45	6-Aug	1	1916

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing.

^'Trapmar' is also a forage variety. All varieties were compared with 'Otal' spring feed barley as the standard variety.

Table 18. Average yields and quality measurements for all malting barley variety test plots in the Fairbanks area.

Barley Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test wt. (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
6-row malting, spring										
Argyle	Manitoba	3	4224	88	85	51	0	12-Aug	16	2126
B 1602	Colorado	1	5010	104	101	41	0	9-Aug	13	2089
Bonanza	Manitoba	3	3600	75	73	52	0	11-Aug	15	2121
Dual	Colorado	1	5405	113	109	39	0	9-Aug	13	2080
Morex	Minnesota	3	3475	72	121	47	32	30-Jul	3	2212
Stander	Minnesota	1	4967	103	100	45	0	12-Aug	16	2126
2-row malting, spring										
B 1215	Colorado	2	4690	98	88	48	0	10-Aug	14	2116
Ellice	Manitoba	3	4000	83	144	49	7	30-Jul	3	2230
Harrington	Saskatchewan	5	4089	85	93	46	2	12-Aug	16	2323
Klages	Idaho	3	3922	82	142	50	12	31-Jul	4	2254

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. All varieties were compared with 'Otal' spring feed barley as the standard variety.

Table 19. Average grain quality measurements for select malting barley varieties from test plots in the Fairbanks area.

Barley Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)	Plump Kernels (% >6/64")	Thin Kernels (% <5/64")	Broken Kernels (%)	Kernel Moisture (%)	Germination Energy (%)
6-row Malting Industry Standards			10.5-13.5%	<1.1%	<1.1%	>80%	<3%	<5%	12-14%	>98%
6-row malting, spring										
Argyle	Manitoba	3	18.60	0.32	0.32	92.9	5.9	0.5	12.4	91
B 1602	Colorado	1	14.46	0.38	0.34	96.2	4.1	0.4	12.3	92
Bonanza	Manitoba	3	19.78	0.41	0.30	88.9	7.8	0.7	13.6	93
Dual	Colorado	1	15.27	0.40	0.33	N/D	N/D	N/D	N/D	N/D
Morex	Minnesota	3	14.31	0.36	0.35	93.0	6.2	0.9	13.2	90
Stander	Minnesota	1	14.40	0.39	0.38	N/D	N/D	N/D	N/D	N/D
2-row Malting Industry Standards			10.5-12.5%	<1.1%	<1.1%	>90%	<3%	<5%	12-14%	>98%
2-row malting, spring										
B 1215	Colorado	2	13.17	0.32	0.34	N/D	N/D	N/D	N/D	N/D
Ellice	Manitoba	3	14.00	0.41	0.37	N/D	N/D	N/D	N/D	N/D
Harrington	Saskatchewan	5	14.44	0.35	0.29	95.3	3.2	1.0	14.2	88
Klages	Idaho	3	15.56	0.42	0.38	N/D	N/D	N/D	N/D	N/D

N/D = No Data. All varieties were compared with 'Otal' spring feed barley as the standard variety.

Table 20. Average malt quality measurements for select malting barley varieties from test plots in the Fairbanks area.

Barley Variety Name	Source	Malt Protein (%)	Plump Kernels (% >6/64")	B-glucan Enzyme (ppm)	Fine - Coarse Extract (%)	Soluble/ Total Protein (%)	Soluble Protein (%)	Malt Extract (%)	Wort Color (°Lovi.)	Diastatic Power (°Lintner)	α-Amylase (20 DU)	Malt Quality (rank)
6-row Malting Industry Standards		11.3-13.3%	>60%	<120	<1.2%	42-47%	5.2-5.7%	79%	1.8-2.2	>140	>45	<5
6-row malting, spring												
Argyle	Manitoba	N/D	N/D	N/D	3.0	34.1	6.31	76.5	1.5	149	40.9	2
B 1602	Colorado	12.70	90.0	141	1.6	42.4	5.46	79.5	2.2	133	38.1	8
Bonanza	Manitoba	N/D	N/D	N/D	3.7	32.5	6.38	75.5	1.4	128	38.3	7
Morex	Minnesota	N/D	N/D	N/D	4.8	30.1	6.12	74.9	1.1	129	33.9	11
2-row Malting Industry Standards		10.8-12.9%	>70%	<100	<1.2%	40-47%	4.4-5.6%	81%	1.6-2.2	>120	>45	<5
2-row malting, spring												
Harrington	Saskatchewan	12.90	80	123	5.3	33.0	5.57	77.5	1.2	102	36.4	6

N/D = No Data. All varieties were compared with 'Otal' spring feed barley as the standard variety.

Table 21. Average yields and quality measurements for all malting barley variety test plots in the Eielson area.

Barley Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test wt. (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
6-row malting, spring										
B 1602	Colorado	3	3696	77	205	42	0	14-Aug	11	2188
Dual	Colorado	3	3425	71	183	40	0	14-Aug	11	2188
Stander	Minnesota	3	3516	73	195	42	0	13-Aug	10	2175
2-row malting, spring										
B 1215	Colorado	3	2673	56	145	44	0	18-Aug	15	2265
Harrington	Saskatchewan	3	3002	63	172	41	0	17-Aug	14	2241

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. All varieties were compared with 'Otal' spring feed barley as the standard variety.

Table 22. Average grain quality measurements for select malting barley varieties from test plots in the Eielson area.

Barley Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)
6-row Malting Industry Standards			10.5-13.5%	<1.1%	<1.1%
6-row malting, spring					
B 1602	Colorado	3	19.64	0.34	0.45
Dual	Colorado	3	19.78	0.34	0.50
Stander	Minnesota	3	19.75	0.31	0.48
2-row Malting Industry Standards			10.5-12.5%	<1.1%	<1.1%
2-row malting, spring					
B 1215	Colorado	3	19.36	0.29	0.47
Harrington	Saskatchewan	3	19.23	0.31	0.47

All varieties were compared with 'Otal' spring feed barley as the standard variety.

Table 23. Average yields and quality measurements for all malting barley variety test plots in the Delta Junction area, dryland site.

Barley Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test wt. (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
6-row malting, spring										
B 1602	Colorado	7	1790	37	91	42	0	6-Aug	4	2207
Dual	Colorado	3	2054	43	102	41	0	5-Aug	3	2190
Morex	Minnesota	2	3089	64	81	50	0	30-Aug	28	2484
Stander	Minnesota	3	1567	33	76	43	0	5-Aug	3	2181
2-row malting, spring										
B 1215	Colorado	4	1787	37	85	43	0	8-Aug	6	2161
Ellice	Manitoba	3	3640	76	105	52	0	17-Aug	15	2261
Harrington	Saskatchewan	10	1621	34	95	43	0	11-Aug	9	2197
Klages	Idaho	3	3217	67	90	52	0	21-Aug	19	2319

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. All varieties were compared with 'Otal' spring feed barley as the standard variety.

Table 24. Average grain quality measurements for select malting barley varieties from test plots in the Delta Junction area, dryland site.

Barley Variety Name	Source	Years Tested	Crude Protein (%)	P (%)	K (%)	Plump Kernels (% >6/64")	Thin Kernels (% <5/64")	Broken Kernels (%)	Kernel Moisture (%)	Germination Energy (%)
6-row Malting Industry Standards			**10.5-13.5%**	**<1.1%**	**<1.1%**	**>80%**	**<3%**	**<5%**	**12-14%**	**>98%**
6-row malting, spring										
B 1602	Colorado	7	12.63	0.22	0.25	95.5	4.2	0.3	10.3	82
Dual	Colorado	3	12.73	0.23	0.29	N/D	N/D	N/D	N/D	N/D
Morex	Minnesota	2	14.15	0.23	0.24	N/D	N/D	N/D	N/D	N/D
Stander	Minnesota	3	12.85	0.22	0.31	N/D	N/D	N/D	N/D	N/D
2-row Malting Industry Standards			**10.5-12.5%**	**<1.1%**	**<1.1%**	**>90%**	**<3%**	**<5%**	**12-14%**	**>98%**
2-row malting, spring										
B 1215	Colorado	4	13.46	0.21	0.32	N/D	N/D	N/D	N/D	N/D
Ellice	Manitoba	3	13.13	0.22	0.31	N/D	N/D	N/D	N/D	N/D
Harrington	Saskatchewan	10	13.85	0.23	0.33	94.4	4.5	1.1	9.4	58
Klages	Idaho	3	14.50	0.22	0.26	N/D	N/D	N/D	N/D	N/D

N/D = No Data. All varieties were compared with 'Otal' spring feed barley as the standard variety.

Table 25. Average malt quality measurements for select malting barley varieties from test plots in the Delta Junction area, dryland site.

Barley Variety Name	Source	Malt Protein (%)	Plump Kernels (% > 6/64")	β-glucan Enzyme (ppm)	Fine - Coarse Extract (%)	Soluble/ Total Protein (%)	Soluble Protein (%)	Malt Extract (%)	Wort Color (°Lovi.)	Diastatic Power (°Lintner)	α-Amylase (20 DU)	Malt Quality (rank)
6-row Malting Industry Standards		**11.3-13.3%**	**>60%**	**<120**	**<1.2%**	**42-47%**	**5.2-5.7%**	**79%**	**1.8-2.2**	**>140**	**>45**	**<5**
6-row malting, spring												
B 1602	Colorado	11.39	93.6	141	2.1	40.9	5.34	78.9	2.2	120	20.6	12
2-row Malting Industry Standards		**10.8-12.9%**	**>70%**	**<100**	**<1.2%**	**40-47%**	**4.4-5.6%**	**81%**	**1.6-2.2**	**>120**	**>45**	**<5**
2-row malting, spring												
Harrington	Saskatchewan	10.75	92	103	3.9	31.9	4.91	77.0	1.2	109.5	36.6	11

All varieties were compared with 'Otal' spring feed barley as the standard variety.

Table 26. Average yields and quality measurements for all malting barley variety test plots in the Delta Junction area, irrigated site.

Barley Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test wt. (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
6-row malting, spring										
B 1602	Colorado	4	2713	57	91	46	0	7-Aug	1	2182
Dual	Colorado	2	4269	89	112	45	0	3-Aug	-3	2117
Stander	Minnesota	2	3623	75	95	47	0	3-Aug	-3	2122
2-row malting, spring										
B 1202	Colorado	1	3719	77	92	48	0	3-Aug	-3	2107
B 1215	Colorado	3	3719	77	100	45	0	9-Aug	3	2160
Crest	Washington	1	3877	81	96	47	0	7-Aug	1	2240
Galena	Colorado	1	4031	84	100	47	0	3-Aug	-3	2129
Harrington	Saskatchewan	5	3054	64	101	46	0	10-Aug	4	2199
M 14	Colorado	1	3162	66	79	47	0	3-Aug	-3	2125

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. All varieties were compared with 'Otal' spring feed barley as the standard variety.

Table 27. Average yields and quality measurements for all malting barley variety test plots in the Palmer area.

Barley Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test wt. (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
6-row malting, spring										
Argyle	Manitoba	3	2813	59	59	50	0	28-Aug	23	2591
B 1602	Colorado	1	4801	100	94	46	25	14-Aug	9	2298
Bonanza	Manitoba	3	2842	59	59	51	0	28-Aug	23	2591
Morex	Minnesota	1	3647	76	112	50	0	28-Aug	23	2591
2-row malting, spring										
B 1215	Colorado	1	4801	80	169	46	25	18-Aug	13	2211
Ellice	Manitoba	1	3847	80	118	53	0	28-Aug	23	2591
Harrington	Saskatchewan	4	3812	79	120	46	6	18-Aug	13	2430
Hector	Alberta	1	0	0	0	0	40	15-Aug	10	2591
Klages	Idaho	1	3589	75	110	54	0	28-Aug	23	2591
Stein	Saskatchewan	2	3106	65	95	48	40	12-Aug	7	2054

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. All varieties were compared with 'Otal' spring feed barley as the standard variety.

Table 28. Average grain quality measurements for select malting barley varieties from test plots in the Palmer area.

Barley Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)	Plump Kernels (% >6/64")	Thin Kernels (% <5/64")	Broken Kernels (%)	Kernel Moisture (%)	Germination Energy (%)
6-row Malting Industry Standards			**10.5-13.5%**	**<1.1%**	**<1.1%**	**>80%**	**<3%**	**<5%**	**12-14%**	**>98%**
6-row malting, spring										
Argyle	Manitoba	3	13.80	0.33	0.30	82.7	10.1	0.6	12.2	89
Bonanza	Manitoba	3	14.10	0.34	0.31	84.1	8.9	1.1	13.5	91
Morex	Minnesota	1	15.70	0.36	0.35	89.5	9.9	0.9	13.0	90
2-row Malting Industry Standards			**10.5-12.5%**	**<1.1%**	**<1.1%**	**>90%**	**<3%**	**<5%**	**12-14%**	**>98%**
2-row malting, spring										
Harrington	Saskatchewan	4	13.80	0.35	0.29	87.5	7.5	1.2	14.3	88

All varieties were compared with 'Otal' spring feed barley as the standard variety.

Table 29. Average malt quality measurements for select malting barley varieties from test plots in the Palmer area.

Barley Variety Name	Source	Malt Protein (%)	Plump Kernels (% >6/64")	β-glucan Enzyme (ppm)	Fine - Coarse Extract (%)	Soluble/ Total Protein (%)	Soluble Protein (%)	Malt Extract (%)	Wort Color (°Lovi.)	Diastatic Power (°Lintner)	α-Amylase (20 DU)	Malt Quality (rank)
6-row Malting Industry Standards		**11.3-13.3%**	**>60%**	**<120**	**<1.2%**	**42-47%**	**5.2-5.7%**	**79%**	**1.8-2.2**	**>140**	**>45**	**<5**
6-row malting, spring												
Argyle	Manitoba	N/D	N/D	N/D	1.7	29.7	3.94	77.8	1.4	126	35.6	7
Bonanza	Manitoba	N/D	N/D	N/D	1.5	29.0	4.06	76.3	1.4	110	33.0	11
Morex	Minnesota	N/D	N/D	N/D	2.4	32.1	1.97	76.6	1.3	123	34.9	5
2-row Malting Industry Standards		10.8-12.9%	>70%	<100	<1.2%	40-47%	4.4-5.6%	81%	1.6-2.2	>120	>45	<5
2-row malting, spring												
Harrington	Saskatchewan	N/D	N/D	N/D	2.5	32.1	4.18	76.9	1.2	102	36.5	3

N/D = No Data. All varieties were compared with 'Otal' spring feed barley as the standard variety.

Haybet 2-row hooded forage spring barley growing on the Fairbanks Experiment Farm August 5, 2005

A 6-row barley growing at Fairbanks August 5, 2011

Oats

Oat Performance Trials — Spring Feed Oats

Oats are the second most important true cereal grain crop for Alaska after barley, and are well adapted to the state's long day length and short growing season. Oats are 7 to 10 days later in maturing than the early season barley varieties. Because oat seed germinates well in cold and wet soils, oats grown for seed can be planted early in the season in areas that are poorly drained. Oats are also more tolerant of acidic soils than barley or wheat and can produce high yields when soil pH values range between 5.0 and 5.5. According to D.C. Church (1979), the crude protein content of feed oat ranges from 11% to 14%, with crude fiber from 10% to 14% and a total dry matter content of 80-90%. This very high fiber content is due to the hull that covers the seed, which can average between 28% and 45% of the total weight of the seed. This fiber is poorly digested by swine and poultry, which limits oats' use as a feed. It has more use as a portion of the feed for ruminants and horses, especially breeding stock, but it has lower carbohydrates and energy than barley. Hulless oat varieties don't have the fibrous hulls and are more easily digested by monogastrics like swine and poultry. They also have a higher crude protein content of 11% to 17%, making hulless oats a higher energy feed. Oats are also planted for hay or in other forage mixes where seed production is not critical. In this case, planting can occur after all other spring cereal grains have been planted. Date of planting and fertilizer rate trials conducted at the Fairbanks test site have determined that oats planted between June 1 and June 15 grow taller and produce greater forage biomass than earlier planting dates. This quick increase in growth is due to greater precipitation and warmer soil temperatures that occur in early June at the Fairbanks site, as opposed to the lower precipitation and colder soil temperatures of May. Field peas are often interseeded with oats to produce a more nutritionally balanced forage. The cereal grain stems also help to support the pea vines, making the forage easier to harvest. A.L. Brundage and others (1979) determined that seed yields of both peas and oats grown in Alaska declined in oat/pea intercropping compared to either oat or peas grown alone. However, the nutritive composition (crude protein and nutritive minerals) of the oat/pea forage was higher than in either oats or peas grown separately as forage. S.H. Begna and others (2011) also determined that an oat/pea intercrop grown in interior Alaska can improve the forage quality (higher crude protein) over that of peas or oats grown alone. This study also determined that growing oats and peas together lowers the weed competition by shading the soil, which reduces the total number of germinating weeds as well as the size of the weeds that do manage to germinate. Oats combined for seed also produce a high-quality bedding straw because they don't have the rough awns found in barley.

Three main types of feed oats have been tested in Alaska: common, black, and red. The first and most widely tested is the common or white oat (*Avena sativa* L.). Seed from the common oat are white or yellow with the hulls still attached. The second most important oat for Alaska is the black oat (*Avena strigosa* L.). The outer hull is black or dark brown in color. It is not to be confused with the wild oat, which is also black in color. Wild oats (*Avena fatua* L.) are taller, more vigorous plants with widely spaced equilateral,

Still-green oat heads, summer 2010

Petri dish full of 'Nip', cleaned black feed oats

spreading panicles. The seeds have long, twisted awns and shatter easily when ripe, making this weed difficult to control in other grain crops. The last feed oat is the red oat (*Avena byzantina* C. Koch). Red oats are usually grown as an early maturing winter grain in central California and reach maturity before the summer drought season begins. In Alaska, however, red oats are 10 to 14 days later in maturity, with lower yields and test weights than the standard yellow oat varieties. For this reason there are no recommended red oat varieties for Alaska. Oats grown for animal feed are fed either whole, ground, or rolled.

Fertilization, tillage practices, and seeding depths are identical to barley. As with barley, soils with moderate to high levels of available nutrients should receive a complete fertilizer blend of nitrogen, phosphorus, potassium, and sulfur at a ratio of 3:2:1:0.5 N, P_2O_5, K_2O, and S. With irrigated farming practices, the ratio should be reduced to about 1.5:1:0.5:0.25. Additionally, application rates of 0.5 to 1.0 pound per acre of boron can increase yields and improve disease resistance. Actual percentages of each nutrient and the application rate varies according to specific soil test results. The fertilizer can be broadcast before spring tillage or portions can be banded at planting. Avoid excess nitrogen fertilizer because it can induce lodging, especially if grown under irrigation. However, when oats are grown as a forage, nitrogen becomes the most limiting nutrient. In certain rare situations, excess nitrogen and slow-growing conditions with reduced phosphate uptake can produce forage with nitrate levels high enough to poison livestock. Any samples of 0.44% nitrate or higher can be potentially toxic to livestock. Proper phosphate applications can reduce this occurrence. Since the straw is as valuable as the grain, it too is removed from the field. This tends to reduce available potassium levels in the soil. Therefore, an increase in the potassium rate is needed when removal of all plant residues or continuous cropping has occurred. In all cases, follow the specific fertilizer recommendations from soil tests.

To conserve soil moisture, minimum tillage is recommended for incorporating fertilizer material and plant residue and preparing the seedbed. Pulling a packer behind the tillage implement and using a seed drill equipped with press wheels ensures that the seed is in contact with moist soil during the time needed for germination. This is especially true if the crop is to be irrigated. The soil should be irrigated sufficiently to bring the soil moisture levels to close to the maximum water-holding capacity before tillage. Do not irrigate above the maximum water-holding capacity before tillage and planting as this could cause a soil crust to form on the surface that would impede seedling emergence, reduce plant density, and lower seed yields. Seeding depth and rate is the same as that for barley, 1.5 to 2.5 inches, or to moisture, and 90 to 100 pounds of pure live seed per acre. To reduce late tillering, the heavier seeding rate should be used when oats are to be produced for seed. Lighter rates can be used for hay production and rates can be cut to one-quarter less when interseeded with legumes for forage production. Use of certified seed is strongly recommended. Certified seed has strict limits on maximum content of weed seeds or diseased kernels and must meet a minimum percent germination. This helps to ensure good germination and emergence and reduces weed and disease infestations. Some varieties of oats have high seed dormancy requirements, especially the red oat varieties. If fresh seed is used without satisfying the dormancy requirement, poor germination and emergence results. Seed dormancy requirements can be met by storing seed in an unheated area over the winter.

Like barley, irrigation should begin again after the crop has reached about 50% emergence to avoid any problems with emergence from too hard of a crust on the surface.

A Kubota disk tiller

An example of the damage that can be inflicted by migratory birds, in this case primarily by Sandhill cranes. This field (barley) is shown at the Fairbanks Experiment Farm, August 11, 2014.

Thereafter, a good range of irrigation plus precipitation is around 0.5 to 1.0 inch per week. Irrigation should continue until the crop has reached the 50% headed growth stage.

Using IPM techniques, assess each field for all pests (weeds, diseases, and insects) and plan control measures accordingly. Weed control in oats is the same as for barley, a combination of mechanical and chemical summer fallow to reduce number and species of weeds for the following year and an application of a post-emergence herbicide when needed as determined through IPM practices. If weed populations have been determined to be high enough to cause a potential loss in yield or quality of the crop then the application of herbicides may be warranted. Oats are more susceptible than barley to injury from 2,4-D compounds and residual herbicides from previous years. Best broad-leaved weed control has been with broadleaf-selective herbicides Bromoxynil, MCPA, or Diglycolamine tank mixes which are labeled for use on oats, applied when the oats were 4 to 6 inches tall (3- to 5-leaf growth stage), but before the boot stage. Herbicide-resistant wild oats have become an increasingly serious problem in Alaska. The best control of wild oats and other grassy weeds is with crop rotations. In a fallow year, weeds can be sprayed with a nonselective herbicide such as glyphosate (Roundup) or controlled with tillage. Seeds in the soil can be brought to the surface with tillage to germinate, and then tilled again to kill them. Always remember to read the pesticide label and follow the directions for mixing, application, and disposal.

Oat loose smut (*Ustilago avenae*), leaf blotch (*Scolecotrichum graminis*), and Alternaria blotch (*Alternaria* sp.) are fungal diseases that have been found on oats in Alaska. Barley yellow dwarf virus (BYDV) has also been found on oats. Yield loss to these diseases has been minimal over the years. They can be controlled by using clean certified seed or disease-resistant varieties. The same insect pests that affect barley also affect oats. The most serious insect pests for oats are aphids (family Aphididae) and grasshoppers, including the lesser migratory grasshopper (*Melanoplus sanguinipes* Fabricias), the northern grasshopper (*Melanoplus borealis* Fieber), and the clear-winged grasshopper (*Camnula pellucida* Scudder). Oats, however, are less subject to insect predation than either barley or wheat. If insect population levels and damage have been determined to be too high through IPM practices, then the application of an insecticide may be warranted. Insecticide sprays or baits can help control heavy infestations if applied at the nymph growth stage. Always remember to read the pesticide label and follow the directions on mixing, application, and disposal. Contact your local Cooperative Extension Service for more information on pest control (see Appendix 1 for addresses and contact information).

Large flocks of returning migratory waterfowl can cause serious damage to these varieties merely by walking down the row and pecking out each newly emerging plant. In the fall, migrating waterfowl often prefer the hulless oat varieties. If the grain is significantly lodged, damage can increase dramatically. Otherwise, they usually work the edges of fields where they have a large field of vision. Propane scare cannons, designed to swivel in different directions and go off at uneven time intervals, seem to work best at keeping birds out of fields. Check with and inform the neighbors before setting up cannons.

Large ungulates like moose and bison can also cause serious damage to the crop. A single moose or a cow and calf pair usually don't cause much damage to large fields but can wipe out small-scale plots over the summer. They prefer all oat types to barley or wheat because of the lack of rough awns, and will keep coming back through the season to graze. In the Delta Junction area, bison congregate in large herds that don't usually cause serious damage until their fall migrations north of the Alaska Highway. This migration occurs during the time when the grain is mature, ripe, and ready for harvest. The bison may not only eat large portions of the crop, but a large herd walking through or bedding down in the field can flatten the crop into the ground, making harvest impossible. Brown bears (grizzlies) are also attracted to all oat crops. They will often graze on the crop from emergence up to maturity when the plants start to turn yellow. It is illegal to harass wildlife in Alaska so the only control is to erect large (6 feet or higher), stout, highly visible fencing that can direct the animals around the fields. For more information on wildlife control in agricultural fields, contact the local office of the Alaska Department of Fish and Game.

If the crop grown is intended for sale as seed for future planting, the fields should be inspected before harvest to insure that the highest quality crop is being grown in order to meet the standards for certified seed (blue tag on the seed bag). The fields should be planted in clean ground and not in ground in which the same crop that is being certified was planted the previous year. There can be only 1 plant out of 1,000 of another oat variety as well as 1 plant

Oats and wheat at the Matanuska Experiment Farm, August 7, 2014. At the far left, what is left of rows of wheat (now primarily weeds) after the spring predation of migratory birds and a summer's growth of weeds. Sandhill cranes and geese will walk along rows of germinating hulless grains and eat their fill, leaving only a few remnants of the crop. Center row: Alaska oat breed 'Ceal' and row at right, the taller 'Toral'.

Ripening 'Toral' spring feed oat heads, shown growing here at the Fairbanks Experiment Farm August 5, 2005. 'Toral' was the standard variety against which all other varieties were compared in this report.

out of 2,000 that is an inseparable crop, and there must be no objectionable weeds (prohibited or restricted noxious weeds) such as wild oats or quackgrass seed. The seed lots after harvest should also be inspected to meet the certified seed standards. For more information about field and seed lot inspections, contact the local office of the state Division of Agriculture, Department of Natural Resources or the Alaska Seed Growers Association (see Appendix 1 for addresses and contact information).

As with barley, oats stop growing when the seed reaches the hard dough stage (the kernels can't be dented when pressed with a thumbnail). The typical seed moisture content at this stage is between 25% and 35%. Oats can be harvested at this moisture content, but significant losses in germination occur during storage. The grain must be around 12 to 13% moisture for safe, long-term storage. Higher moisture contents can germinate or mold the stored seed and lower moisture contents can damage the embryo, reducing germination ability. Both situations reduce the quality of the stored grain. Harvesting before or at the hard dough stage results in a fair amount of green, high-moisture heads. This underdeveloped grain is low in yield, test weights, and market value. Also, harvesting before the hard dough stage results in a reduction in yield of both grain and straw. Oats grown for hay should be mowed in the soft dough stage for the best quality, highest protein content hay.

Oats can be swathed and allowed to air dry in windrows until the seed reaches 13% moisture, or they can be combined directly. Similar to barley, care must be taken in swathing or combining to prevent or reduce losses from shattering, crinkling, and weathering. Head shatter usually occurs on overripe oats, although some varieties are more susceptible than others. Crinkling occurs when the heads bend over and nod toward the ground. The stems may break soon after maturity, especially in damp weather. Weathering, or sun bleaching, occurs when the grain swells when damp but doesn't shrink back after drying. The kernels are less dense and thus have a lower test weight, although other quality measurements are unaffected.

Combine settings should be adjusted so that the concave clearance and cylinder speed produces the highest amount of clean seed without cracking the kernels. To reduce the incidence of peeling or skinning the hull and exposing the embryo, augers should be run full, or at slower speeds if not full. Any embryo damage during this process lowers the germination ability of that seed for next year. Every time grain is handled, kernel damage occurs. This is not as important in grain grown for animal feed as it is in seed crops. The highest price paid to the producer is for the highest quality oats.

In Alaska there is a strong market for both oat seed and hay, which are primarily grown as animal feed supplements. There is also a seed production industry to provide local farmers with certified seed. Lacking the rough awns of barley straw, oat straw is in high demand for use as animal bedding, especially with local dog mushers. In many years, the value of the straw is close to or equal to the value of the seed produced per acre.

Recommended Variety Descriptions for Spring Feed Oats

Note: See Appendix 1 for the addresses of seed suppliers.

'Athabasca' is an early-maturing, medium-height, stiff-strawed, high-yielding, yellow-glumed, spring feed oat selection made at the Canada Agriculture Research Station at Lacombe, Alberta in 1966. It matures 2 to 3 days later than 'Toral' but is equal or higher yielding in both seed and forage. It is resistant to lodging and shattering. This is an older variety so seed sources may be difficult to obtain. Direct inquiries about seed sources to the Alaska Farmers Co-op elevator in Delta Junction, SeCan Association, or Agricore United.

'Cascade' is a relatively mid- to late-maturing, tall, stiff-strawed, high-yielding, yellow-glumed, spring feed oat developed at the Canada Agriculture Research Station at Lacombe, Alberta in 1979. It is a cross between 'Random' and 'Forward'. Since it is a late-maturing variety, there is a high risk of low yields and immature seed when planted late. Despite maturing later by 4 to 7 days than 'Toral', this oat has consistently been a high-yielding variety for both seed and forage production in our trials. Direct inquiries about seed sources to the SeCan Association or Agricore United.

'Ceal' is an early-maturing, short, stiff-strawed, high-yielding, white-glumed, spring feed oat released in 1978 by the USDA-ARS plant breeding program at the Matanuska Experiment Farm. It was selected from a cross between 'Climax', an early-maturing oat from Sweden, and a later maturing, high-yielding, yellow-glumed oat, 'Eaton', from Michigan. 'Ceal' is a good oat for grain production in areas where oat maturity has been marginal. However, it is not recommended for annual forage mixtures because it matures much earlier and produces lower biomass yields due to its short stature. It is 2 to 3 days earlier in maturity and slightly lower in seed and forage yields than 'Toral'. Direct inquiries about seed sources to the Alaska Seed Growers Association or the Alaska Plant Materials Center.

'Nip' is an early-maturing, tall, stiff-strawed, high-yielding, black-glumed, spring feed oat selected in Sweden in the late 1950s. It has good resistance to lodging and produces good yields of both seed and forage. It can be planted late and still produce good seed yields. It also has fairly good tolerance to late summer or early fall frosts. 'Nip' is 3 to 5 days later than 'Toral' and slightly lower in seed yields but higher in forage yields. Seed sources for 'Nip' are only available in Alaska. Direct inquiries about seed sources to the Alaska Seed Growers Association or the Alaska Plant Materials Center.

'Toral' is a midseason, tall, stiff-strawed, high-yielding, yellow-glumed, spring feed oat released in 1977 by the USDA-ARS plant breeding program at the Matanuska Experiment Farm. It was selected from a cross between an early-maturing black-glumed oat from Sweden, 'Orion III', and a later maturing, high-yielding, yellow-glumed Polish oat, 'Tatrzanski'. 'Toral' is a good general-purpose oat with consistently high yields for both seed and forage. This was the standard variety against which all other oat varieties were compared in this report. Direct inquiries about seed sources to the Alaska Seed Growers Association or the Alaska Plant Materials Center.

Spring Hulless (Naked) Oats

As with hulless barley, the outside hull of hulless oat (*Avena nuda* L.) varieties detaches from the kernel when harvested, exposing the embryo and leaving a hulless or naked kernel. In recent years there has been an increased interest in producing hulless oats, not only for diets of nonruminant animals, which can't digest the fibrous hulls of hulled oats, but also for human consumption in items such as breakfast cereals and health foods. Oat flour contains agents that retard rancidity in fats and is used as an antioxidant and a stabilizer for dairy products. When included in human diets, oats may lower blood cholesterol levels. Similar to hulless barley, hulless oats have high soluble fiber content (beta-glucans). This high fiber level helps to remove cholesterol from the digestive system and stabilize blood sugar levels. Oat fiber also has antioxidant compounds called avenanthramides that help prevent free radicals from damaging the LDL cholesterol (George Mateljan Foundation 2011). To be consumed by humans, hulled oat varieties must be dehulled through an abrasion process or must be processed into a flake. Dehulling has the potential to also remove some of the bran and germ, lowering the nutrient content of the seed. Oat flakes are made from hulled oats, cleaned, sized, and dried to 6% moisture, dehulled, steamed, and pressed between steel rollers. Quick oats are small, thin flakes cut from the groats and then rolled. Prices paid to the producer for hulless oats are much higher than for hulled varieties when used for human consumption niche markets.

The same major drawbacks in producing hulless barley exist for producing hulless oats. Most varieties are late- or very late-maturing, are low-yielding, and producers need an established niche market to obtain a high price for the crop. The exposed embryo on hulless oats can be damaged during handling, and embryo damage reduces the germination ability of any seed lot. With a lower percentage of pure live seed, a greater volume of seed must be purchased for planting. For seed grade, a higher percentage of hulls can be left on to reduce the possibility of embryo damage. Feed grade hulless oats can't retain more than 15% of the hulls. More than this results in a lower price paid to the producer. For food grades, no more than 5% of the hulls can remain. This is difficult to achieve when combining. It is better to harvest with a higher percentage of hulls retained and remove them during handling processes. Hulls can be removed by additional buffing of the seed before shipping to market. Any seed lot not meeting the higher food grades is purchased at lower feed grade prices.

Fertilization, tillage practices, irrigation scheduling, and seeding depths are identical to those for regular hulled oats. Avoid excessive nitrogen fertilization because most hulless varieties are late-maturing and weak-stemmed. Too much nitrogen can delay maturity further and induce lodging, especially if grown under irrigation. When selecting a field to plant, check the cropping history and pick one in which volunteer hulled oats or wild oats are unlikely to come up in the crop. A year of summer fallow before planting helps to reduce the incidence of both volunteer oats and fungal diseases transmitted by crop residues.

As mentioned previously, because the embryo is exposed on hulless oats it can be damaged in handling, which reduces the germination ability of the seed. It is not uncommon to have certified seed lots with less than 90% germination. Improved germination comes from seed lots where the combine operator did not set the combine to thresh all the hulls from the seed at harvest. Seeding rates similar to that of hulled oats are desirable (90 to 100 pounds per acre of pure live seed). However, hulless oats have smaller kernels than hulled oats and higher bushel weights. They also flow faster through seeder metering systems. Adjust seeding rates accordingly.

Pest control is the same as that for regular hulled oats. Weed control is a combination of mechanical and chemical summer fallow to reduce the number and species of weeds for the following year and an application of a post-emergence herbicide when needed as determined through IPM practices. If weed populations have been determined through IPM practices to be high enough to cause a potential loss in yield or quality of the crop then the application of herbicides may be warranted. Food-grade hulless oats can't contain any diseased kernels. Use of clean, certified seed is recommended. The use of certified seed is very important in producing commercial food-grade hulless oats. Industry standards for food-grade hulless oats have very strict limits on the amount of foreign material and diseased kernels that can be in any seed lot. Insect pests and their control are the same as for

Grains at heading stage at the Fairbanks Experiment Farm, June 30, 2010. From left to right: Barley, wheat, oats, camelina, Polish canola.

regular oats. If insect population levels and damage have been determined through IPM practices to be too high, then the application of an insecticide may be warranted. Always remember to read the pesticide label to be sure the crop is specified and follow the directions on mixing, application, and disposal. Contact your local Cooperative Extension Service for more information on pest control (see Appendix 1 for addresses and contact information).

Hulless oats are usually later maturing, so the crop may still be in the fields when waterfowl begin their fall migrations. As with hulless barley, hulless oats are a favorite energy food for migrating waterfowl. Use of propane scare cannons, designed to swivel in different directions and go off at uneven time intervals, is recommended. Check with and inform the neighbors before setting up cannons. For more information on wildlife control in agricultural fields, contact the local office of the Alaska Department of Fish and Game.

Hulless oats stop growing when they reach the hard dough stage, the same as for hulled oats. They can be harvested using the same methods as hulled oats. However, 12% or lower moisture is considered good for safe, long-term storage conditions and when used for the human food industry. Higher quality grain can be achieved when swathing or combining at the lowest moisture content. To slow down the feeding rate when combining hulless oats, reduce the front concave opening and cylinder speed for proper threshing and hull removal. Increase the air flow to improve hull removal. To reduce embryo damage, run augers at full capacity or slow them down. Hulless oats do not flow well during handling, which can cause an increase in cracked kernels and damaged embryos. Continual checking for hulls left on the seed or cracked seeds and adjusting combining methods is important, because food-grade seed can contain only 4% cracked hulls. Food-grade hulless oats can't contain any diseased kernels, other crops, or foreign material. On-farm cleaning and sizing of the seed lot to food-grade standards before shipment results in higher prices paid to the producer. Clean-outs can be used on farm or sold as feed grade.

There is an increased interest in producing hulless oats for human consumption as whole grain and flour for sale in local markets in Alaska. There are no large-scale flour or flaking mills in the state and no elevators are set up to

Spring feed oats growing in the Delta Junction area August 4, 2014. At right is 'Ceal' and at left, 'Toral'.

accept hulless oats. There is only a limited acreage presently grown for on-farm use as a supplement for livestock feed and for human consumption. Like hulled oats, hulless oat straw lacks the rough awns of barley straw so there could be a high demand for use as animal bedding.

Similar to barley, all commercial food-grade oat products, which include whole kernel grain and processed flour, are regulated and inspected by state and federal agencies before sale to the public. In Alaska, the Department of Environmental Conservation regulates and inspects commercial food-grade grain products under the Food Safety and Sanitation Program - Food Processors. More information can be obtained at the DEC website, http://dec.alaska.gov/commish/regulations/index.htm or contact your local DEC environmental health officer (see Appendix 1 for addresses and contact information).

Nationally, commercial food-grade grain products are regulated and inspected by the U.S. Food and Drug Administration (FDA) under the Good Manufacturing Practice (GMP) of Title 21 of the Federal Food, Drug and Cosmetic Act, part 110 - Sanitary conditions. More detailed information can be found in the USFDA publication, "Guide to Inspections of Grain Product Manufacturers," located at the FDA website, www.fda.gov/.

Recommended Variety Description for Hulless Oats

Note: See Appendix 1 for the addresses of seed suppliers.

'AC Belmont' is a late-maturing, mid-tall, stiff-strawed, mid-yielding, naked-kerneled spring oat released in 1992 by Agriculture Canada (AC) in Winnipeg, Manitoba. It matures 2 to 3 days later and is lower yielding than 'Toral' yellow feed oat. It does have good resistance to lodging and oat loose smut. Up to 12% non-hulless kernels are common. This variety is protected by Canadian plant breeders' rights. Producers may save seed for their own use on their own farms, but sale or transfer of seed is prohibited without written permission and a payment of royalties to the breeder. Direct inquiries about seed sources to the SeCan Association.

'AC Gwen' is a late-maturing, mid-tall, stiff-strawed, high-yielding, naked-kerneled spring oat released in 2000 by Agriculture Canada (AC) in Winnipeg, Manitoba. It matures only 1 to 2 days later and is lower yielding than 'Toral' yellow feed oat. It does have good resistance to lodging and oat loose smut. It is better yielding with fewer percent non-hulless kernels than 'AC Belmont'. This variety is protected by Canadian plant breeders' rights. Producers may save seed for their own use on their own farms, but sale or transfer of seed is prohibited without written permission and a payment of royalties to the breeder. Direct inquiries about seed sources to the SeCan Association.

Cleaned hulless yellow oats.

Yields and Quality by Location for Spring Feed and Hulless Oats

Common and hulless oats are bought and sold by weight. Standard test weights for both are used as the legal unit for crop sales. The standard test weight for clean, dry, and undamaged common, black, and red oats is 32 pounds per bushel. Similar condition hulless oats have a test weight of 44 pounds per bushel. Higher prices are paid to the producer for these niche crops, but only if they meet the quality criteria mentioned above. Other than test weights, additional samples are taken at the elevator for common oats to determine quality. For hulless oats, additional samples should be taken on farm to determine quality. Any seed lots not meeting food grade for hulless oats should be used as feed grade. It is important then for the producer to clean and size all seed lots before delivery to the elevator or a niche market. Test weights can differ between cultivars and can change within a single cultivar depending on cultural practices, weather conditions, and location where grown. Test weight is used here as a measure of grain quality to determine maturity. Yields are expressed here in pounds per acre and bushels per acre. Determine bushels per acre by dividing the yield of any specific cultivar by the standard test weight. Biomass yields are given, on a dry weight basis, for a few select varieties as a measure of forage production. For forage varieties, this information was collected when the plants were at the soft dough stage for whole plant forage production as animal feed.

Tables 30, 32, 34, 36, and 37 list feed and hulless oat yields and quality measurements for all test locations: Fairbanks, Eielson, Delta Junction, and Palmer. All sites in the Delta Junction area have been combined into either the Delta dryland site (Table 34) or, if grown under irrigation, the Delta irrigated site (Table 36). Each table also contains information on oat type (yellow feed, black feed, hulless, etc.), the source or the location of where it was bred, and the years it was tested at each location. Maturity in this study was defined as when 50% of the heads for each plot were at the hard dough stage (light yellow heads with kernels that did not dent when pressed with a thumbnail). Growing degree days (GDD) for average maturity were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. The low temperature point for all oats in this report is the freezing point of water, 32°F. The GDD calculations for each day were then added to the preceding GDD value to determine the cumulative value to the date at which the specific variety had reached 50% maturity. All varieties were compared with 'Toral' yellow feed oat as the standard variety. Yields as a percent of the standard variety 'Toral' were determined by dividing the average yield of each variety by the average yield of 'Toral'. Maturity vs. Std. (Standard variety) are the number of days each variety reached 50% maturity either before or after the number of days that 'Toral' reached 50% maturity.

Tables 31, 33, 35, and 38 list the animal feed and human food (for hulless oats) quality analyses of the seed or forage, on a dry weight basis, for select oat varieties for the Fairbanks, Eielson, Delta Junction dryland, and Palmer test locations. They are presented here without statistical differences and solely for the reader's benefit. More detailed information and explanation about the industry standards for feed oats and food-grade hulless oats that follow can be obtained from D.C. Church (1979), J.H. Martin and others (1976), and the George Matelijan Foundation (2011). Detailed explanation of the feed analysis that follow as well as laboratory procedures can be obtained from J. Schroeder (1994) and G.J. Michaelson and others (1987). As with the yield tables, all sites in the Delta Junction area have been combined together.

Percent crude protein is calculated from the total percent nitrogen analysis of the seed multiplied by a constant of 6.25. Crude protein is made up of amino acids, which are 16% nitrogen, as well as other, non-protein portions of the plant, and so percent crude protein is not a measure of true protein. Industry standards for hulless oats are set for a range between 11% and 17% crude protein, which is higher than that for hulled feed oats (11-14%). Higher values have greater nutritional food value, but too high a value (>17% for hulless oats or >14% for feed oats) is an indicator of immature green seed, which makes a lower quality grade flour because it turns rancid quicker. Industry standards for forage oats are 10-12% crude protein. Higher values have greater nutritional value, but too high a value (>12%) is a possible indicator of high nitrate levels in the forage. Forage samples should also be analyzed for nitrate (NO_3^-) concentrations. Any samples of 0.44% or higher can be potentially toxic to livestock. In a standard feed analysis, other major nutrient mineral concentrations commonly measured are percent phosphorus (%P), potassium (%K), and calcium (%Ca).

Percent neutral detergent fiber (%NDF) is a measure of the percentage of partially digestible plant material (lignin, hemicellulose, and cellulose). Lower levels of NDF usually result in a higher animal intake of the feed. It is also used to calculate the dry matter intake (DMI), where DMI = 120 ÷ %NDF. This value is later used to determine the relative feed value.

Percent acid detergent fiber (%ADF) is a measure of the highly indigestible plant material (lignin and cellulose). Higher levels of ADF usually indicate a low digestibility of the plant material. It is also used to calculate the digestible dry matter (DDM), where DDM = 88.9 - (0.779 x %ADF). This value is also later used to determine the relative feed value.

The percent in vitro dry matter digestibility (%IVDMD) is a laboratory simulation of plant material digestibility in a rumen of a cow. A known weight of plant material is digested in a simulated rumen for a given period of time. After digestion is complete, the residue that is left is weighed and the difference is the estimated percentage of the plant material that is potentially digestible or a measure of potential metabolizable energy.

The relative feed value (RFV) is a unitless index that combines the nutritional factors of the dry matter intake and the digestible dry matter of the plant material, where RFV = (DDM x DMI) ÷ 1.29. Plant material with an ADF of 41% and a NDF of 53% has a RFV of 100. All other plant material is compared to this value. Lower ADF and NDF values will cause the RFV to increase. The higher the RFV, the lower the overall quality of the feed.

Table 30. Average yields and quality measurements for all oat varieties from test plots in the Fairbanks area.

Oat Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test Weight (lbs/bu)	Biomass Yield (lbs/acre)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Yellow feed, spring											
Athabasca	Alberta	10	3322	104	90	38	6154	1	4-Aug	3	2178
Calibre	Saskatchewan	7	3955	124	112	40	N/D	1	6-Aug	5	2319
Cascade	Alberta	9	4139	129	113	36	6185	0	5-Aug	4	2238
Ceal	Alaska	6	2569	80	62	39	5860	10	28-Jul	-4	2004
Derby	Alberta	1	3654	114	124	38	N/D	0	10-Aug	9	2184
Jasper	Alberta	3	3676	115	99	39	N/D	2	1-Aug	0	2282
OT 238	Alberta	2	3161	99	77	34	N/D	0	4-Aug	3	2363
OT 736	Alberta	1	3103	97	105	34	N/D	0	1-Aug	0	2266
OT 745	Alberta	1	3553	111	120	38	N/D	0	1-Aug	0	2266
OT 755	Alberta	2	4012	125	98	32	N/D	0	4-Aug	3	2363
Pol	Sweden	3	3285	103	89	30	N/D	0	1-Aug	0	2282
Proat	Minnesota	1	2193	69	74	38	N/D	0	30-Jul	-2	2215
Riel	Manitoba	3	3977	124	108	39	N/D	0	3-Aug	2	2336
Toral	Alaska	19	3886	121	100	39	6079	11	1-Aug	0	2141
Red feed, spring											
Bates 89	California	1	2535	79	56	34	N/D	0	17-Aug	16	2271
Kanota	California	1	1515	47	34	30	N/D	0	15-Aug	14	2205
Montezuma	California	1	2178	68	48	28	N/D	0	15-Aug	14	2224
Pert	California	1	2696	84	60	32	N/D	0	21-Aug	20	2340
Sierra	California	1	2902	91	65	28	N/D	0	20-Aug	19	2321
Black feed, spring											
Nip	Sweden	6	3539	111	87	35	6034	1	6-Aug	5	2220
Hulless, spring											
AC Belmont	Manitoba	5	2888	66	77	43	N/D	17	3-Aug	2	2244
AC Gwen	Manitoba	4	3012	68	81	42	N/D	11	1-Aug	0	2238
Equavena	Quebec	3	2538	58	69	45	N/D	3	28-Jul	-4	2178
Freedom	Maine	5	2851	65	80	42	N/D	0	5-Aug	4	2336
Pennuda	Pennsylvania	4	1055	24	31	41	N/D	0	4-Aug	3	2207
Tibor	Alberta	2	2508	57	61	44	N/D	0	5-Aug	4	2396

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. All varieties were compared with 'Toral' yellow spring feed oat as the standard variety.

Table 31. Average quality measurements for select oat varieties from test plots in the Fairbanks area.

Oat Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)	Total Ca (%)	NDF (%)	ADF (%)	IVDMD (%)	Relative Feed Value
Feed Industry Standards			**11-14%**	**0.3-0.5%**	**0.4-0.6%**	**0.05-0.08%**	**25-45%**	**10-25%**	**>70%**	**<302**
Yellow feed, spring										
Athabasca	Alberta	10	13.81	0.38	0.40	N/D	N/D	N/D	N/D	N/D
Calibre	Saskatchewan	7	12.56	0.34	0.44	N/D	N/D	N/D	N/D	N/D
Cascade	Alberta	9	11.50	0.29	0.41	N/D	N/D	N/D	N/D	N/D
Ceal	Alaska	6	14.94	0.39	0.40	N/D	N/D	N/D	N/D	N/D
Toral	Alaska	19	12.64	0.38	0.41	N/D	N/D	N/D	N/D	N/D
Forage Industry Standards			**10-12%**	**0.3-0.5%**	**0.4-0.6%**	**0.05-0.1%**	**50-65%**	**25-55%**	**>50%**	**<128**
Yellow feed, spring										
Athabasca	Alberta	10	10.59	0.46	0.34	0.03	52.59	39.82	53	101
Calibre	Saskatchewan	7	9.65	0.43	0.34	N/D	N/D	N/D	N/D	N/D
Cascade	Alberta	9	9.05	0.49	0.35	0.04	59.44	38.16	58	111
Ceal	Alaska	6	10.82	0.47	0.38	0.03	55.79	33.73	52	103
Toral	Alaska	19	10.25	0.46	0.32	0.03	60.10	38.48	57	90
Black feed, spring										
Nip	Sweden	6	10.48	0.45	0.33	N/D	N/D	N/D	N/D	N/D
Hulless Food Industry Standards			**11-17%**	**0.3-0.5%**	**0.4-0.6%**	**0.05-0.1%**	**N/A**	**N/A**	**N/A**	**N/A**
Hulless, spring										
AC Belmont	Manitoba	5	13.31	0.37	0.40	N/D	N/A	N/A	N/A	N/A
AC Gwen	Manitoba	4	11.50	0.36	0.44	N/D	N/A	N/A	N/A	N/A
Equavena	Quebec	3	14.06	0.39	0.50	N/D	N/A	N/A	N/A	N/A
Freedom	Maine	5	13.69	0.33	0.41	N/D	N/A	N/A	N/A	N/A
Pennuda	Pennsylvania	4	17.06	0.48	0.50	N/D	N/A	N/A	N/A	N/A
Tibor	Alberta	2	13.4	0.32	0.41	N/D	N/A	N/A	N/A	N/A

Feed analysis done on mature, ripe seed. Forage analysis done on whole plant biomass at soft dough stage. Hulless analysis done on mature, ripe seed. All varieties were compared with 'Toral' yellow spring feed oat as the standard variety. N/D = No Data, N/A = Not Applicable.

Table 32. Average yields and quality measurements for all oat varieties from test plots in the Eielson area.

Oat Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test Weight (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Yellow feed, spring										
Athabasca	Alberta	4	2491	78	93	41	0	8-Aug	-1	2287
Calibre	Saskatchewan	4	3045	95	107	42	0	13-Aug	4	2420
Cascade	Alberta	4	3561	111	133	41	0	12-Aug	3	2392
Toral	Alaska	4	2724	85	100	42	0	9-Aug	0	2302
Black feed, spring										
Nip	Sweden	1	1205	38	91	38	0	13-Aug	4	2244
Hulless, spring										
Freedom	Maine	4	1897	43	67	43	0	15-Aug	6	2473
Pennuda	Pennsylvania	3	1500	34	52	43	0	9-Aug	0	2346

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. All varieties were compared with 'Toral' yellow spring feed oat as the standard variety.

Table 33. Average quality measurements for select oat varieties from test plots in the Eielson area.

Oat Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)
Feed Industry Standards			**11-14%**	**0.3-0.5%**	**0.4-0.6%**
Yellow feed, spring					
Athabasca	Alberta	4	11.81	0.37	0.39
Calibre	Saskatchewan	4	12.00	0.38	0.43
Cascade	Alberta	4	10.69	0.34	0.39
Toral	Alaska	4	11.88	0.39	0.46
Hulless Food Industry Standards			**11-17%**	**0.3-0.5%**	**0.4-0.6%**
Hulless, spring					
Freedom	Maine	4	14.25	0.47	0.44
Pennuda	Pennsylvania	3	17.13	0.47	0.42

Feed analysis done on mature, ripe seed. Hulless analysis done on mature, ripe seed. All varieties were compared with 'Toral' yellow spring feed oat as the standard variety.

Typical Alaska-size pest browsing on 'Ceal' and 'Toral' oats in a Delta Junction plot, August 4, 2011. Both varieties were developed in Alaska. To the left of the oats are rows of 'Ingal' and 'Nogal' wheat, also developed in Alaska, while to the right are field peas 'Midas', showing small white flowers, developed by the Swedish company Svalof Weibull. Behind the moose and grains are potatoes in bloom (pink) in a study conducted by Megan Lene of the effect of using lime vs. no lime in the soil. On the other side of the road are weeds in bloom: bromegrass, foxtail grass, yellow hawksbeard.

Table 34. Average yields and quality measurements for all oat varieties from test plots in the Delta Junction area, dryland.

Oat Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test Weight (lbs/bu)	Biomass Yield (lbs/acre)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Yellow feed, spring											
Athabasca	Alberta	13	2401	75	92	38	5582	0	15-Aug	4	2276
Calibre	Saskatchewan	8	2486	78	82	41	N/D	0	18-Aug	7	2437
Cascade	Alberta	12	2867	90	111	39	5736	0	17-Aug	6	2338
Ceal	Alaska	7	1507	47	67	36	5301	0	10-Aug	-1	2279
Derby	Alberta	1	460	14	25	26	N/D	0	13-Aug	2	1912
Jasper	Alberta	3	3340	104	91	41	N/D	0	31-Aug	20	2515
OT 238	Alberta	2	3412	107	85	36	N/D	0	30-Aug	19	2484
OT 736	Alberta	1	3122	98	104	35	N/D	0	1-Sep	21	2577
OT 745	Alberta	1	2654	83	88	38	N/D	0	1-Sep	21	2577
OT 755	Alberta	2	4458	139	109	39	N/D	0	30-Aug	19	2484
Pol	Sweden	3	2922	91	78	36	N/D	0	29-Aug	18	2497
Proat	Minnesota	1	1992	62	66	41	N/D	0	29-Aug	18	2556
Riel	Manitoba	3	3145	98	84	37	N/D	0	31-Aug	20	2515
Toral	Alaska	22	2525	79	100	38	5466	0	11-Aug	0	2286
Red feed, spring											
Bates 89	California	2	876	27	61	39	N/D	0	27-Aug	16	2325
Kanota	California	2	802	25	55	37	N/D	0	26-Aug	15	2314
Montezuma	California	2	746	23	52	39	N/D	0	25-Aug	14	2297
Pert	California	2	857	27	59	42	N/D	0	28-Aug	17	2338
Sierra	California	2	703	22	49	37	N/D	0	29-Aug	18	2353
Black feed, spring											
Nip	Sweden	9	2341	73	84	37	5337	0	20-Aug	9	2279
Hulless, spring											
AC Belmont	Manitoba	6	2541	58	77	39	N/D	0	14-Aug	3	2220
AC Gwen	Manitoba	4	2306	52	74	38	N/D	0	13-Aug	2	2210
Equavena	Quebec	2	1787	41	54	41	N/D	0	14-Aug	3	2209
Freedom	Maine	7	1815	41	68	42	N/D	0	17-Aug	6	2589
Pennuda	Pennsylvania	4	802	18	43	41	N/D	0	13-Aug	2	2327
Tibor	Alberta	2	1895	43	45	44	N/D	0	30-Aug	19	2484

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. All varieties were compared with 'Toral' yellow spring feed oat as the standard variety.

Table 35. Average quality measurements for select oat varieties from test plots in the Delta Junction area, dryland.

Oat Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)	Total Ca (%)	NDF (%)	ADF (%)	IVDMD (%)	Relative Feed Value
Feed Industry Standards			**11-14%**	**0.3-0.5%**	**0.4-0.6%**	**0.05-0.08%**	**25-45%**	**10-25%**	**>70%**	**<302**
Yellow feed, spring										
Athabasca	Alberta	13	17.44	0.38	0.44	N/D	N/D	N/D	N/D	N/D
Calibre	Saskatchewan	8	15.00	0.32	0.53	N/D	N/D	N/D	N/D	N/D
Cascade	Alberta	12	14.69	0.33	0.42	N/D	N/D	N/D	N/D	N/D
Ceal	Alaska	7	12.75	0.28	0.46	N/D	N/D	N/D	N/D	N/D
Toral	Alaska	22	15.00	0.29	0.46	N/D	N/D	N/D	N/D	N/D
Forage Industry Standards			**11-14%**	**0.3-0.5%**	**0.4-0.6%**	**0.05-0.1%**	**50-65%**	**25-55%**	**>50%**	**<128**
Yellow feed, spring										
Athabasca	Alberta	13	13.49	0.47	0.33	0.03	50.61	37.31	56	131
Calibre	Saskatchewan	8	12.37	0.43	0.35	N/D	N/D	N/D	N/D	N/D
Cascade	Alberta	12	11.06	0.44	0.31	0.04	53.82	38.58	57	100
Ceal	Alaska	7	10.40	0.39	0.35	0.03	51.49	32.47	51	114
Toral	Alaska	22	12.05	0.39	0.35	0.03	58.01	37.61	55	94
Black feed, spring										
Nip	Sweden	9	10.32	0.42	0.32	N/D	N/D	N/D	N/D	N/D
Hulless Food Industry Standards			**11-17%**	**0.3-0.5%**	**0.4-0.6%**	**0.05-0.1%**	**N/A**	**N/A**	**N/A**	**N/A**
Hulless, spring										
AC Belmont	Manitoba	6	12.75	0.32	0.42	N/D	N/A	N/A	N/A	N/A
AC Gwen	Manitoba	7	12.75	0.31	0.42	N/D	N/A	N/A	N/A	N/A
Equavena	Quebec	2	17.31	0.31	0.49	N/D	N/A	N/A	N/A	N/A
Freedom	Maine	2	15.63	0.29	0.47	N/D	N/A	N/A	N/A	N/A
Pennuda	Pennsylvania	4	15.63	0.29	0.48	N/D	N/A	N/A	N/A	N/A
Tibor	Alberta	2	13.38	0.31	0.53	N/D	N/A	N/A	N/A	N/A

Feed analysis done on mature, ripe seed. Forage analysis done on whole plant biomass at soft dough stage. Hulless analysis done on mature ripe seed. All varieties were compared with 'Toral' yellow spring feed oat as the standard variety. N/D = No Data, N/A = Not Applicable.

Table 36. Average yields and quality measurements for all oat varieties from test plots in the Delta Junction area, irrigated.

Oat Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test Weight (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Yellow feed, spring										
Athabasca	Alberta	3	3676	115	89	40	0	7-Aug	-9	2136
Cascade	Alberta	3	4738	148	115	38	0	13-Aug	-3	2257
Toral	Alaska	5	3101	97	100	39	0	16-Aug	0	2340
Black feed, spring										
Nip	Sweden	3	3959	124	96	39	0	9-Aug	-7	2176
Hulless, spring										
AC Belmont	Manitoba	1	3666	83	91	43	0	17-Aug	1	2471
Freedom	Maine	1	3566	81	89	45	0	17-Aug	1	2465

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. All varieties were compared with 'Toral' yellow spring feed oat as the standard variety.

Table 37. Average yields and quality measurements for all oat varieties from test plots in the Palmer area.

Oat Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test Weight (lbs/bu)	Lodging (%)	Biomass Yield (lbs/acre)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Yellow feed, spring											
Athabasca	Alberta	4	3366	105	88	38	6	5238	11-Aug	3	2209
Calibre	Saskatchewan	1	3988	125	104	40	0	N/D	28-Aug	20	2591
Cascade	Alberta	3	4510	141	111	38	8	5444	15-Aug	7	2306
Ceal	Alaska	5	1189	37	62	36	8	5060	13-Aug	5	2018
Jasper	Alberta	1	3918	122	103	40	0	N/D	28-Aug	20	2591
OT 238	Alberta	1	2517	79	66	36	0	N/D	29-Aug	21	2611
OT 745	Alberta	1	4147	130	109	38	0	N/D	29-Aug	21	2611
Pol	Sweden	1	3386	106	89	34	0	N/D	13-Aug	5	2208
Riel	Manitoba	1	3641	114	95	37	0	N/D	23-Aug	15	2467
Toral	Alaska	12	2614	82	100	38	21	5379	8-Aug	0	2109
Black feed, spring											
Nip	Sweden	3	3759	117	95	37	8	5183	11-Aug	3	2205
Hulless, spring											
AC Belmont	Manitoba	5	1862	42	81	40	23	N/D	12-Aug	4	2374
AC Gwen	Manitoba	4	2289	52	102	41	28	N/D	14-Aug	6	2385
Equavena	Quebec	2	1056	24	80	41	0	N/D	14-Aug	6	2354
Freedom	Maine	1	2013	46	53	42	0	N/D	29-Aug	21	2611
Pennuda	Pennsylvania	1	324	7	12	42	0	N/D	12-Aug	4	2340
Tibor	Alberta	1	1882	43	49	43	0	N/D	29-Aug	21	2611

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. All varieties were compared with 'Toral' yellow spring feed oat as the standard variety. N/D = No Data

Table 38. Average quality measurements for select oat varieties from test plots in the Palmer area.

Oat Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)	Total Ca (%)	NDF (%)	ADF (%)	IVDMD (%)	Relative Feed Value
Forage Industry Standards			**11-14%**	**0.3-0.5%**	**0.4-0.6%**	**0.05-0.1%**	**50-65%**	**25-55%**	**>50%**	**<128**
Yellow feed, spring										
Athabasca	Alberta	4	11.24	0.21	0.35	0.03	54.70	39.25	61	98
Cascade	Alberta	3	12.10	0.24	0.34	0.04	59.09	38.84	58	92
Ceal	Alaska	5	10.75	0.21	0.35	0.03	54.78	33.69	52	106
Toral	Alaska	12	11.49	0.24	0.37	0.04	62.42	39.44	57	87
Black feed, spring										
Nip	Sweden	3	10.49	0.21	0.33	0.04	N/D	N/D	N/D	N/D

Forage analysis done on whole plant biomass at soft dough stage. All varieties were compared with 'Toral' yellow spring feed oat as the standard variety. N/D = No Data.

Wheat

Wheat Performance Trials—Spring Wheat

Wheat is of limited importance as a true cereal grain crop for Alaska due to its long growing season. Two species of spring wheat were tested in Alaska as part of this study. The bread wheat varieties (*Triticum aesitivum* subspecies *vulgare* L.) are made up of the hard red spring wheats (true bread flour wheat) and the soft white wheats (pastry flour wheat). The other spring wheat species tested in Alaska has been the macaroni or durum wheat (*Triticum durum* Desf.). These are also divided into 2 types. The white or amber (most common pasta flour wheat), and red durum wheats (rarely grown). Most of the wheat varieties tested in this study were obtained from Canadian sources. Canadian wheat grades subdivide hard red spring wheat further into the hard red spring bread wheats, the prairie hard red spring wheats or semi-dwarf varieties, and the extra strong or utility hard red spring wheats. The seed heads of hard red spring wheat can be awnless, tip awned or fully awned, depending on the variety. Durum wheats have long stiff awns and compact seed heads. All other things being equal, kernels of awned varieties photosynthesize more than varieties without awns, resulting in higher levels of carbohydrates, higher test weights, and quicker drying during ripening.

The main uses for wheat in Alaska are in niche markets for human consumption as whole grain "berries," flour for baked products, breakfast foods, pasta, and health foods. According to D.C. Church (1979), the crude protein content of wheat varies depending on the type. Hard red bread wheat will have crude protein values of 13% to 17%, while soft white pastry wheat will have values of 10% to 13%. All wheat types will have very low crude fiber values of 2% to 4% with a total dry matter content of 80% to 90%. Wheat has a higher value as a human food but is a very palatable, high-energy feed for livestock diets, where it is cracked or rolled and for poultry diets where it is fed whole. High test weight wheat produces higher percentages of flour than lower test weight wheat. The average flour return for standard test weight wheat (60 pounds per bushel) is 72%. The remaining 28% consists of bran and shorts removed in the milling process. The bran is the outer covering of the wheat kernel removed before milling and the shorts (or standard middlings) are the coarse particles of the endosperm left after milling. Since most of the inner portions of the wheat kernel have gone into the production of flour, the bran and shorts will have a high concentration of crude protein (17% to 19%) and fiber (8% to 12%). These high-protein, high-fiber byproducts are used in dairy, swine, and poultry feeds. The highest prices paid to the producer is for the human-consumption quality wheat.

Wheat is much later maturing than barley or oats and maturity is highly dependent on climate. If the weather is warm and dry for a month after pollination, it matures on average 10 days later than barley. If the weather for that same period is cool and wet, an additional 10 to 15 days are required. Light frosts during heading can cause sterility, while light frosts before the plant reaches full maturity stops any further grain development. Early-maturing hard red spring wheat varieties are the best adapted for Alaska growing conditions, but are considered somewhat marginal. Spring white and durum wheats require a longer frost-free growing season to reach maturity than the hard red spring wheats, and are not recommended for Alaska.

Fertilization, tillage practices, and seeding depths are identical to barley and oats. Soils with moderate to high levels of available nutrients should receive a complete fertilizer blend of nitrogen, phosphorus, potassium, and sulfur at a ratio of 3:2:1:0.5 N, P_2O_5, K_2O, and S. With irrigated farming practices, the ratio should be reduced to about 1.5:1:0.5:0.25. Additionally, application rates of 0.5 to 1.0 pound per acre of boron can increase yields and improve disease resistance. Actual percentages of each nutrient and the application rate varies according to specific soil test results. The fertilizer can be broadcast before spring tillage or portions can be banded at planting. High-gluten protein content in the seed is needed for high-quality bread flour. The ratio of starch to protein in the seed is a factor of

Closeup of a healthy, ripe head of wheat

Green, unripe wheat heads against a brown paper backdrop

temperature, soil moisture, and available nitrogen during the flowering growth stage. Cool wet weather during this growth stage produces a plump kernel that is high in starch and low in protein. Hot dry weather produces small, dark, hard kernels high in gluten and low in starch. Lack of sufficient available nitrogen produces starchy, soft "yellow berry" kernels. Excess nitrogen fertilizer should be avoided as it can induce lodging and delay maturity, especially if grown under irrigation. Differences in protein content and quality among varieties affect flour quality.

To conserve soil moisture, minimum tillage is recommended for incorporating fertilizer material and plant residue and preparing the seedbed. Pulling a packer behind the tillage implement and using a seed drill equipped with press wheels ensure that the seed is in contact with moist soil during the time needed for germination. This is especially true if the crop is to be irrigated. The soil should be irrigated sufficiently to bring the soil moisture levels to close to the maximum water-holding capacity before tillage. It is very important not to irrigate above the maximum water-holding capacity before tillage and planting as this could cause a soil crust to form on the surface that would impede seedling emergence, reduce plant density, and lower seed yields. Seeding depth and rate is the same as that for barley and oats, 1.5 to 2.5 inches, or to moisture, and 90 to 100 pounds of pure live seed per acre. To reduce late tillering, the heavier seeding rates are to be used when wheat is to be produced for seed. Early planting dates are recommended to utilize as much of the short growing season as possible. Use of certified seed is strongly recommended. Certified seed has strict limits on maximum content of weed seeds and diseased kernels and must meet a minimum percent germination. This helps to ensure good germination and emergence and reduces weed and disease infestations.

Like barley and oats, irrigation should begin again after the crop has reached about 50% emergence to avoid any problems with emergence from too hard of a crust on the surface. Thereafter, a good range of irrigation plus precipitation is around 0.5 to 1.0 inch per week. Irrigation should continue until the crop has reached the 50% headed growth stage.

Pest control in wheat is the same as for barley and oats. Using IPM techniques, assess each field for all pests (weeds, diseases, and insects) and plan control measures accordingly. Weed control is a combination of mechanical and chemical summer fallow to reduce the number and species of weeds for the following season and an application of a post-emergence herbicide when needed as determined through IPM practices. If weed populations have been determined to be high enough to cause a potential loss in yield or quality of the crop then the application of herbicides may be warranted. The best broad-leaved weed control can be achieved with with broadleaf-selective herbicides Bromoxynil, MCPA, or Diglycolamine tank mixes or a 2,4-D amine, which are labeled for use on wheat, applied when the wheat was 4 to 6 inches tall (3- to 5-leaf stage), but before the boot stage. Best control of grassy weeds was through a combination of mechanical and chemical summer fallow. To eliminate grassy weeds with chemical fallow, a broad-spectrum, nonselective post-emergence herbicide such as glyphosate (Roundup) can be used. Wheat loose smut (*Ustilago tritici*), bacterial mosaic (*Corynebacterium tessellaria*), and barley stripe mosaic (*Pyrenophora graminea*) are diseases that have been found on wheat in Alaska. Yield loss to these diseases has been minimal over the years. They can be controlled by using clean certified seed or disease resistant varieties. The same insect pests that affect barley and oats also affect wheat. The most serious insect pests for wheat are aphids (family Aphididae) and grasshoppers, including the lesser migratory grasshopper (*Melanoplus sanguinipes* Fabricias), the northern grasshopper (*Melanoplus borealis* Fieber), and the clear-winged grasshopper (*Camnula pellucida* Scudder). If insect population levels and damage

Spring and winter wheat growing at the Fairbanks Experiment Farm, June 9, 2011

have been determined to be too high through IPM practices, then the application of an insecticide may be warranted. Insecticide sprays or baits can help control heavy infestations if applied at the nymph growth stage. Always remember to read the pesticide label to be sure the crop is specified and follow the directions on mixing, application, and disposal. Contact your local Cooperative Extension Service for more information on pest control (see Appendix 1 for addresses and contact information).

Wheat is later maturing than barley or oats, so the crop may still be in the fields when waterfowl begin fall migrations. As with hulless barley and hulless oats, wheat is a favorite energy food for migrating waterfowl. Use of propane scare cannons, designed to swivel in different directions and go off at uneven time intervals, is recommended. Check with and inform the neighbors before setting up cannons.

Large ungulates like moose and bison can also cause serious damage to the crop. A single moose or a cow and calf pair usually don't cause much damage to large fields, but can wipe out small-scale plots over the summer. They are attracted to newly emerging plants and will keep coming back through maturity to graze. In the Delta Junction area, bison congregate in large herds that don't usually cause serious damage until their fall migrations north of the Alaska Highway. This migration occurs during the time when the grain is mature, ripe, and ready for harvest. They will not only eat large portions of the crop, but a large herd walking through or bedding down in the field can flatten the crop into the ground, making harvest impossible. It is illegal to harass wildlife in Alaska so the only control is to erect large (6 feet or higher), stout, highly visible fencing that can direct the animals around the fields. For more information on wildlife control in agricultural fields, contact the local office of the Alaska Department of Fish and Game.

If the crop grown is intended for sale as seed for future planting, the fields should be inspected before harvest to insure that the highest quality crop is being grown in order to meet the standards for certified seed (blue tag on the seed bag). The fields should be planted in clean ground and not in ground in which the same crop that is being certified was planted the previous year. There can be only 1 plant out of 1,000 of another wheat variety as well as 1 plant out of 2,000 that is an inseparable crop like rye or hulless barley seed and there must be no objectionable weeds (prohibited or restricted noxious weeds). The seed lots after harvest should also be inspected to meet the certified seed standards. For more information about field and seed lot inspections, contact the local office of the state

Division of Agriculture, Department of Natural Resources or the Alaska Seed Growers Association (see Appendix 1 for addresses and contact information).

As with barley and oats, wheat stops growing when the seed reaches the hard dough stage (the kernels can't be dented when pressed with a thumbnail). The typical seed moisture content at this stage is 25% to 35%. Although wheat can be harvested at this moisture content, significant loss of germination ability occurs during storage. The grain must be around 12% to 13% moisture for safe, long-term storage. Higher moisture contents can germinate or mold the stored seed, and lower moisture contents can damage the embryo, reducing germination ability. Both situations reduce the quality of the stored grain. Harvesting before or at the hard dough stage results in a fair amount of green, high-moisture heads. This underdeveloped grain is low in yield, test weights, and market value. Highest quality grain can be achieved by swathing or combining at the lowest moisture content. Because wheat seed is about the same size and shape as hulless barley and hulless oats with heavy test weights, harvest wheat using the same combine settings. When combining wheat, slow down the feeding rate by reducing the front concave opening and cylinder speed for proper threshing and hull removal. An increase of the airflow can improve hull removal. To reduce embryo damage, run augers at full capacity or slow them down. Because food-grade seed only allows 4% cracked hulls, continual checking for hulls left on the seed or cracked seeds and adjusting combining methods is important. Early maturing wheat also has a tendency to head shatter and lodge. Waiting for the grain to field dry to 13% moisture can result in significant yield reductions due to shattering of the seed. To reduce head shattering, harvest grain at a higher than optimal moisture content, then use on-farm drying to get the stored grain to 13% moisture.

Many of the drawbacks in producing wheat are the same as for hulless barley and hulless oats. Most wheat varieties are late or very late maturing, are relatively lower yielding, and require an established niche market for the producer to obtain a premium price for the crop. No more than 15% of the hulls can be left on for producing food-grade wheat. More than this results in a lower price paid to the producer. Food-grade wheat can retain no more than 5% of the hulls, which are easily removed during combining. If needed, additional seed buffing can be done to remove hulls before shipping to market. Food-grade wheat can't contain any more than 4% diseased kernels, other crops, or foreign material. Any seed lot not meeting the higher food grades is purchased at lower feed-grade prices. On-farm cleaning and sizing of the seed lot to food-grade standards before shipment results in higher prices paid to the producer. Clean-outs can be used on farm or sold as feed grade.

The Alaska market for wheat is limited due to the difficulty in consistently producing a viable crop. However, there is an increased interest in producing wheat for human consumption as whole grain and flour for sale in local markets. There are no large-scale, in-state mills to process food-grade flour and no elevator is set up to accept wheat. A number of small-scale on-farm mills exist. Alaska wheat is sold primarily as whole grain kernels (berries), as wheat flour in local health food markets, or is grown for on-farm use as an animal feed. A limited seed production industry provides local farmers with certified seed. Like oat straw, wheat straw may be used for animal bedding because it lacks the rough awns of barley straw.

Similar to barley and oats, all commercial food-grade wheat products, which include whole kernel grain and processed flour, are regulated and inspected by state and federal agencies before sale to the public. In Alaska, the Department of Environmental Conservation regulates and inspects commercial food-grade grain products under the Food Safety and Sanitation Program - Food Processors. More information can be obtained at the DEC website, http://dec.alaska.gov/commish/regulations/index.htm or contact your local DEC environmental health officer (see Appendix 1 for addresses and contact information).

Nationally, commercial food-grade grain products are regulated and inspected by the U.S. Food and Drug Administration (FDA) under the Good Manufacturing Practice (GMP) of Title 21 of the Federal Food, Drug and Cosmetic Act, part 110 - Sanitary conditions. More detailed information can be found in the FDA publication, "Guide to Inspections of Grain Product Manufacturers," located at the FDA website, www.fda.gov/.

Recommended Variety Descriptions for Spring Wheat

Note: See Appendix 1 for the addresses of seed suppliers.

'AC Intrepid' is an early-maturing, mid-tall (Canadian hard red spring bread wheat), stiff-strawed, red-glumed, red-kerneled, awned, hard red spring wheat released in 1997 by the plant breeding program of Agriculture Canada (AC) in Swift Current, Alberta. Maturity is about the same with yields that are higher than 'Ingal' but with lighter test weights. 'AC Intrepid' is more susceptible to loose smut fungal attacks compared with 'Ingal'. It is satisfactory for milling and baking. Direct inquires about seed sources to Canterra Seeds.

'CDC Bounty' is an early-maturing, mid-tall (Canadian hard red spring bread wheat), red-glumed, red-kerneled, awned, hard red spring wheat released in 1999 by the Crop Development Centre (CDC) plant breeding program at the University of Saskatchewan in Saskatoon. Average maturity is about 1 to 2 days later but yields and

'Ingal' growing at the Fairbanks Experiment Farm. This hard red spring wheat was the standard variety against which all other wheat, rye, and triticale varieties were compared in this report.

test weights are higher than 'Ingal'. 'CDC Bounty' is more resistant to loose smut fungal attacks compared with 'Ingal'. It is satisfactory for milling and baking. Direct inquiries about seed sources to Canterra Seeds.

'Cutler' is an early-maturing, semi-dwarf (Canadian prairie spring wheat), stiff-strawed, red-glumed, red-kerneled, hard red spring wheat released in 1990 by the breeding program of the Department of Natural Resources at the University of Alberta in Edmonton. It is resistant to lodging and head shatter and also is tolerant of acidic soils. Average maturity is 3 days later than 'Ingal', but yield is about equal. 'Cutler' is susceptible to wheat smut and is not drought tolerant. It is satisfactory for milling and baking. Direct inquiries about seed sources to the University of Alberta.

'Ingal' is an early-maturing, semi-dwarf (Canadian prairie spring wheat), stiff-strawed, red-glumed, red-kerneled, awned, hard red spring wheat released in 1981 by the USDA-ARS plant breeding program at the Matanuska Experiment Farm. It was selected from a cross between a variety developed in Alaska, 'Gasser', and 'Norin No. 16' from the USDA World Wheat Collection. Seed kernels of 'Ingal' are smaller than average, requiring modifications to drill seed metering and to combine settings at harvest. Also, 'Ingal' is prone to head shatter at harvest in adverse weather conditions, such as heavy rains or high winds. 'Ingal' is satisfactory for milling and baking. This was the standard variety against which all other wheat, rye, and triticale varieties were compared in this report. Direct inquiries about seed sources to the Alaska Seed Growers Association or the Alaska Plant Materials Center.

'Nogal', a hard red spring wheat developed in Alaska and shown here growing at the Fairbanks Experiment Farm August 5, 2011

'Nogal' is an early-maturing, mid-tall (Canadian hard red spring bread wheat), stiff-strawed, red-glumed, red-kerneled, awned, hard red spring wheat released in 1981 by the USDA-ARS plant breeding program at the Matanuska Experiment Farm. It was selected from a cross between a variety developed in Alaska, 'Gasser', and a Norwegian cultivar, 'Norrona'. 'Nogal' is later maturing by 3 to 5 days than 'Ingal' but is higher yielding, with equal test weights due to the larger kernels. 'Nogal' is satisfactory for milling and baking. Direct inquiries about seed sources to the Alaska Seed Growers Association or the Alaska Plant Materials Center.

'Roblin' is an early-maturing mid-tall (Canadian hard red spring bread wheat), stiff-strawed, red-glumed, red-kerneled, awned, hard red spring wheat released in 1986 by the plant breeding program of Agriculture Canada (AC) in Winnipeg, Alberta. 'Roblin' is about 5 days later maturing than 'Ingal' but with higher yields. It is more susceptible to loose smut fungal attacks and is not drought tolerant. It is satisfactory for milling and baking. Direct inquiries about seed sources to the SeCan Association.

Spelt Wheat and Related Species

Spelt wheat (*Triticum spelta* L.) is considered a genetic parent of common wheat. It is a primitive form of wheat that more closely resembles the wheatgrass (*Agropyron* sp.) family than true bread wheat. The seed head is long, slender, and awnless. Most of the hulls remain on the kernel after threshing. It is very late maturing, but continues to ripen even under cool, wet conditions when most bread wheats do not. Its primary use is as livestock feed, although there is some limited traditional use for human consumption. For digestibility, the hull must be removed in a dehulling process similar to hulled barley and oats before incorporating spelt wheat into any nonruminant or human diet. Spelt wheat is not accepted as a class of bread wheat.

Other similar primitive wheats that are also considered to be possible genetic parents of common wheat are emmer wheat *(Triticum dicoccon)* and

Closeup of an ear of spelt (above), June 15, 2014, growing in the Netherlands. Wikimedia Creative Commons Attribution-Share Alike 3.0 Unported, 2.5 Generic, 2.0 Generic and 1.0 Generic license

Row of 'Finley' winter wheat growing in Fairbanks August 5, 2011, very sparse compared to 'Decade'

Row of 'Decade' red winter wheat growing in Fairbanks August 5, 2011

einkorn wheat (*Triticum monococcum* L.). Emmer wheat differs from spelt wheat by having shorter, denser, and flatter heads. Einkorn, or one-grain, wheat differs from the other two by literally having only 1 fertile floret in each head. Like spelt wheat, most of the hulls of emmer and einkorn wheat remain on the kernel after threshing. They are also very late-maturing and low-yielding compared to the common wheats.

There is a limited niche market for spelt wheat in the United States that is currently undeveloped in Alaska. Spelt wheat production practices are identical to common wheat, except for the longer growing period. The late maturity, extra dehulling cost for human consumption, greater availability of other grains for livestock feed, limited or nonexistent markets, and the difficulty in obtaining seed make this crop economically unviable for Alaska. For these reasons, no spelt, emmer, or einkorn wheat varieties are generally recommended. However, just because there was a crop failure for this study does not mean that they might not be able to be successfully grown somewhere within the state. Therefore, the reader is not discouraged from trying any of the spelt, emmer, or einkorn varieties not recommended, but the probability of success in attempting to produce these crops will likely be low.

Winter Wheat

Winter wheat varieties are also bread wheats (*Triticum aesitivum* subspecies *vulgare* L.). They are made up of 4 types: the hard red winter wheat varieties, the hard white winter varieties, the soft white winter wheat varieties, and the soft red winter wheat varieties. Hard red, hard white, and soft white winter wheats are adapted to areas of low precipitation (less than 35 inches annually), while soft red winter wheats are usually grown in areas of higher annual precipitation. Fertilization rates, tillage practices, seeding depths, irrigation practices, weed and insect control, harvesting, cleaning, and storage are the same as for spring wheat. Winter wheat is usually planted in early fall. In its first year, it produces a small, low rosette of vegetative growth to build up root reserves before winter dormancy. The next spring it produces an upright plant with a seed head similar in appearance to annual grains. No winter grains (barley, wheat, or rye) have performed well in Alaska for many reasons. To build up enough root reserves to survive the winter, the grain must be planted in late July to early August. This leads to a 13-month season for winter grains because they can't be harvested until the following August or September. An annual grain crop can be planted and harvested in about 3 to 4 months and a new crop planted the following year.

In Alaska the photoperiod, even in late July to early August, can lead to other problems. L.J. Klebesadel (1969) found in tests on winter rye varieties that long daylength caused nonadapted varieties to grow more rapidly as seedlings, which results in the buildup of fewer root reserves and, consequently, a high rate of winter kill, which is the second and most serious problem. Some varieties of winter grain can tolerate low temperatures quite well; certain winter wheat varieties have been known to survive -40°F temperature, and winter temperatures under the snowpack are almost always warmer than that. If the snowpack blows off the field, unadapted varieties can die when temperatures get too low and the rosette suffers freezing injury. After the snowpack has melted and the rosettes green up, there are still many days of potential freezing temperatures. If the snowpack is thin or absent, low humidity can desiccate rosettes. With the snowpack in place, humidity under it is high and snowmold fungi, including white snowmold (*Sclerotinia borealis*), sclerotial Low Temperature Basidiomycetes (sLTB), and pink snowmold (*Gerlachia nivalis*) can attack the plants and kill the rosettes. These snowmold fungi are present on the plant tissue before winter and only grow and spread in the spring when temperature and moisture conditions are right. Studies by F.J. Wooding and J.H. McBeath (1984) found that applying a low-cost organic fungicide like pentachloronitrobenzene (Terraclor) in the fall is effective against the white snowmold, but not pink snowmold. Newer varieties have been bred to be snowmold resistant and survive winter dormancy under the snowpack quite well. Unfortunately, the photoperiod response extends into the following growing season. Many winter wheat varieties require a period of darkness after reaching the heading growth stage to fully mature. In Alaska, that time isn't reached until mid- to late August. This means that even though these newer winter wheat varieties will reach the 50% heading growth stage a week or so earlier than spring wheat varieties, they won't reach 50% maturity until the same time or later.

Winter grains have been tested primarily in the Fairbanks and Delta Junction dryland areas. A couple of cultural methods to trap snow have been tested to increase the winter survival rate in the Delta Junction area. The first method was to plant through standing stubble. This requires that the stubble (6 to 8 inches high) from the previous year is not tilled under in the spring, that weeds were controlled by chemical fallow using a broad-spectrum herbicide such as glyphosate (Roundup) through the summer, and that no-till fertilization and planting be used in the late summer. The second method was to plant in shallow furrows (2 to 4 inches deep) in fallow ground. Weed control during the summer was mechanical, fertilization could be broadcast and incorporated with tillage before planting or banded with the seed at planting, and furrows could be made by increasing the down force on the row openers and packer wheels of the seed drill at planting. Both methods did work to trap more snow than regular fallow planted ground, but winter survival rates were still extremely low so no growth and yield data were collected.

Because the Fairbanks site is the only one where snow cover typically is not blown off of the fields, winter grains had much better winter survival rates. Of all the different types of winter wheats, the hard red and hard white winter wheat varieties performed the best due to the low annual precipitation (around 11 inches). For the variety trial tests, no fungicides to prevent snowmold were applied. Few plants of any of the tested older varieties (before the year 2000) survived the winter consistently over the years. Those older varieties that had some survival had poor yields, often only returning the same yield as the volume of seed that was originally planted. However, the newer varieties (after the year 2000), bred with snowmold resistance, have much better survival rates and often mature at close to the same time with as high a seed yield as the best spring-planted wheat varieties. The extreme differences in yields between winter wheat and spring wheat, the cost in time of 13 months versus 3 to 4 months, and the high probability of winter kill potentially make winter wheat an economically unviable crop for most of Alaska. Due to these cultural problems, no varieties of winter wheat are generally recommended. However, just because there was a crop failure for this study does not mean that it might not be able to be successfully grown somewhere within the state. Therefore, the reader is not discouraged from trying any of the winter wheat varieties not recommended, but the probability of success in attempting to produce these crops will likely be low. On the other hand, if you live in an area where there is a guarantee of a consistent snow cover and a long, warm growing season (high cumulative GDD) like the Fairbanks area, then winter wheat might be successfully grown. For this location, the newer (after 2000) hard red winter wheat varieties listed below have consistently produced acceptable seed yields.

As mentioned previously, the Alaska market for all wheat types is limited due to the difficulty in consistently producing a viable crop (an even greater problem for winter wheat). However, there is an increased interest in producing wheat for human consumption as whole grain and flour for sale in local markets. There are no large-scale, in-state mills to process food-grade flour and no elevator is set up to accept wheat. A number of small-scale on-farm mills exist. Alaska wheat is sold primarily as whole grain kernels (berries) or as wheat flour in local health food markets, which does command higher prices.

Recommended Variety Descriptions for Winter Wheat

Note: See Appendix 1 for the addresses of seed suppliers.

'Decade' is a mid- to early-maturing, semi-dwarf, stiff-strawed, awned, white-glumed, red-kerneled, high winter-hardy, hard red winter wheat released in 2010 jointly by the winter wheat plant breeding program at Montana State University in Bozeman and the Williston Research Extension Center of North Dakota State University. 'Decade' is about equal in maturity with 'Ingal' hard red spring wheat but lower yielding. Its high straw strength makes it resistant to lodging. It is satisfactory for milling and baking. This variety is protected by the United States Plant Variety Protection Act (Title V). Producers may save seed for their own use on their own farms, but sale or transfer of seed is prohibited without written permission and a payment of fees to the breeder. Direct inquiries about seed sources to the North Dakota State Seed Department.

'Jerry' is a mid- to early-maturing, mid-tall, stiff-strawed, awned, white-glumed, red-kerneled, high winter-hardy, hard red winter wheat released in 2001 by the plant breeding program at North Dakota State University in Fargo. 'Jerry' is a cross between 'Roughrider' and 'Arapahoe' hard red winter wheats. It is about equal in maturity with 'Ingal' hard red spring wheat but lower yielding. Its high straw strength makes it resistant to lodging. It is satisfactory for milling and baking. Direct inquiries about seed sources to the North Dakota State Seed Department.

'Yellowstone' is a mid- to early-maturing, mid-tall, stiff-strawed, awned, white-glumed, red-kerneled, high winter-hardy, hard red winter wheat released in 2005 by the AES winter wheat plant breeding program at Montana State University in Bozeman. 'Yellowstone' is a cross between 'Judith' and 'Promontory' hard red winter wheats. It is about equal in maturity with 'Ingal' hard red spring wheat but lower yielding. Its high straw strength makes it resistant to lodging. It is satisfactory for milling and baking. This variety is protected by the United States Plant Variety Protection Act (Title V). Producers may save seed for their own use on their own farms, but sale or transfer of seed is prohibited without written permission and a payment of fees to the breeder. Direct inquiries about seed sources to Montana State University.

Yields and Quality by Location for Spring, Spelt, and Winter Wheat

Wheat grain is bought and sold by weight. Similar to other small grains, a standard test weight for wheat is used as the legal unit for crop sales. This standard test weight for clean, dry, and undamaged spring and winter wheat is 60 pounds per bushel. There is no standard test weight for spelt wheat. Highest prices are paid to the producer for this niche crop, but only if it meets the quality criteria mentioned previously. Other than test weights, additional samples should be taken to determine quality. Any seed lots not meeting food grade for wheat should be used as feed grade. It is important then for the producer to clean and size all seed lots before delivery to a niche market. Test weights can differ between cultivars and can change within a single cultivar, depending on cultural practices, weather conditions, and location where grown. It is used here as a measure of grain quality to determine maturity. Yields are expressed here in pounds per acre and bushels per acre. Determine bushels per acre by dividing the yield of any specific cultivar by the standard test weight.

Tables 39, 41, 43, 45, and 46 list yields and quality measurements for wheat varieties for all test locations: Fairbanks, Eielson, Delta Junction, and Palmer. All sites in the Delta Junction area have been combined into either the Delta dryland site (Table 43) or, if grown under irrigation, the Delta irrigated site (Table 45). Each table also contains information on wheat type (hard red spring, semi-dwarf, etc.), the source or the location of where it was bred, and the years it was tested at each location. Maturity in this study was defined as when 50% of the heads for each plot were at the hard dough stage (the heads were a light yellow in color and the kernels did not dent when pressed with a thumbnail). Growing degree days (GDD) for average maturity were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. The low temperature point for wheat in this report is the freezing point of water, 32°F. The GDD calculations for each day were then added to the preceding GDD value to determine the cumulative value to the date at which the specific variety had reached 50% maturity. For winter wheat varieties, the cumulative GDD values were based on an average of 375 days after planting. This includes the GDD from planting to freeze-up in the fall and from green-up to maturity the following season. There were no irrigation studies done on winter wheat. All varieties were compared with 'Ingal' hard red spring wheat as the standard variety. Yield as a percent of the standard variety 'Ingal' was determined by dividing the average yield of each variety by the average yield of 'Ingal'. Maturity vs. Std. (Standard variety) is the number of days each variety reached 50% maturity either before or after the number of days that 'Ingal' reached 50% maturity.

Tables 40, 42, 44, and 47 list the quality analyses of the seed for select wheat varieties for the Fairbanks, Eielson, Delta Junction dryland, and Palmer test locations. They are presented here without statistical differences and solely for the reader's benefit. More detailed information and explanation about the industry standards for feed and food-grade wheat that follow can be obtained from D.C. Church (1979) and J.H. Martin and others (1976). Detailed explanation of the feed analysis that follows as well as laboratory procedures can be obtained from J. Schroeder (1994) and G.J. Michaelson and others (1987). As with the yield tables, all sites in the Delta Junction area have been combined together.

Percent crude protein is calculated from the total percent nitrogen analysis of the seed multiplied by a constant of 6.25. Crude protein is made up of amino acids, which are 16% nitrogen, as well as other, non-protein portions of the plant, and so percent crude protein is not a measure of true protein. Industry standards for hard red wheat are set for a range between 13% and 17%, and for soft white wheat at 10% and 13% crude protein. Higher values have greater nutritional food value, but too high a value (>17% for hard red wheat and >13% for soft white wheat) is an indicator of immature green seed, which makes a lower quality grade flour because it turns rancid quicker. In a standard feed analysis, other major nutrient mineral concentrations commonly measured are percent phosphorus (%P) and potassium (%K).

Wheat growing at the Fairbanks Experiment Farm August 5, 2011. This is a Canadian wheat, likely 'CDC Bounty' (from the Crop Development Centre). Note the dramatic difference in ripeness between this wheat and the Alaska wheat 'Nogal', shown on page 90.

Table 39. Average yields and quality measurements for all wheat varieties from test plots in the Fairbanks area.

Wheat Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test Weight (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Hard red, spring										
AC Intrepid	Saskatchewan	5	3963	66	143	60	22	1-Aug	1	2217
AC Splendor	Saskatchewan	3	2127	35	95	57	20	10-Aug	10	2332
Canuck	Manitoba	1	2860	48	113	62	0	5-Aug	5	2438
CDC Alsask	Saskatchewan	2	4196	70	171	62	38	9-Aug	9	2323
CDC Bounty	Saskatchewan	5	3377	56	123	61	33	2-Aug	2	2242
CDC Osler	Saskatchewan	2	4163	69	170	62	20	8-Aug	8	2307
Chena	Alaska	3	4112	69	119	58	18	3-Aug	3	2342
Conway	Saskatchewan	1	3285	55	130	61	0	5-Aug	5	2438
Gasser	Alaska	3	2847	47	84	55	45	3-Aug	3	2342
Katepwa	Manitoba	1	3528	59	140	61	0	5-Aug	5	2438
Kenyon	Saskatchewan	2	4881	81	125	63	0	5-Aug	5	2406
Laura	Alberta	2	5065	84	129	63	0	6-Aug	6	2427
Nogal	Alaska	12	3201	53	120	58	24	2-Aug	2	2219
Park	Alberta	3	3681	61	108	60	2	4-Aug	4	2361
PT 425	Saskatchewan	3	2237	37	95	57	39	11-Aug	11	2337
PT 430	Saskatchewan	3	3060	51	122	57	9	10-Aug	10	2330
PT 437	Saskatchewan	3	2569	43	113	57	21	9-Aug	9	2312
Roblin	Manitoba	10	3325	55	124	59	5	4-Aug	4	2286
Tapio	Finland	3	5032	84	147	60	0	5-Aug	5	2399
Ulla	Finland	1	3403	57	135	57	0	3-Aug	3	2323
Vidal	Alaska	6	2892	48	100	53	0	4-Aug	4	2379
Hard red semi-dwarf, spring										
Cutler	Alberta	3	2518	42	116	57	0	5-Aug	5	2300
Explorer	Montana	3	3081	51	124	55	41	10-Aug	10	2339
Hi-Line	Montana	3	3105	52	129	56	29	10-Aug	10	2342
HY 320	Saskatchewan	2	5546	92	141	62	0	6-Aug	6	2427
Ingal	Alaska	17	2684	45	100	56	25	31-Jul	0	2143
McNeal	Montana	3	2889	48	126	55	15	8-Aug	8	2287
MT 0245	Montana	3	2833	47	143	56	49	12-Aug	12	2388
Oslo	Colorado	2	4169	69	107	60	0	5-Aug	5	2406
Hard red utility, spring										
Blue Sky	Alberta	2	5105	85	131	61	0	6-Aug	6	2427
CDC Walrus	Saskatchewan	2	3592	60	147	61	25	9-Aug	9	2327
Wildcat	Alberta	2	4659	78	119	59	0	5-Aug	5	2406
Spelt, spring										
Speltz	South Dakota	1	3420	57	127	51	0	21-Aug	21	2769
Hard red, winter										
Blackhawk	Nebraska	1	136	2	5	47	0	17-Aug	17	3750
Bauermeister	Washington	3	1593	27	59	59	8	30-Jul	-1	3430
Cheyenne	Nebraska	2	122	2	5	48	0	17-Aug	17	3750

Table 39. Average yields and quality measurements for all wheat varieties from test plots in the Fairbanks area (continued).

Decade	Montana	3	1568	26	58	59	5	27-Jul	-4	3349
Finley	Washington	3	1347	22	50	58	28	4-Aug	4	3545
Froid	Montana	7	2004	33	75	55	0	10-Aug	10	3581
Jerry	North Dakota	3	2221	37	83	60	22	24-Jul	-7	3264
Kharkov	Quebec	1	445	7	17	50	0	15-Aug	15	3704
Lancer	Colorado	2	336	6	12	48	0	15-Aug	15	3704
NB 66403	Nebraska	2	2020	34	75	50	0	10-Aug	10	3581
Norstar	Alberta	2	779	13	29	64	0	10-Aug	10	3581
Omaha	Nebraska	3	859	14	32	51	0	10-Aug	10	3581
Roughrider	North Dakota	2	649	11	24	64	0	10-Aug	10	3581
Sawmont	United States	3	1905	32	71	55	0	10-Aug	10	3581
Scout 66	Nebraska	2	59	1	2	49	0	17-Aug	17	3750
Shoshoni	Nebraska	3	1652	28	61	55	0	10-Aug	10	3581
Sundance	Alberta	2	653	11	24	63	0	10-Aug	10	3581
Trader	United States	2	360	6	13	49	0	15-Aug	15	3704
Trapper	United States	3	1411	24	52	51	0	10-Aug	10	3581
Warrior	Nebraska	2	304	5	11	49	0	15-Aug	15	3704
Winalta	Alberta	2	206	3	8	48	0	15-Aug	15	3704
Yellowstone	Montana	3	2034	34	76	59	8	27-Jul	-4	3333
Hard white, winter										
MDM	Washington	3	3172	53	118	60	27	6-Aug	6	3606
Soft white, winter										
Eltan	Washington	3	2731	46	102	58	43	7-Aug	7	3622
Xerpha	Washington	3	2335	39	87	59	8	30-Jul	-1	3430

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Winter wheat GDD are based on an average of 375 days after planting. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. All varieties were compared with 'Ingal' hard red spring wheat as the standard variety.

Table 40. Average quality measurements for select wheat varieties from test plots in the Fairbanks area.

Wheat Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)
Flour Industry Standards			13-17%	0.3-0.5%	0.4-0.6%
Hard red, spring					
AC Intrepid	Saskatchewan	5	16.21	0.32	0.39
AC Splendor	Saskatchewan	3	16.80	0.43	0.34
CDC Bounty	Saskatchewan	5	16.33	0.40	0.36
Nogal	Alaska	12	17.40	0.31	0.35
PT 425	Saskatchewan	3	17.00	0.34	0.42
PT 430	Saskatchewan	3	15.70	0.34	0.39
PT 437	Saskatchewan	3	15.60	0.31	0.42
Roblin	Manitoba	10	14.56	0.32	0.41
Vidal	Alaska	6	13.69	0.31	0.38
Hard red semi-dwarf, spring					
Cutler	Alberta	3	14.19	0.34	0.42
Explorer	Montana	3	14.90	0.44	0.34
Hi-Line	Montana	3	13.90	0.33	0.37
Ingal	Alaska	17	14.50	0.44	0.35
McNeal	Montana	3	15.10	0.33	0.38
MT 0245	Montana	3	14.90	0.31	0.37

All varieties were compared with 'Ingal' hard red spring wheat as the standard variety.

Table 41. Average yields and quality measurements for all wheat varieties from test plots in the Eielson area.

Wheat Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test Weight (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Hard red, spring										
Nogal	Alaska	1	0	0	0	0	0	13-Aug	8	2525
Roblin	Manitoba	2	2623	44	108	54	0	17-Aug	12	2520
Vidal	Alaska	2	824	14	64	52	0	17-Aug	12	2601
Hard red semi-dwarf, spring										
Cutler	Alberta	3	2147	36	103	54	0	15-Aug	10	2506
Ingal	Alaska	3	2058	34	100	56	0	5-Aug	0	2253

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. All varieties were compared with 'Ingal' hard red spring wheat as the standard variety.

Table 42. Average quality measurements for select wheat varieties from test plots in the Eielson area.

Wheat Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)
Flour Industry Standards			13-17%	0.3-0.5%	0.4-0.6%
Hard red, spring					
Roblin	Manitoba	2	13.59	0.40	0.45
Vidal	Alaska	2	14.44	0.41	0.48
Hard red semi-dwarf, spring					
Cutler	Alberta	3	12.56	0.38	0.46
Ingal	Alaska	3	13.50	0.43	0.46

All varieties were compared with 'Ingal' hard red spring wheat as the standard variety.

Table 43. Average yields and quality measurements for all wheat varieties from test plots in the Delta Junction area, dryland.

Wheat Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test Weight (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Hard red, spring										
AC Intrepid	Saskatchewan	5	1282	21	128	52	0	8-Aug	0	2301
AC Splendor	Saskatchewan	3	1456	24	119	52	0	16-Aug	8	2458
CDC Alsask	Saskatchewan	2	1265	21	203	53	0	23-Aug	15	2546
CDC Bounty	Saskatchewan	5	1009	17	101	53	0	9-Aug	1	2322
CDC Osler	Saskatchewan	2	1002	17	160	52	0	24-Aug	16	2555
Canuck	Manitoba	1	2515	42	90	60	0	29-Aug	21	2556
Chena	Alaska	3	3951	66	120	59	0	29-Aug	21	2497
Conway	Saskatchewan	1	2830	47	102	60	0	27-Aug	19	2523
Gasser	Alaska	3	3092	52	92	60	0	29-Aug	21	2497
Katepwa	Manitoba	1	3046	51	109	60	0	29-Aug	21	2556
Kenyon	Saskatchewan	2	3567	59	99	58	0	30-Aug	22	2484
Laura	Alberta	2	3448	57	96	56	0	30-Aug	22	2484
Nogal	Alaska	12	2085	35	130	57	0	15-Aug	7	2417
Park	Alberta	3	3317	55	100	59	0	30-Aug	22	2508
PT 425	Saskatchewan	3	1304	22	106	54	0	16-Aug	8	2457
PT 430	Saskatchewan	3	1642	27	133	51	0	16-Aug	8	2463
PT 437	Saskatchewan	3	1636	27	133	55	0	15-Aug	7	2450
Roblin	Manitoba	11	1682	28	113	54	0	13-Aug	5	2369
Tapio	Finland	3	3902	65	116	55	0	31-Aug	23	2515
Ulla	Finland	1	3115	52	112	60	0	1-Sep	24	2577
Vidal	Alaska	7	2209	37	91	52	0	23-Aug	15	2482
Hard red semi-dwarf, spring										
Cutler	Alberta	3	1170	19	107	51	0	7-Aug	-1	2487
Explorer	Montana	3	1682	28	137	52	0	16-Aug	8	2459
Hi-Line	Montana	3	1568	26	127	55	0	16-Aug	8	2469
HY 320	Saskatchewan	2	4507	75	125	57	0	30-Aug	22	2484
Ingal	Alaska	20	1509	25	100	55	0	8-Aug	0	2252
McNeal	Montana	3	1553	26	126	55	0	13-Aug	5	2401
MT 0245	Montana	3	1623	27	131	51	0	17-Aug	9	2490
Oslo	Colorado	2	3419	57	95	56	0	30-Aug	22	2484
Hard red utility, spring										
Blue Sky	Alberta	2	4059	68	112	57	0	30-Aug	22	2484
CDC Walrus	Saskatchewan	2	483	8	77	51	0	24-Aug	16	2567
Wildcat	Alberta	2	4271	71	118	57	0	30-Aug	22	2484
Spelt, spring										
Speltz	South Dakota	2	2400	40	156	50	0	23-Aug	15	2585
Hard red, winter										
Bauermeister	Washington	3	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Decade	Montana	3	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Finley	Washington	3	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D

Table 43. Average yields and quality measurements for all wheat varieties from test plots in the Delta Junction area, dryland, continued.

Jerry	North Dakota	3	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Yellowstone	Montana	3	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Hard white, winter										
MDM	Washington	3	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Soft white, winter										
Eltan	Washington	3	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Xerpha	Washington	3	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. All varieties were compared with 'Ingal' hard red spring wheat as the standard variety. N/D = No Data.

Table 44. Average quality measurements for select wheat varieties from test plots in the Delta Junction area, dryland.

Wheat Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)
Flour Industry Standards			**13-17%**	**0.3-0.5%**	**0.4-0.6%**
Hard red, spring					
AC Intrepid	Saskatchewan	5	12.88	0.29	0.46
AC Splendor	Saskatchewan	3	16.80	0.29	0.46
CDC Bounty	Saskatchewan	5	15.69	0.36	0.39
Nogal	Alaska	12	16.80	0.22	0.42
PT 425	Saskatchewan	3	17.10	0.26	0.31
PT 430	Saskatchewan	3	15.20	0.28	0.42
PT 437	Saskatchewan	3	16.30	0.26	0.36
Roblin	Manitoba	11	15.95	0.27	0.40
Vidal	Alaska	7	15.00	0.28	0.31
Hard red semi-dwarf, spring					
Cutler	Alberta	3	15.44	0.28	0.42
Explorer	Montana	3	15.20	0.22	0.42
Hi-Line	Montana	3	16.60	0.28	0.46
Ingal	Alaska	20	13.60	0.36	0.42
McNeal	Montana	3	16.70	0.29	0.42
MT 0245	Montana	3	15.80	0.28	0.36

All varieties were compared with 'Ingal' hard red spring wheat as the standard variety.


Left: 'MDM', a semi-dwarf hard white winter wheat from Washington State University, shown growing here at the Fairbanks Experiment Farm on August 5, 2011. 'MDM' was named after wheat grower and research supporter Michael D. Moore of Kahlotus, Washington. Right: Agriculture Canada's 'AC Intrepid', a hard red spring wheat from Saskatchewan, also photographed growing August 5, 2011 at the Fairbanks Experiment Farm.

Table 45. Average yields and quality measurements for all wheat varieties from test plots in the Delta Junction area, irrigated.

Wheat Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test Weight (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Hard red, spring										
AC Intrepid	Saskatchewan	2	954	16	130	55	0	23-Aug	13	2543
Hard red semi-dwarf, spring										
Cutler	Alberta	1	2695	45	105	58	0	13-Aug	3	2380
Ingal	Alaska	5	1876	31	100	55	0	10-Aug	0	2205
Hard red utility, spring										
Lazer	Alberta	1	2834	47	110	56	0	17-Aug	7	2465

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. All varieties were compared with 'Ingal' hard red spring wheat as the standard variety.

Table 46. Average yields and quality measurements for all wheat varieties from test plots in the Palmer area.

Wheat Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test Weight (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Hard red, spring										
AC Intrepid	Saskatchewan	4	1827	30	98	57	3	1-Aug	-5	2040
AC Splendor	Saskatchewan	3	1431	24	95	55	63	31-Aug	25	2474
CDC Alsask	Saskatchewan	1	646	11	78	55	0	17-Aug	11	2015
CDC Bounty	Saskatchewan	4	1591	27	92	58	12	1-Aug	-5	2055
CDC Osler	Saskatchewan	1	523	9	63	55	0	17-Aug	11	2030
Chena	Alaska	1	3398	57	168	61	0	29-Aug	23	2611
Gasser	Alaska	1	2678	45	132	59	0	29-Aug	23	2611
Kenyon	Saskatchewan	1	2939	49	145	62	0	29-Aug	23	2611
Laura	Alberta	1	3105	52	153	63	0	29-Aug	23	2611
Nogal	Alaska	6	1558	26	106	57	39	17-Aug	11	2162
Park	Alberta	1	2969	49	147	63	0	29-Aug	23	2611
PT 425	Saskatchewan	3	1818	30	118	55	63	1-Sep	26	2484
PT 430	Saskatchewan	3	2036	34	133	53	63	1-Sep	26	2488
PT 437	Saskatchewan	3	1958	33	128	55	63	1-Sep	26	2480
Roblin	Manitoba	6	1774	30	102	57	7	7-Aug	1	2153
Tapio	Finland	1	2983	50	147	62	0	29-Aug	23	2611
Vidal	Alaska	2	3067	51	152	60	0	29-Aug	23	2611
Hard red semi-dwarf, spring										
Explorer	Montana	3	1454	24	97	51	63	30-Aug	24	2440
Hi-Line	Montana	3	1460	24	97	54	63	30-Aug	24	2456
HY 320	Saskatchewan	1	3237	54	160	62	0	29-Aug	23	2611
Ingal	Alaska	11	1797	30	100	57	43	6-Aug	0	2056
McNeal	Montana	3	1826	30	116	49	63	30-Aug	24	2434
MT 0245	Montana	3	1900	32	123	50	93	31-Aug	25	2463
Oslo	Colorado	1	2239	37	111	60	0	29-Aug	23	2611
Hard red utility, spring										
Blue Sky	Alberta	1	3354	56	166	61	0	29-Aug	23	2611
CDC Walrus	Saskatchewan	1	470	8	57	55	0	18-Aug	12	2037
Wildcat	Alberta	1	2525	42	125	60	0	29-Aug	23	2611

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. All varieties were compared with 'Ingal' hard red spring wheat as the standard variety.

Table 47. Average quality measurements for select wheat varieties from test plots in the Palmer area.

Wheat Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)
Flour Industry Standards			13-17%	0.3-0.5%	0.4-0.6%
Hard red, spring					
AC Intrepid	Saskatchewan	4	16.33	0.32	0.38
AC Splendor	Saskatchewan	3	16.48	0.33	0.36
CDC Bounty	Saskatchewan	4	16.57	0.39	0.33
Nogal	Alaska	6	16.70	0.35	0.34
PT 425	Saskatchewan	3	16.89	0.34	0.38
PT 430	Saskatchewan	3	16.25	0.34	0.39
PT 437	Saskatchewan	3	16.33	0.30	0.40
Roblin	Manitoba	6	16.94	0.36	0.39
Hard red semi-dwarf, spring					
Explorer	Montana	3	15.90	0.44	0.35
Hi-Line	Montana	3	15.32	0.33	0.38
Ingal	Alaska	11	15.51	0.44	0.34
McNeal	Montana	3	15.21	0.33	0.38
MT 0245	Montana	3	15.02	0.31	0.37

All varieties were compared with 'Ingal' hard red spring wheat as the standard variety.

Spring 2011 winter wheat survival trials at the Fairbanks Experiment Farm. Note winter kill from desiccation. Front rows, yellow flag: 'Decade' hard red winter wheat. Front rows, green flag: 'Eltan' soft white winter wheat.

Rye and Triticale

Spring Rye

The true cereal grain rye (*Secale cereale* L.) has been shown to be even less adapted for Alaska than wheat. Similar to wheat, rye has a long growing season requirement but yields less than many wheat varieties. M.B. McLelland (2001) found that rye has lower digestibility and palatability when fed to livestock and must be blended with other grains. It should make up less than one-third of the feed mix. Rye is susceptible to head shatter, making it difficult to harvest and resulting in many volunteer plants emerging in the field next season. However, rye's biggest problem is the susceptibility to ergot disease (*Claviceps purpurea*). Ergot is a fungal disease that can be toxic to livestock and humans. Rye seed lots containing 0.5% or more ergot are rejected as food-grade quality for human consumption. Seed lots containing between 0.3% and 0.5% are considered "ergoty" and must be cleaned before milling. Ergot is the most prevalent fungal disease that has been found on rye in Alaska. The weather conditions best suited for producing ergot are warm, moist spring weather followed by warm dry conditions during the flowering growth stage. Ergot forms on the plant during the flowering growth stage, later producing sclerotia when the plant matures. The sclerotia can fall to the ground with regular rye seed when head shatter occurs or be in with the seed at harvest. It overwinters in the soil and can infect plants grown the following year. Ergot can also infect other small grains with the following order of susceptibility: rye, triticale, barley, durum wheat, common wheat, and oats.

The primary use of rye is as bread flour. D.C. Church (1979) reports that the protein concentration of rye is less than that of hard red wheat but similar to soft white wheat at 10% to 14%. Rye is very similar to wheat with very low crude fiber values of 2% to 4% with a total dry matter content of 80% to 90%. Rye flour does not have true gluten proteins but it contains proteins that make a nutritious, dark, heavy leavened bread. Secondary uses are in the distillation of rye whisky and as a low-value, not very palatable livestock feed. Rye, because of its tall growth characteristic, is also used as an annual forage crop either by itself or with legumes. Also, it is used as a green manure crop to help smother annual weeds and increase soil organic matter content.

Fertilization, tillage practices, and seeding depths are identical to that of wheat. Soils with moderate to high levels of available nutrients should receive a complete fertilizer blend of nitrogen, phosphorus, potassium, and sulfur at a ratio of 3:2:1:0.5 N, P_2O_5, K_2O, and S. With irrigated farming practices, the ratio should be reduced to about 1.5:1:0.5:0.25. Additionally, application rates of 0.5 to 1.0 pound per acre of boron can increase yields and improve disease resistance. Actual percentages of each nutrient and the application rate varies according to specific soil test results. The fertilizer can be broadcast before spring tillage or portions can be banded at planting. Avoid excess nitrogen fertilizer because it can induce lodging and delay

Close-up of ergot (Claviceps purpurea) *growing on a head of rye in the Netherlands, showing the purple tinge of the fungus' mycelium that gives the disease its taxonomic name. Photo from Wikimedia, taken by Rasbak, and used under a Creative Commons CC BY-SA 3.0 license* maturity, especially if grown under irrigation. Rye can be more productive on poor soils than other small grains because it is tolerant of acidic and sandy soil conditions.

To conserve soil moisture, minimum tillage is recommended for incorporating fertilizer material and plant residue and preparing the seedbed. Pulling a packer behind the tillage implement and using a seed drill equipped with press wheels ensure that the seed is in contact with moist soil during the time needed for germination. This is especially true if the crop is to be irrigated. The soil should be irrigated sufficiently to bring the soil moisture levels to close to the maximum water-holding capacity before tillage. It is very important not to irrigate above the maximum water-holding capacity before tillage and planting as this could cause a soil crust to form on the surface that would impede seedling emergence, reduce plant density, and lower seed yields. Seeding depth and rate is the same as that for wheat, 1.5 to 2.5 inches, or to moisture, and 90 to 100 pounds of pure live seed per acre. The heavier seeding rates should be used to reduce late tillering and if rye is grown as a forage crop. Early planting dates are recommended to utilize as much of the short growing season as possible. Use of certified seed is strongly recommended. Certified seed has strict limits on maximum content of weed seeds and diseased kernels and must meet a minimum percent germination. This helps to ensure good germination and emergence and reduces weed and disease infestations. Rye is an open-pollinated crop, unlike most other small grains, which are self pollinated. This trait makes it very susceptible to attack from ergot fungus. If 2 distinct varieties are planted in close proximity to each other, cross pollination results. Cross-pollinated seed cannot be sold as either of the original seed varieties.

Close-up of a healthy head of rye in flower. Image from Wikimedia, taken by Rasbak in the Netherlands, Creative Commons CC BY-SA-3.0 license

Like barley, oats, and wheat, irrigation should begin again after the crop has reached about 50% emergence to avoid any problems with emergence from too hard of a crust on the surface. Thereafter, a good range of irrigation plus precipitation is around 0.5 to 1.0 inch per week. Irrigation should continue until the crop has reached the 50% headed growth stage.

Pest control in rye is the same as for other grains. Using IPM techniques, assess each field for all pests (weeds, diseases, and insects) and plan control measures accordingly. If weed populations have been determined to be high enough to cause a potential loss in yield or quality of the crop then the application of herbicides may be warranted. Weed control is a combination of mechanical and chemical summer fallow to reduce the number and species of weeds for the following season and an application of a post-emergence herbicide when needed as determined through IPM practices. The best broad-leaved weed control can be with broadleaf-selective herbicides Bromoxynil, MCPA, or Diglycolamine tank mixes or a 2,4-D amine, which are labeled for use on rye, applied when the rye is 4 to 6 inches tall (3- to 5-leaf growth stage), but before the boot stage. The best control of grassy weeds can be through a combination of mechanical and chemical summer fallow. To eliminate grassy weeds with chemical fallow, a broad-spectrum, nonselective, post-emergence herbicide such as glyphosate (Roundup) can be used. Ergot is controlled by planting clean seed in soil that has not shown signs of ergot for at least the previous 2 years. Ergoty rye can also be mown for forage or grazed before flowering occurs. The same insect pests that affect barley, oats, and wheat also affect rye. The most serious insect pests for rye are aphids (family Aphididae) and grasshoppers, including the lesser migratory grasshopper (*Melanoplus sanguinipes* Fabricias), the northern grasshopper (*Melanoplus borealis* Fieber), and the clear-winged grasshopper (*Camnula pellucida* Scudder). If insect population levels and damage have been determined to be too high through IPM practices, then the application of an insecticide may be warranted. Insecticide sprays or baits can help control heavy infestations if applied at the nymph growth stage. Always remember to read the pesticide label to be sure the crop is specified and follow the directions on mixing, application, and disposal. Contact your local Cooperative

Extension Service for more information on pest control (see Appendix 1 for addresses and contact information).

Rye is even later maturing than wheat, so the crop may still be in the fields when waterfowl begin fall migrations. Rye, however, is not preferred by waterfowl as a food source, especially if wheat or hulless barley are present nearby. When rye is the only crop in the field, using propane scare cannons designed to swivel in different directions and go off at uneven time intervals is recommended to keep migratory waterfowl away. Check with and inform the neighbors before setting up cannons.

Large ungulates like moose and bison can also cause some damage to the crop. However, rye is not a preferred food source if barley or oats are grown nearby. In the Delta Junction area, bison congregate in large herds that don't usually cause serious damage until their fall migrations north of the Alaska Highway. This migration occurs during the time when the grain is mature, ripe, and ready for harvest. They might not eat large portions of the crop, but a large herd walking through or bedding down in the field can flatten the crop into the ground, making harvest impossible. It is illegal to harass wildlife in Alaska so the only control is to erect large (6 feet or higher), stout, highly visible fencing that can direct the animals around the fields. For more information on wildlife control in agricultural fields, contact the local office of the Alaska Department of Fish and Game.

If the crop grown is intended for sale as seed for future planting, the fields should be inspected before harvest to ensure that the highest quality crop is being grown in order to meet the standards for certified seed (blue tag on the seed bag). The fields should be planted in clean ground and not in ground in which the same crop that is being certified was planted the previous year. There can be only 1 plant out of 1,000 of another rye variety as well as 1 plant out of 2,000 that is an inseparable crop like wheat seed and there are no objectionable weeds (prohibited or restricted noxious weeds). The seed lots after harvest should also be inspected to meet the certified seed standards. For more information about field and seed lot inspections, contact the local office of the state Division of Agriculture, Department of Natural Resources or the Alaska Seed Growers Association (see Appendix 1 for addresses and contact information).

As with wheat, rye stops growing when the seed reaches the hard dough stage (the kernels can't be dented when pressed with a thumbnail). The typical seed moisture content at this stage is 25% to 35%. Rye can be harvested at this moisture content, but significant losses in germination occur during storage. Rye seed must be around 2% to 13% moisture for safe, long-term storage. Higher moisture contents can germinate or mold the stored seed; lower moisture contents can damage the embryo, reducing germination ability. Both situations reduce the quality of the stored grain. Harvesting before or at the hard dough stage results in a fair amount of green, high-moisture heads. This underdeveloped grain is low in yield, test weights, and market value. Higher quality grain can be achieved when swathing or combining at the lowest moisture content. The same combine settings used for wheat should be used to harvest rye. When combining rye, reduce the front concave opening and cylinder speed for proper threshing and hull removal. This slows down the feeding rate. Increase the air flow to improve hull removal. Run augers at full capacity or slow them down to reduce embryo damage. Because food-grade seed allows only 4% cracked hulls, continual checking for hulls left on the seed or cracked seeds and adjusting combining methods is important. Due to rye's strong tendency to head shatter, waiting for the grain to field dry to 13% moisture can result in significant yield reductions. To reduce this, the grain should be harvested at a higher than optimal moisture content. This requires on-farm drying to get stored grain to 12% moisture. Spring rye can have deceptively high yields, because it is very late maturing and a large portion of the seed harvested can be immature, high in moisture, and not ripe.

Rye production has the same major drawbacks as wheat production. All rye varieties are late or very late maturing and they are lower yielding than wheat, and Alaska lacks a niche market where the producer can obtain a high price for the crop. For feed grade, no more than 15% of the hulls can remain without lowering the crop's value. For food grade no more than 5% of the hulls can remain. When harvesting rye, the hulls are easily removed during the combining process. Additional buffing of the seed to remove hulls can be done, if needed, before shipping to market. Food-grade rye can't contain more than 0.3% ergot-diseased kernels and 4% or less of other crops or foreign material. Any seed lot not meeting the higher food grades is purchased at the lower feed-grade prices and any seed lots with more than 0.5% ergot are rejected. On-farm cleaning and sizing of the seed lot to food-grade standards before shipment results in higher prices paid to the producer. Clean-outs can be used on farm or sold as feed grade. Ergot can be removed with air aspiration seed cleaners or infected seed can be soaked in a 20% salt water solution. Ergot floats to the top and can be skimmed off. The seed must then be washed in clean water and dried back to 12% moisture content before feeding or storage. Ergot sclerotia must be destroyed to prevent any further contamination in following years.

In Alaska there is even less of a market for rye than for wheat due to the difficulty in consistently producing a viable crop. However, there is an increased interest in producing rye for human consumption as whole grain and flour for sale in local markets. Although there are no large-scale mills in the state to process food-grade flour, there are a number of small-scale on-farm mills. There are no elevators currently set up to accept rye grain in Alaska. Rye is sold primarily as whole grain flour in local health food markets. Rye lacks the rough awns of barley straw and is suitable for animal bedding.

Similar to wheat, all commercial food-grade rye products, which include whole kernel grain and processed flour, are regulated and inspected by state and federal agencies before sale to the public. In Alaska, the Department of Environmental Conservation regulates and inspects commercial food-grade grain products under the Food Safety and Sanitation Program - Food Processors. More information can be obtained at the DEC website, http://dec.alaska.gov/commish/regulations/index.htm or contact your local DEC environmental health officer (see Appendix 1 for addresses and contact information).

Nationally, commercial food-grade grain products are regulated and inspected by the U.S. Food and Drug Administration (FDA) under the Good Manufacturing Practice (GMP) of Title 21 of the Federal Food, Drug and Cosmetic Act, part 110 - Sanitary conditions. More detailed information can be found in the FDA publication, "Guide to Inspections of Grain Product Manufacturers," located at the FDA website, www.fda.gov/.

Recommended Variety Descriptions for Spring Rye

Note: See Appendix 1 for the addresses of seed suppliers.

'Gazelle' is a late-maturing, tall, stiff-strawed, moderately high-yielding, spring rye released in 1974 from the plant breeding program of the University of Saskatchewan in Saskatoon. It was a selection out of a German strain. It is 2 to 3 weeks later in maturity than 'Ingal' hard red spring wheat, but on favorable years has out-yielded 'Ingal'. In Alaska, it is highly susceptible to ergot, with average contamination levels between 0.01% and 5.10%. This is an older variety so seed may be difficult to find. Direct inquiries about seed sources to the Canadian Seed Growers Association, Stock Seed Distribution Committee.

Winter Rye

Winter rye varieties are in the same species as spring rye (*Secale cereale* L.). Winter rye is generally better adapted than winter wheat to cold growing conditions. Fertilization rates, tillage practices, seeding depths, irrigation practices, weed and insect control, harvesting, cleaning, and storage are the same as for spring rye. Winter rye, like winter wheat, is usually planted in early fall. It produces a small, low rosette of vegetative growth that builds up root reserves before

'Berbral' winter rye on the left and 'Jerry' hard red winter wheat on the right at the Fairbanks Experiment Farm, spring 2011

undergoing winter dormancy. The next spring it produces an upright plant with a seed head similar in appearance to annual grains. The same problems encountered in Alaska for winter wheat production are also found for winter rye. Winter rye should be planted in late July to early August for harvest the following August or September. This leads to a 13-month growing season, compared to an annual grain crop that can be planted and harvested in around 3 to 4 months with an additional crop planted the following year. L.J. Klebesadel (1969) found in tests on winter rye varieties that long day length caused nonadapted varieties to grow more rapidly as seedlings; a low amount of root reserves were built up, resulting in a high rate of winter kill. When the snowpack blows or melts off the field, nonadapted varieties can be killed if the temperatures get low enough to cause freezing injury to the rosette. Winter humidity levels are quite low, causing sublimation from the top soil layers and plants into the snowpack and then into the atmosphere. This causes the rosettes to desiccate, in effect freeze-drying them. When moisture conditions under the snowpack are high enough, certain species of snowmold fungi, including white snowmold (*Sclerotinia borealis*) and pink snowmold (*Gerlachia nivalis*), can attack the plants and kill them. These snowmold fungi are present on the plant tissue before winter and only grow and spread in the spring when temperature and moisture conditions are right. Studies by F.J. Wooding and J.H. McBeath (1984) found that a low-cost organic fungicide like pentachloronitrobenzene (Terraclor) applied in the fall was effective against white snowmold, but not pink snowmold. The most important problem is the susceptibility of this crop to ergot (*Claviceps purpurea*) fungal disease and its difficulty to control. The best methods are the same as those for controlling ergot in spring rye.

Winter grains have been tested primarily in the Fairbanks and Delta Junction dryland areas. A couple of cultural methods to trap snow have been tested to increase the winter survival rate in the Delta Junction area. The first method was to plant through standing stubble. This required that the stubble (6 to 8 inches tall) from the previous year is not tilled under in the spring, that weeds were controlled by chemical fallow using a broad spectrum herbicide such as glyphosate (Roundup) through the summer, and that no-till fertilization and planting be used in the late summer. The second method was to plant in shallow furrows (2 to 4 inches deep) in fallow ground. Weed control during the summer was mechanical, fertilization could be broadcast and incorporated with tillage before planting or banded with the seed at planting, and furrows could be made by increasing the downward force on the row openers and packer wheels of the seed drill at planting. Both methods did work to trap more snow than regular fallow planted ground, but winter survival rates were still fairly low.

The Fairbanks site was the only location where winter

Berbral' winter rye at heading stage, June 9, 2011, Fairbanks Experiment Farm rye has had limited success, because the snow cover is generally not blown off of the fields. For the variety trial tests no fungicides to prevent snowmold were applied. The first few years of testing produced excellent results, with winter rye producing on average 70% higher yields than spring rye. However, long-term testing found little consistency in winter survival and poor yields resulted in years where winterkill was greatest. Spring rye generally produces higher and more consistent yields than winter rye; also the cost in time of 13 versus 3 to 4 months, the susceptibility to ergot and snowmolds, very late maturity, and the high probability of winterkill potentially reduce the economic viability of winter rye as a crop for most of Alaska. Due to these cultural problems, no varieties of winter rye are generally recommended. However, just because there was a crop failure for this study does not mean that it might not be able to be successfully grown somewhere within the state. Therefore, the reader is not discouraged from trying any of the winter rye varieties not recommended, but the probability of success in attempting to produce these crops will likely be low. On the other hand, if you live in an area where there is a guarantee of a consistent snow cover and a long, warm growing season (high cumulative GDD) like the Fairbanks area, then winter rye might be successfully grown. The winter rye variety listed below has produced consistent seed and forage yields at this location.

As mentioned previously, the Alaska market for rye is limited due to the difficulty in consistently producing a viable crop, especially for winter rye. However, there is an increased interest in producing rye for human consumption as whole grain and flour for sale in local markets. There are no large-scale, in-state mills to process food-grade flour and no elevator is set up to accept rye. A number of small-scale on-farm mills exist. Alaska rye is sold primarily as whole-grain kernels or as flour in local health food markets, which does command higher prices.

Recommended Variety Descriptions for Winter Rye

Note: See Appendix 1 for the addresses of seed suppliers.

'Bebral' is a late-maturing, very tall, stiff-strawed, high-yielding winter rye released in 1981 from the USDA-ARS plant breeding program at the Matanuska Experiment Farm. 'Bebral' is only 2 to 3 days later in maturity with yields slightly lower than or equal to 'Ingal' hard red spring wheat. Its tall plant height produces good forage yields with moderate lodging resistance. Direct inquiries about seed sources to the Alaska Seed Growers Association or the Alaska Plant Materials Center.

Spring Triticale

Triticale (X *Triticosecale* Whittmack) is a man-made true cereal grain crop, a cross between wheat (*Triticum*) and rye (*Secale*). Most of these crosses have been with durum wheat varieties. The crop was developed to combine the winter hardiness characteristics of rye with the bread making characteristics of wheat. Even though this crop has been around for more than 100 years, it is still in the experimental stages of development. Little acreage is grown in North America and only small areas for testing have been grown in Alaska. Like the rye varieties, triticale is very late maturing and highly susceptible to ergot. Triticale kernels are larger than those of wheat and have a higher lysine (sulfur-containing amino acid) content for improved nutrition. Triticale has higher seed yields and better drought resistance than wheat. It is highly resistant to head shatter and lodging.

The primary use of triticale is for bread flour. D.C. Church (1979) reports that the protein concentration of triticale is about that of hard red wheat (11% to 15%) but with a higher lysine content. Triticale, like rye, is very similar to wheat with very low crude fiber values of 2% to 4% and a total dry matter content of 80% to 90%. A secondary use is as a high-energy livestock feed. Triticale can be used as the only grain in poultry diets and has a similar value to a barley and wheat mixture in swine diets. Triticale is also used as an annual forage crop either

Triticale, a hybrid of wheat and rye developed in Scotland and Sweden more than 100 years ago and further refined over the last century, is still considered to be in its experimental stages. Photo by Markus Hagenlocher, from Wikimedia, CC BY-SA-3.0 license by itself or interseeded with legumes. It has about a 10% higher forage yield than either barley or oats. The quality of the forage ranks between that of barley and oats.

Fertilization, tillage practices, and seeding depths are identical with that of rye. Soils with moderate to high levels of available nutrients should receive a complete fertilizer blend of nitrogen, phosphorus, potassium, and sulfur at a ratio of 3:2:1:0.5 N, P_2O_5, K_2O, and S. With irrigated farming practices, the ratio should be reduced to about 1.5:1:0.5:0.25. Additionally, application rates of 0.5 to 1.0 pound per acre of boron can increase yields and improve disease resistance. Actual percentages of each nutrient and the application rate varies according to specific soil test results. The fertilizer can be broadcast before spring tillage or portions can be banded at planting. Avoid excess nitrogen fertilizer because it can induce lodging and delay maturity, especially if grown under irrigation.

To conserve soil moisture, minimum tillage is recommended for incorporating fertilizer material and plant residue and preparing the seedbed. Pulling a packer behind the tillage implement and using a seed drill equipped with press wheels ensure that the seed is in contact with moist soil during the time needed for germination. This is especially true if the crop is to be irrigated. The soil should be irrigated sufficiently to bring the soil moisture levels to close to the maximum water-holding capacity before tillage. It is very important not to irrigate above the maximum water-holding capacity before tillage and planting, as this could cause a soil crust to form on the surface that would impede seedling emergence, reduce plant density, and lower seed yields. Seeding depth and rate is the same as that for rye, 1.5 to 2.5 inches, or to moisture, and 90 to 100 pounds of pure live seed per acre used to reduce late tillering. The heavier seeding rates are recommended when triticale is grown for forage. Early planting dates are recommended to utilize as much of the short growing season as possible. Use of certified seed is strongly recommended. Certified seed has strict limits on maximum content of weed seeds and diseased kernels and must meet a minimum percent germination. This helps to ensure good germination and emergence and reduces weed and disease infestations.

Like rye, irrigation should begin again after the crop has reached about 50% emergence to avoid any problems with emergence from too hard of a crust on the surface. Thereafter, a good range of irrigation plus precipitation is around 0.5 to 1.0 inch per week. Irrigation should continue until the crop has reached the 50% headed growth stage.

Pest control in triticale is the same as for wheat and rye. Using IPM techniques, assess each field for all pests (weeds, diseases, and insects) and plan control measures accordingly. If weed populations have been determined to be high enough to cause a potential loss in yield or quality of the crop then the application of herbicides may be warranted. Weed control is a combination of mechanical and chemical summer fallow to reduce the number and species of weeds for the following season and an application of a post-emergence herbicide when needed as determined through IPM practices. The best broad-leaved weed control can be with broadleaf-selective herbicides Bromoxynil, MCPA, or Diglycolamine tank mixes or a 2,4-D amine which are labeled for use on triticale, applied when the triticale is 4 to 6 inches tall (3- to 5-leaf growth stage), but before the boot stage. To eliminate grassy weeds with chemical fallow, a broad-spectrum, nonselective, post-emergence herbicide such as glyphosate (Roundup) can be used. Ergot (*Claviceps purpurea*) is the most prevalent fungal disease that has been found on triticale in Alaska. The weather conditions best suited for ergot are warm, moist spring weather followed by warm, dry conditions during the flowering growth stage. Ergot forms on the plant during the flowering growth stage, later producing sclerotia when the plant matures. It can survive over winter in the soil and can infect plants grown in the following year. Control of ergot is by planting clean seed in soil that has not shown signs of ergot for at least the previous 2 years.

Variety trials at the Fairbanks Experiment Farm, summer 2005

As with rye, ergoty triticale can also be mown for forage or grazed before flowering occurs. The same insect pests that affect rye and wheat also affect triticale. The most serious insect pests are aphids (family Aphididae) and grasshoppers, including the lesser migratory grasshopper (*Melanoplus sanguinipes* Fabricias), the northern grasshopper (*Melanoplus borealis* Fieber), and the clear-winged grasshopper (*Camnula pellucida* Scudder). If insect population levels and damage have been determined to be too high through IPM practices, then the application of an insecticide may be warranted. Insecticide sprays or baits can help control heavy infestations if applied at the nymph growth stage. Always remember to read the pesticide label to be sure the crop is specified and follow the directions on mixing, application, and disposal. Contact your local Cooperative Extension Service for more information on pest control (see Appendix 1 for addresses and contact information).

Triticale, like rye, is even later maturing than wheat, so the crop may still be in the fields when waterfowl begin fall migrations. Triticale, like wheat, is preferred to rye by waterfowl as an energy source. Using propane scare cannons designed to swivel in different directions and go off at uneven time intervals is recommended to keep migratory waterfowl away. Check with and inform the neighbors before setting up cannons.

Large ungulates like moose and bison can also cause some damage to the crop. A single moose or a cow and calf pair usually don't cause much damage to large fields, but can wipe out small-scale plots over the summer. They are attracted to newly emerging plants and will keep coming back through maturity to graze. In the Delta Junction area, bison congregate in large herds that don't usually cause serious damage until their fall migrations north of the Alaska Highway. This migration occurs during the time when the grain is mature, ripe, and ready for harvest. They will not only eat large portions of the crop, but a large herd walking through or bedding down in the field can flatten the crop into the ground, making harvest impossible. It is illegal to harass wildlife in Alaska so the only control is to erect large (6 feet or higher), stout, highly visible fencing that can direct the animals around the fields. For more information on wildlife control in agricultural fields, contact the local office of the Alaska Department of Fish and Game.

Like wheat and rye, triticale stops growing when the seed reaches the hard dough stage (the kernels can't be dented when pressed with a thumbnail). The typical seed moisture content at this stage is 25% to 35%. Triticale can be harvested at this moisture content, but significant losses in germination occur during storage. The seed must be 12% to 13% moisture for safe, long-term storage. Higher moisture content can result in germination or molding of the stored seed, and lower moisture content can damage the embryo, reducing germination ability. Both situations reduce the quality of the stored grain. Harvesting before or at the hard dough stage results in a fair amount of green, high-moisture heads. This underdeveloped grain is low in yield, test weights, and market value. The highest quality grain can be achieved when swathing or combining at the lowest possible moisture content. Because triticale is resistant to head shatter and lodging, it can remain standing in the field until it reaches a low percent moisture and then be direct combined. If it is swathed, there is a high possibility of sprouting in the windrow. The same combine settings as for wheat should be used to harvest triticale. For proper threshing and hull removal when combining triticale, reduce the front concave opening and cylinder speed, which slows the feeding rate accordingly. Increase the air flow to improve hull removal. Run augers at full capacity or slow them down to reduce the embryo damage. Because food-grade seed can contain only 4% cracked hulls, continual checking for hulls left on the seed or cracked seeds and adjusting combining methods is important. Triticale can have deceptively high yields because it is very late maturing and a large portion of the seed harvested is immature and not ripe. On-farm drying of the seed is necessary to reduce the moisture content.

There are major drawbacks in Alaska triticale production. All varieties are late or very late maturing and an established niche market is required for the producer to obtain the highest crop price. For feed grade more than 15% of the hulls left on the kernels will lower the price paid to the producer. For food grades, no more than 5% of the hulls can be left on. When harvesting triticale, the hulls are not as easily removed during the combining process as they are for either wheat or rye. Additional buffing of the seed to remove hulls can be done, if needed, before shipping to market. Food-grade triticale can contain no more than 0.3% ergot-diseased kernels and 4% or less other crops or foreign material. Any seed lot not meeting the higher food grades is purchased at lower feed-grade prices and any seed lots with more than 0.5% ergot are rejected. On-farm cleaning and sizing of the seed lot to food-grade standards before shipment results in higher prices paid to the producer. Ergot can be removed using the same methods described for rye. Clean-outs can be used on farm or sold as feed grade.

Similar to rye, triticale has a limited market in Alaska due to the difficulty in consistently producing a viable crop. However, there is an increased interest in producing triticale for human consumption as whole grain and flour for sale in local markets. There are no large-scale mills in the state to process food-grade flour, although there are a number of small-scale, on-farm mills. Currently there are no elevators set up to accept triticale in Alaska. Triticale is sold primarily as whole grain flour in local health food markets, with secondary use as a forage crop. Like rye and wheat straw, triticale straw lacks the rough awns of barley straw and could be used for animal bedding.

Similar to rye, all commercial food-grade triticale products, which include whole-kernel grain and processed flour, are regulated and inspected by state and federal agencies before sale to the public. In Alaska, the Department of Environmental Conservation regulates and inspects commercial food-grade grain products under the Food Safety and Sanitation Program - Food Processors. More information can be obtained at the DEC website, http://dec.alaska.gov/commish/regulations/index.htm or contact your local DEC environmental health officer (see Appendix 1 for addresses and contact information).

Nationally, commercial food-grade grain products are regulated and inspected by the U.S. Food and Drug Administration (FDA) under the Good Manufacturing Practice (GMP) of Title 21 of the Federal Food, Drug and Cosmetic Act, part 110 - Sanitary conditions. More detailed information can be found in the FDA publication, "Guide to Inspections of Grain Product Manufacturers," located at the FDA website, www.fda.gov/.

Recommended Variety Descriptions for Spring Triticale

Note: See Appendix 1 for the addresses of seed suppliers.

'Carman' is a late-maturing, mid-tall, stiff-strawed, moderately high-yielding spring triticale released in 1980 from the Department of Plant Science of the University of Manitoba. It was a selection from a cross between a Canadian triticale line and a Mexican line. It is 2 to 3 weeks later in maturity than 'Ingal' hard red spring wheat but under favorable conditions can out-yield 'Ingal'. In Alaska it is susceptible to ergot, with average contamination levels between 0.01% and 0.91%. This variety has been deregistered and is now in the public domain. This is an older variety so seed sources may be difficult to obtain. Direct inquiries about seed sources to the SeCan Association or the University of Manitoba.

'Berbral' winter rye growing on the Fairbanks Experiment Farm, summer 2009, with Robert Van Veldhuizen standing in its midst. The rye's height is quite evident.

Winter Triticale

Winter triticale varieties are members of the same species as spring triticale (X *Triticosecale* Whittmack). Fertilization rates, tillage practices, seeding depths, irrigation practices, weed and insect control, harvesting, cleaning, and storage are the same as for spring wheat and rye. Winter triticale, like winter wheat and winter rye, is usually planted in early fall. It produces a small, low rosette of vegetative growth that builds up root reserves before winter dormancy. The next spring it assumes an upright growth form with a seed head similar in appearance to other annual grains. The same problems for producing winter rye exist for producing winter triticale. First there is a 13-month growing season rather than the 3- to 4-month season for an annual grain crop. Further, winter triticale, like all winter grains in Alaska, is susceptible to winterkill from freezing injury to the rosette, desiccation and freeze-drying of the rosette, and attacks of snowmold fungi, including white snowmold (*Sclerotinia borealis*) and pink snowmold (*Gerlachia nivalis*). Another important problem is the susceptibility of this crop to ergot (*Claviceps purpurea*) fungal disease and the difficulty of controlling it. These factors all detract from the economic viability of this crop in Alaska. Due to the lack of consistent success with other winter grains in Alaska, no winter triticale varieties were tested during this period. However, F.J. Wooding and others tested an experimental line of winter triticale ('6TA131') in the Fairbanks area before this study with no success. Due to these cultural problems, no varieties of winter triticale are generally recommended. However, just because there was a crop failure for this study does not mean that it might not be able to be successfully grown somewhere within the state. Therefore, the reader is not discouraged from trying any of the winter triticale varieties not recommended, but the probability of success in attempting to produce these crops will likely be low.

Yields and Quality by Location for Spring Rye, Winter Rye, and Triticale

Rye and triticale (spring and winter) are bought and sold by weight. Similar to other small grains, there is a standard test weight for both rye and triticale that is used as the legal unit for crop sales. This standard test weight for clean, dry, and undamaged rye and triticale is 56 pounds per bushel. Highest prices are paid to the producer for these niche crops when they meet the quality criteria mentioned previously. Other than test weights, additional on-farm samples should be taken to determine quality. Because seed lots not meeting food grade for either rye or triticale should be used as feed grade, it is important for the producer to clean and size all seed lots before delivery to a niche market. Test weights can differ between cultivars and can change within a single cultivar, depending on cultural practices, weather conditions, and location where grown. Test weight is used here as a measure of grain quality to determine maturity. Yields are expressed here in pounds per acre and bushels per acre. Determine bushels per acre by dividing the yield of any specific cultivar by the standard test weight.

Tables 48 and 50 list yields and quality measurements for rye and triticale varieties for 2 test locations: Fairbanks and Delta Junction. All sites in the Delta Junction area have been combined into the Delta dryland site (Table 50). There were no irrigation studies done for either spring or winter rye or triticale. Each table also contains information on grain type (spring or winter), the source or the location of where it was bred, and the years it was tested at each location. Maturity in this study was defined as when 50% of the heads for each plot were at the hard dough stage (light yellow heads and kernels that did not dent when pressed with a thumbnail).

Growing degree days (GDD) for average maturity were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. The low temperature point for both rye and triticale in this report is the freezing point of water, 32°F. The GDD calculations for each day were then added to the preceding GDD value to determine the cumulative value to the date at which the specific variety had reached 50% maturity. For winter rye and triticale varieties, the cumulative GDD values were based on an average of 375 days after planting. This includes the GDD from planting to freezeup in the fall and from greenup to maturity the following season. All varieties were compared with 'Ingal' hard red spring wheat as the standard variety. Yield as a percent of the standard variety 'Ingal' was determined by dividing the average yield of each variety by the average yield of 'Ingal'. Maturity vs. Std. (Standard variety) is the number of days each variety reached 50% maturity either before or after the number of days that 'Ingal' reached 50% maturity. Biomass yields are given, on a dry weight basis, for 'Bebral' winter rye as a measure of forage production. This information was collected when the plants were at the soft dough stage for whole plant forage production as animal feed.

Tables 49 and 51 list the animal feed quality analysis for 'Bebral' winter rye forage, on a dry weight basis, for the Fairbanks and Delta Junction dryland test locations. It is presented here without statistical differences and solely for the reader's benefit. More detailed information and explanation about the industry standards for feed and food-grade rye and triticale that follow can be obtained from D.C. Church (1979) and J.H. Martin and others (1976). Detailed explanation of the feed analysis that follows as well as laboratory procedures can be obtained from J. Schroeder (1994) and G.J. Michaelson and others (1987). As with the yield tables, all sites in the Delta Junction area have been combined together.

Percent crude protein is calculated from the total percent nitrogen analysis of the seed multiplied by a constant of 6.25. Crude protein is made up of amino acids, which are 16% nitrogen, as well as other, non-protein portions of the plant, and so percent crude protein is not a measure of true protein. Industry standards for food-grade rye are between 10% and 14%, and for triticale 11-15% crude protein. Higher values have greater nutritional food value, but too high a value (>14% for rye and >15% for triticale) is an indicator of immature green seed which makes a lower quality grade flour because it turns rancid quicker. Industry standards for forage rye are 12% to 18% crude protein. In a standard feed analysis, other major nutrient mineral concentrations commonly measured are percent phosphorus (%P), potassium (%K), and calcium (%Ca).

Percent neutral detergent fiber (%NDF) is a measure of the percentage of partially digestible plant material (lignin, hemicellulose, and cellulose). Lower levels of NDF usually result in a higher animal intake of the feed. It is also used to calculate the dry matter intake (DMI), where DMI = 120 ÷ %NDF. This value is later used to determine the relative feed value.

Percent acid detergent fiber (%ADF) is a measure of the highly indigestible plant material (lignin and cellulose). Higher levels of ADF usually indicate a low digestibility of the plant material. It is also used to calculate the digestible dry matter (DDM), where DDM = 88.9 - (0.779 x %ADF). This value is also later used to determine the relative feed value.

The percent in vitro dry matter digestibility (%IVDMD) is a laboratory simulation of plant material digestibility in a rumen of a cow. A known weight of plant material is digested in a simulated rumen for a given period of time. After digestion is complete, the residue that is left is weighed and the difference is the estimated percentage of the plant material that is potentially digestible or a measure of potential metabolizable energy.

The relative feed value (RFV) is a unitless index that combines the nutritional factors of the dry matter intake and the digestible dry matter of the plant material, where RFV = (DDM x DMI)/1.29. Plant material with an ADF of 41% and a NDF of 53% has a RFV of 100. All other plant material is compared to this value. Lower ADF and NDF values will cause the RFV to increase. The higher the RFV, the lower the overall quality of the feed.

Table 48. Average yields and quality measurements for all spring rye, winter rye, and triticale varieties from test plots in the Fairbanks area.

Rye & Triticale Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test Weight (lbs/bu)	Biomass Yield (lbs/acre)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Rye, spring											
Gazelle	Saskatchewan	3	5208	93	194	55	N/D	0	21-Aug	21	2769
Karlshulder	Germany	1	0	0	0	0	N/D	0	21-Aug	21	2769
Norwegian	Norway	1	1867	33	69	51	N/D	0	21-Aug	21	2769
Petkusser	Germany	1	0	0	0	0	N/D	0	21-Aug	21	2769
Prolific	Canada	5	2599	46	97	52	N/D	0	21-Aug	21	2769
Rye, winter											
Bebral	Alaska	4	2487	41	93	46	4046	38	2-Aug	2	3474
Jussi	Finland	1	28	1	1	49	N/D	0	21-Aug	21	3854
Saskatoon	Saskatchewan	5	674	12	25	56	N/D	0	21-Aug	21	3854
Triticale, spring											
Carman	Manitoba	1	6024	108	224	50	N/D	0	21-Aug	21	2769
Welsh	Manitoba	2	3823	68	142	46	N/D	0	21-Aug	21	2769

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Winter rye GDD are based on an average of 375 days after planting. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. N/D = No Data. All varieties were compared with 'Ingal' hard red spring wheat as the standard variety.

Table 49. Average quality forage measurements for 'Bebral' winter rye from test plots in the Fairbanks area.

Rye Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)	Total Ca (%)	NDF (%)	ADF (%)	IVDMD (%)	Relative Feed Value
Forage Industry Standards			12-18%	0.3-0.5%	0.4-0.6%	0.05-0.1%	51-65%	32-42%	>45%	<116
Rye, winter										
Bebral	Alaska	4	17.52	0.32	0.35	0.06	34.82	45.29	89	143

Forage analysis done on whole plant biomass at soft dough stage.

Table 50. Average yields and quality measurements for all spring rye, winter rye, and triticale varieties from test plots in the Delta Junction area, dryland.

Rye & Triticale Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test Weight (lbs/bu)	Biomass Yield (lbs/acre)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Rye, spring											
Gazelle	Saskatchewan	3	1703	30	110	49	N/D	0	23-Aug	15	2585
Norwegian	Norway	1	2769	49	180	48	N/D	0	23-Aug	15	2585
Prolific	Canada	2	873	16	57	37	N/D	0	23-Aug	15	2585
Rye, winter											
Bebral	Alaska	3	0	0	0	0	3678	15	21-Aug	13	3384
Triticale, spring											
Carman	Manitoba	1	3091	55	200	39	N/D	0	23-Aug	15	2585
Welsh	Manitoba	2	2134	38	138	40	N/D	0	23-Aug	15	2585

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Winter rye GDD are based on an average of 375 days after planting. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. N/D = No Data. All varieties were compared with 'Ingal' hard red spring wheat as the standard variety.

Table 51. Average forage quality measurements for 'Bebral' winter rye from test plots in the Delta Junction area, dryland.

Rye Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)	Total Ca (%)	NDF (%)	ADF (%)	IVDMD (%)	Relative Feed Value
Forage Industry Standards			12-18%	0.3-0.5%	0.4-0.6%	0.05-0.1%	51-65%	32-42%	>45%	<116
Rye, winter										
Bebral	Alaska	3	15.50	0.31	0.45	0.06	34.36	48.91	83	138

Forage analysis done on whole plant biomass at soft dough stage.

Wild Rice

Spring Wild Rice

Wild rice (*Zizania aquatica* L.) has been evaluated as a true cereal grain crop several times in a number of locations throughout interior Alaska. G.H. Whiting and others (1978) and D. Smith (1995) have reported yields from trials that have been low and inconsistent. Wild rice is found only as far north as Canada's Lake Winnipeg. Wild rice can grow in shallow, clear, nonturbid water from 6 inches to 4 feet deep but does the best at 2 feet. It requires the presence of a slow-moving current, doing best along shallow lake shores where inlets or outlets of small streams are present. Wild rice should be broadcast seeded into shallow water on saturated, fine-textured silt at rates of 20 to 30 pounds per acre, depending on variety and growth habit. Use of certified seed is strongly recommended. Certified seed has strict limits on maximum content of weed and diseased seeds and must meet a minimum percent germination. This helps to ensure good germination and emergence and reduces weed and disease infestations. Germination requires water temperature of around 45°F and full sunlight. Turbidity, floating weeds, or trash that filter available sunlight limits its growth. After germination, the first leaves to emerge need shallow water to float beneath the surface. Subsequent leaves eventually reach the surface to float on top of the water. If water is too shallow during this time, the first leaves may dry out; if it is too deep, the secondary leaves may not reach the surface to float. In both cases the plants die. As the stems develop, new leaves eventually stand upright above the water. Wild rice can grow 3 to 11 feet tall. At the top of the plant, the female flowers (eventual grain) are on a spike above the spikelets of the male flowers. Cross pollination is necessary for grain development. The grain matures from the top of the plant down and shatters easily, making multiple harvests necessary. This also facilitates reseeding, because not all of the seed can be harvested efficiently. Traditional harvest methods consist of knocking the seed heads with a stick or boat paddle so the seed shatters out into the bottom of a boat where it can then be collected. Seed that is kept for planting the following year must be kept constantly moist and at 34°F for 180 days to break dormancy. At no time must this seed be allowed to dry to below 27% moisture before planting or be allowed to freeze because the embryo can be killed. Processing seed for food use must be done quickly after harvest, because green seed can spoil rapidly. This seed must be dried, dehulled, and cleaned before sale as food-grade wild rice.

There are many problems associated with production of wild rice in Alaska. There are very few privately owned small lakes or ponds in which to raise this crop and introduction of this non-native plant into state-owned lakes or ponds is prohibited by numerous state and federal resource agencies. The Alaska environment is also not well-suited for wild rice production. The water is slow to reach the optimum germination temperatures, often not reaching 45°F until midsummer. This shortens the growing season available to a crop that requires a fairly long one to ripen. Wild rice does not compete well with native aquatic plants, such as pond lilies, that can out-compete germinating seedlings. Migratory waterfowl such as ducks and Canada geese eat seeds and germinating seedlings, while moose and muskrat eat whatever plants manage to survive the waterfowl. Producing this crop is labor intensive, and it is difficult to grow commercially. A small niche market in Alaska for wild rice commands a high price paid to producers. It is usually sold in small quantities in health food stores or grocery chains. However, due to the high cost of production and the unlikelihood of consistently producing a large-quantity, high-value crop (even in artificial paddies) wild rice is not an economically viable crop for Alaska. Due to these cultural problems, no varieties of wild rice are recommended. However, just because there was a crop failure of a specific variety does not mean that it might not be able to be successfully grown somewhere within the state. Therefore, the reader is not discouraged from trying any of the crops or varieties not recommended, but the probability of success in attempting to produce those crops or varieties will likely be low.

Yields and Quality by Location for Wild Rice

Tables 52-54 list yields and quality measurements for wild rice varieties for 3 test locations: Fairbanks, Eielson, and Delta Junction. Plots were planted in artificial paddies, private gravel pits, and nearby small lakes. Each table also contains information on the source or the location where it was bred and the years it was tested at each location. Maturity in this study was defined as when 50% of the heads for each plot were at the hard dough stage (the seeds were a dark green or dark brown in color and did not dent when pressed with a thumbnail). Growing degree days (GDD) for average maturity were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. The low temperature point for wild rice in this report is the freezing point of water, 32°F. The GDD calculations for each day were then added to the preceding GDD value to determine the date at which the specific variety had reached 50% maturity. Only 1 variety of wild rice ('Franklin' from Minnesota) reached maturity, in an artificial paddy at the Fairbanks site. No yields were taken as the crop was consumed by local wildlife before a harvest could be attempted. D. Smith (1995) reported that another unnamed variety from the ecoregion of La Ronge, Saskatchewan, reached maturity in local gravel pits and small lakes near Fort Yukon and managed to reseed itself for at least 3 years. However, it too had a lot of predation by muskrats and no significant yield data was collected. Attempts to grow wild rice from the same ecoregion in a private gravel pit at the Eielson site were of little success as no plants reached maturity. Because there are no standard varieties for wild rice in Alaska, there were no comparisons other than among varieties. Wild rice is cross-pollinated, so any 2 specific varieties planted in close proximity would produce hybrid seed, which then could not be sold as either of the parent varieties. Therefore, in recent years wild rice seed has been sold from an "ecoregion" rather than as a specific named variety. Any attempt at producing wild rice in Alaska should use seed ordered from an ecoregion that is from latitudes and under climatic conditions as similar as possible to the area being planted.

Table 52. Average yields and quality measurements for all wild rice varieties from test plots in the Fairbanks area.

Wild Rice Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Lodging (%)	Average Maturity Date	Average Maturity (GDD)*
Food grade						
Canadian K	Saskatchewan	1	0	0	N/D	N/D
Franklin	Minnesota	2	0	0	21-Sep	3272
K2	Minnesota	1	0	0	N/D	N/D
M1	Minnesota	1	0	0	N/D	N/D

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature; N/D = No Data.

Table 53. Average yields and quality measurements for all wild rice varieties from test plots in the Eielson area.

Wild Rice Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Lodging (%)	Average Maturity Date	Average Maturity (GDD)*
Ecoregion, food grade						
La Ronge	Saskatchewan	1	0	0	N/D	N/D

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature; N/D = No Data.

Table 54. Average yields and quality measurements for all wild rice varieties from test plots in the Delta Junction area.

Wild Rice Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Lodging (%)	Average Maturity Date	Average Maturity (GDD)*
Food grade						
Canadian K	Saskatchewan	1	0	0	N/D	N/D
Franklin	Minnesota	1	0	0	N/D	N/D
K2	Minnesota	1	0	0	N/D	N/D
M1	Minnesota	1	0	0	N/D	N/D

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature; N/D = No Data.

Canarygrass

Birdseed Annual Canarygrass

*Closeup of seeds of annual canarygrass (*Phalaris canariensis *L.), with and without hulls. Photo by Steve Hurst of the ARS Systematic Botany and Mycology Laboratory at the USDA-NRCS PLANTS Database.*

Annual canarygrass or canaryseed (*Phalaris canariensis* L.) is a relatively new non-grain niche crop for Alaska. It is a major portion of commercial feed mixes for caged and wild birds. Other portions of typical bird feed mix include proso millet, safflower, sunflower, flax, and canola. Each of these other seed portions are discussed individually in separate sections in this publication.

Annual canarygrass should not be confused with a close relative, reed canarygrass (*Phalaris arundinacea* L.). Reed canarygrass is a perennial forage grass and is much taller (2 to 8 feet) with broad leaves; the seed heads are little spikelets 2 to 8 inches long and contain several quite small seeds. Annual canarygrass, on the other hand, is an annual grass that grows 2 to 3 feet tall. It has fine, narrow leaves that are purple or red at the base of the stem. The stems are tough and wiry and can be difficult to combine unless they are fully mature. If harvested before maturity, they can wrap up in the pick-up reels, the feed augers, and the cylinders, reducing threshing efficiency and possibly even necessitating shutting down the combine to clean out plant residues. The seed heads are small and dense, about 1.5 to 2 inches long. These seed heads remain on the stem after threshing and the seed does not shatter out of the heads when mature. The seed is small and similar in size and shape to flax seed. The hulls, which should be left on for birdseed, are shiny and golden yellow in color.

Dehulled seed is a dark reddish-brown. According to E.M. Abdel-Aal and others (1997), dehulled canarygrass seed averages 18.7% crude protein. This is a higher protein content than wheat but lower in content of the essential amino acid lysine. It is also very high in crude fat (8.7%), with the following averages of mono- and polyunsaturated essential fatty acids: 11% palmitic acid, 29% oleic, an omega-9 fatty acid; 55% linoleic, an omega-6 fatty acid; and 2.5% linolenic, an omega-3 fatty acid. These qualities make canarygrass seed a high-protein, high-energy birdseed. There are small sharp silica hairs at the base of the seed. Dust produced during combining and processing the seed can irritate the skin and respiratory system. Gloves and dust masks should be worn when handling this crop. New varieties without silicacious, irritating seed have been developed in Canada. They have higher test weights but lower yields. They are called "itchless" or "glabrous" varieties and are marketed under the term Canario.

Fertilization, tillage practices, and seeding depths are similar to small grains. However, canarygrass is regularly lower yielding than small grains (average yields are around 800 pounds per acre) and so requires lower levels of available nitrogen. Soils with moderate to low levels of available nutrients should receive a complete fertilizer blend of nitrogen, phosphorus, potassium, and sulfur at a ratio of 1.5:1:0.5:0.25 N, P_2O_5, K_2O, and S. With irrigated farming practices, the ratio should be reduced to about 0.75:0.5:0.25:0.13. Additionally, an application of or boron at 0.5 pound per acre can increase yields and improve disease resistance. Actual percentages of each nutrient and the application rate vary according to specific soil test results. The fertilizer can be broadcast before spring tillage or portions can be banded at planting. Care should be taken when banding nitrogen carriers with the seed because canarygrass seed has a low tolerance to placement with nitrogen fertilizers. Avoid excess nitrogen fertilizer, especially if the crop is grown under irrigation, because it can induce lodging and delay maturity.

To conserve soil moisture, minimum tillage is recommended for incorporating fertilizer material and plant residue and preparing the seedbed. Pulling a packer behind the tillage implement and using a seed drill equipped with press wheels ensures that the seed is in contact with moist soil during the time needed for germination. This is especially true if the crop is to be irrigated. The soil should be irrigated sufficiently to bring the soil moisture levels to close to the maximum water-holding capacity before tillage. It is very important not to irrigate above the maximum water-holding capacity before tillage and planting as this could cause a soil crust to form on the surface that would impede seedling emergence, reduce plant density, and lower seed yields. Seeding depth is the same as that for small grains, 1.5 to 2.5 inches, or to moisture. Seeding rate is 25 to 35 pounds of pure live seed per acre. Because canarygrass tillers profusely, the higher rate should be used to reduce late tillering. Early planting dates are recommended to utilize as much of the short growing season as possible and get the straw as mature as possible before harvest. Use of certified seed is strongly recommended. Certified seed has strict limits on maximum content of weed seeds and diseased seeds and must meet a minimum percent germination. This helps to ensure good germination and emergence and reduces weed and disease infestations.

As with small grains, irrigation should begin again after the crop has reached about 50% emergence to avoid any problems with emergence from too hard of a crust on the surface. Thereafter, a good range of irrigation plus precipitation is around 0.5 to 1.0 inch per week. Irrigation should continue until the crop has reached the 50% headed growth stage.

Pest control in canarygrass is the same as for small grains. Using IPM techniques, assess each field for all pests (weeds, diseases, and insects) and plan control measures accordingly. If weed populations have been determined to be high enough to cause a potential loss in yield or quality of the crop, then the application of herbicides may be warranted. Weed control is a combination of mechanical and chemical summer fallow to reduce the number and species of weeds for the following year and an application of a post-emergence herbicide when needed as determined through IPM practices. The best broad-leaved weed control can be with broadleaf-selective herbicides with Bromoxynil and MCPA tank mixes, which are labeled for use on annual canarygrass, applied when the canarygrass is 4 to 6 inches tall (3- to 5-leaf growth stage), but before the boot stage. R. McVicar and others (2000) found that in Canada a 2,4-D ester formulation can cause stunted, irregular growth and reduced yields and should be avoided. Pennsylvania smartweed (*Polygonum pensylvanicum* L.) and volunteer flax both have seed similar to canarygrass in size, shape, and weight, making them difficult to clean out. Seed lots containing these weed seeds are rejected by purchasers. Planting in clean ground helps to control these weeds. To eliminate grassy weeds with chemical fallow, a broad-spectrum, nonselective, post-emergence herbicide such as glyphosate (Roundup) can be used. No serious diseases have yet been found on canarygrass in Alaska. The same insect pests that affect small grains also affect canarygrass. The most serious insect pests are aphids (family Aphididae) and grasshoppers, including the lesser migratory grasshopper (*Melanoplus sanguinipes* Fabricias), the northern grasshopper (*Melanoplus borealis* Fieber), and the clear-winged grasshopper (*Camnula pellucida* Scudder). If insect population levels and damage have been determined to be too high through IPM practices, then the application of an insecticide may be warranted. Insecticide sprays or baits can help to control heavy infestations if applied at the nymph growth stage. Always remember to read the pesticide label to be sure the crop is specified and follow the directions on mixing, application, and disposal. Contact your local Cooperative Extension Service for more information on pest control (see Appendix 1 for addresses and contact information).

Annual canarygrass is grown specifically for use as birdseed and is later maturing than most small grains, so the crop may still be in the fields when waterfowl migration begins. Because waterfowl have difficulty removing canarygrass seed from the seed heads, large flocks can cause serious lodging while trying to get at the seed. Using a propane scare cannon designed to swivel in different directions and go off at uneven time intervals is recommended to keep migratory waterfowl away. Check with and inform the neighbors before setting up cannons. For more information on wildlife control in agricultural fields, contact the local office of the Alaska Department of Fish and Game.

Similar to small grains, canarygrass stops growing when the seed reaches the hard dough stage (the kernels can't be dented when pressed with a thumbnail). Canarygrass seed must be around 13% moisture for safe, long-term storage. Higher moisture contents can germinate or mold the stored seed and lower moisture contents can damage the embryo, reducing germination ability. Both situations reduce the quality of the stored seed. The highest quality seed can be achieved when swathing or combining at the lowest moisture content. The same combine settings used to harvest small grains should be used to harvest canarygrass. Cylinder speeds need to be reduced for proper threshing. This slows down the feeding rate accordingly. Airflow settings should be reduced because of the smaller seed size to settings similar to those for flax. Run augers at full capacity or slow them down to reduce the potential of dehulling the seed. Continual checking for hulls left on the seed or cracked seeds and adjusting combining methods is important as birdseed acceptance standards allow only 4% hulled seed. Because of the small seed size, all cracks and holes in the combine, augers, trucks, and bins should be sealed to prevent seed loss during handling. Canarygrass does not head shatter so combine operations can wait for the seed to field dry to 13% moisture. This also allows the straw to reach full maturity for easier harvesting. Swathing can be used as the seed continues to dry in the windrow. However, do not swath unless the straw is mature. Green straw, even though dry, is still tough and wiry, impeding the combining process. Birdseed quality standards for canarygrass do not allow for any more than 4% dehulled seed, other crops, or foreign material. Any seed lot not meeting the higher birdseed grades are purchased at lower feed prices. Optimum moisture content for safe, long-term storage of annual canarygrass is 10% to 12%. Typical grain dryers have perforated floor openings that are too large for the small seeds. A 5-mesh nylon sheet over the floor prevents seed loss. On-farm cleaning and sizing of the seed lot to birdseed standards before shipment results in higher prices paid to the producer. Clean-outs can be used on farm or sold as lower-grade seed.

At present, there are no birdseed processing facilities in Alaska nor are there any elevators set up to accept canarygrass seed. There is, however, a large niche market of imported, pre-packaged birdseed sold for both wild and caged birds. This imported seed is sold as either pure or mixed seed blends in feed stores to grocery stores throughout Alaska. Because of the difficulty of producing, handling, and marketing a consistently high-quality canarygrass seed product in Alaska, there is only a limited amount of acreage presently grown and sold on farm to consumers.

Recommended Variety Descriptions for Annual Canarygrass

Note: See Appendix 1 for the addresses of seed suppliers.

'Elias' is an early-maturing, mid-tall, high-yielding annual canarygrass developed at the Minnesota Agricultural Experiment Station in St. Paul in 1983 and registered by the Crop Development Centre at the University of Saskatchewan in Saskatoon in 1988. 'Elias' has a large seed head and long straw, making it susceptible to lodging. Test weights are usually higher than the standard test weight for canarygrass seed. Average crude protein level for Alaska-produced seed is 17.3%. This variety has been deregistered and is now in the public domain. Direct inquiries about seed sources to the Crop Development Centre at the University of Saskatchewan in Saskatoon.

Yields and Quality by Location for Annual Canarygrass

Canarygrass seed, like all birdseed, is bought and sold by weight. Similar to small grains, there is a standard test weight for canarygrass that is used as the legal unit for purchase or sale of the crop. This standard test weight for clean, dry, and undamaged canarygrass is 50 pounds per bushel. Highest prices are paid to the producer for these niche crops, but only if they meet the quality criteria mentioned previously. Besides test weights, additional on-farm samples should be taken to determine quality. Any seed lots not meeting high-quality birdseed standards should be used as lower feed grades. It is important, then, for the producer to clean and size all seed lots before delivery to a niche market. Test weights are used here as a measure of seed quality to determine maturity. Yields are expressed here in pounds per acre and bushels per acre. Determine bushels per acre by dividing the yield of any specific cultivar by the standard test weight.

Tables 55, 57, and 59 list yields and quality measurements for 1 canarygrass variety for 3 test locations: Fairbanks, Eielson, and Delta Junction. All sites in the Delta Junction area have been combined into the Delta dryland site (Table 59). There were no irrigation studies done with canarygrass. Each table also contains information on the source or the location of where it was bred and the years it was tested at each location. Maturity in this study was considered to be when 50% of the heads

Annual canarygrass growing at the Oslo Botanical Garden, Norway, September 2009. Public domain photo from Wikimedia, taken by contributor Daderot.

for each plot were at the hard dough stage. The seed, with hulls, were a golden yellow in color and did not dent when pressed with a thumbnail. Growing degree days (GDD) for average maturity were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. The low temperature point for canarygrass in this report is the freezing point of water, 32°F. The GDD calculations for each day were then added to the preceding GDD value to determine the date at which the specific variety had reached 50% maturity. As there was only 1 variety tested, there was no standard variety with which to compare results.

Tables 56, 58, and 60 list the animal feed quality analysis for 'Elias' canarygrass seed for the Fairbanks, Eielson, and Delta Junction dryland test locations. It is presented here without statistical differences and solely for the reader's benefit. More detailed information and explanation about the industry standards for birdseed-grade canarygrass that follow can be obtained from E.M. Abdel-Aal and others (1997) and McVicar and others (2002). Detailed explanation of the feed analysis that follow as well as laboratory procedures can be obtained from J. Schroeder (1994) and G.J. Michaelson and others (1987). As with the yield tables, all sites in the Delta Junction area have been combined together.

Percent crude protein is calculated from the total percent nitrogen analysis of the seed multiplied by a constant of 6.25. Crude protein is made up of amino acids, which are 16% nitrogen as well as other, non-protein portions of the plant, and so percent crude protein is not a measure of true protein. Industry standards for canarygrass are between 15% and 20%. Higher values have greater nutritional food value, but too high a value (>20%) is an indicator of immature green seed, which makes a lower-quality birdseed because it turns rancid quicker. In a standard feed analysis, other major nutrient mineral concentrations commonly measured are percent phosphorus (%P) and potassium (%K).

Table 55. Average yields and quality measurements for 'Elias' annual canarygrass from test plots in the Fairbanks area.

Canarygrass Variety Name	Source	YearsTested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Test Weight (lbs/bu)	Lodging (%)	Average Maturity Date	Average Maturity (GDD)*
Birdseed, spring								
Elias	Minnesota	3	641	13	47	20	1-Sep	2980

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature.

Table 56. Average quality measurements for 'Elias' annual canarygrass from test plots in the Fairbanks area.

Canarygrass Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)
Birdseed Industry Standards			**15-20%**	**0.4-0.6%**	**0.4-0.6%**
Birdseed, spring					
Elias	Minnesota	3	19.5	0.54	0.57

Analysis done on whole ripe seed.

Table 57. Average yields and quality measurements for 'Elias' annual canarygrass from test plots in the Eielson area.

Canarygrass Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Test Weight (lbs/bu)	Lodging (%)	Average Maturity Date	Average Maturity (GDD)*
Birdseed, spring								
Elias	Minnesota	3	584	12	47	20	10-Sep	3139

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature.

Table 58. Average quality measurements for 'Elias' annual canarygrass from test plots in the Eielson area.

Canarygrass Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)
Birdseed Industry Standards			**15-20%**	**0.4-0.6%**	**0.4-0.6%**
Birdseed, spring					
Elias	Minnesota	3	17.38	0.54	0.47

Analysis done on whole ripe seed.

Table 59. Average yields and quality measurements for 'Elias' annual canarygrass from test plots in the Delta Junction area, dryland.

Canarygrass Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Test Weight (lbs/bu)	Lodging (%)	Average Maturity Date	Average Maturity (GDD)*
Birdseed, spring								
Elias	Minnesota	3	208	4	47	20	2-Sep	2760

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature.

Table 60. Average quality measurements for 'Elias' annual canarygrass from test plots in the Delta Junction area, dryland.

Canarygrass Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)
Birdseed Industry Standards			**15-20%**	**0.4-0.6%**	**0.4-0.6%**
Birdseed, spring					
Elias	Minnesota	3	15.56	0.55	0.49

Analysis done on whole ripe seed.

Millet

Proso, Foxtail, and Japanese Millet

Millet is an annual true cereal grain that matures in 60 to 80 days for most cultivated varieties. Millets should not be confused with annual grain sorghum or milo [*Sorghum bicolor*], which requires a much longer and warmer growing season to mature. Sorghum is efficient at using soil moisture due to its shallow but widespread root system and can produce a crop under drought conditions when most small grains can't. For these reasons, it was tried in Alaska. Unfortunately, it does not germinate when soil temperatures are below 65°F and can be easily killed by light frosts at any time during the growing season.

Millet is used primarily as a portion of commercial feed mixes for caged and wild birds. For the birdseed markets, hulls must be left on, with no more than 4% of the hulls removed. Reddish, plump-seeded varieties are in highest demand by the birdseed markets. Millet is also ground for use as a livestock feed, although it only has 90% to 95% of the feed value of barley. Millet is one of the oldest cultivated cereal grain crops that have been used for human food, primarily as a finely ground flour product. According to E.A. Oelke and others (1990) millet has about 10-13% crude protein, 8% fiber, and 80% to 90% dry matter. However, only 40% of the protein is digestible by nonruminants, making it less nutritious than small grains. If harvested before or at the flowering stage, some varieties can produce a high-quality forage crop. The forage will range between 12% and 20% crude protein. However, all millet types are considered nitrate accumulators. If the fertilization rate for nitrogen is too high or there are droughty growing conditions then nitrates can build up in the plant tissue. Millet with levels of 0.44% or higher can cause growth and health problems if fed to livestock.

Proso Millet

Proso millet (*Panicum miliaceum* L.) has a coarse, hollow stem about 2 feet high and is similiar in diameter to a pencil. The stem and leaves are covered with fine hairs that reduce its palatability as a forage crop, especially when harvested after the flowering growth stage. Because the fine hairs on the plant are an irritant and can cause lump jaw and sore eyes in cattle, millet is considered a weed in eastern Canada. Seed heads are about 5 inches long and consist of many spikelets. They are grouped into varieties based on the shape of the seed head: spreading, loose or one-sided, and compact. Seeds do not mature simultaneously within the seed head and plants are prone to head shatter when ripe. The hulls remain on the seed after threshing and are colored various shades of white, yellow, red, gray, and black. The seed coat is creamy white after the hulls have been removed.

*Closeup of a ripe seed head of proso millet (*Panicum miliaceum *L.). Millet has been grown by humans for about 7,000 years. Photo from Wikimedia, taken by Kurt Stüber, CC-BY-SA 3.0*

Foxtail Millet

Foxtail millet (*Setaria italica* (L.) Beauv.) has slender, erect leafy stems and grows from 1 to 5 feet tall, depending on variety. Foxtail millet can make a high-quality forage crop when it is harvested before heading. If it is to be fed to horses, timing of the forage harvest is critical for hay quality. If cut too early, it can have a laxative effect; if cut too late, glucosides called setarian can build up in the plant tissue, causing a diuretic effect. Seed head length varies from 6 inches to well over 1.5 feet, depending on variety. The head consists of many compressed spikelets held close to the main stem. Seeds do not mature simultaneously within the seed head and plants are prone to head shatter when ripe. The hulls remain on the seed after threshing and are colored various shades of white, yellow, orange, red-orange, green, and dark purple.

Japanese or Barnyard Millet

Japanese or barnyard millet (*Echinochloa frumentacea* W.F. Wright) is a slender plant with a thick and leafy stem that grows 2 to 4 feet tall. If used as a forage crop, it can be difficult to cure effectively because of the thick stems. The best quality hay is obtained when it is cut before heading. It is primarily a pasture crop, having much smaller seed heads than either proso or foxtail millets. Each seed head is made up of 5 to 15 brownish or purple spikelets. Seed size and shape are similar to both proso and foxtail millets, with a light brown hull color.

Fertilization and tillage practices are similar to those of small grains. Millet regularly yields less than small grains, but it grows better under low moisture soil conditions. Therefore, it requires lower levels of available nitrogen to produce an acceptable crop. It competes against weeds better if sufficient nutrients are present. Soils with moderate levels of available nutrients should receive a complete fertilizer blend of nitrogen, phosphorus, potassium, and sulfur, at a ratio of 1.5:1:0.5:0.25 N, P_2O_5, K_2O, and S. With irrigated farming practices, the ratio should be reduced to about 0.75:0.5:0.25:0.13. Additionally, application of 0.5 pound per acre of boron can increase yields and improve disease resistance. Actual percentages of each nutrient and the application rate varies according to specific soil test results. The fertilizer can be broadcast before spring tillage or portions can be banded at planting. Millet does not usually respond to high levels of available nutrients, especially under dryland conditions. If millet follows summer fallow, fertilization may not be required. Millet grown for forage should have higher amounts of nitrogen applied for higher quality hay production. Avoid excess nitrogen fertilizer that can induce lodging and delay maturity, especially if the crop grown under irrigation.

*Foxtail millet (*Setaria italica *(L.) Beauv.) is the second-most widely planted species of millet, and the most important in East Asia. It has the longest history of cultivation among the millets, is a warm-season crop, and is derived from the wild species* Setaria viridis. *Photo from Wikimedia, taken by Markus Hagenlocher, CC-BY-SA 3.0 Unported license*

To conserve soil moisture, minimum tillage is recommended for incorporating fertilizer material and plant residue and preparing the seedbed. Pulling a packer behind the tillage implement and using a seed drill equipped with press wheels ensures that the seed is in contact with moist soil during the time needed for germination. This is especially true if the crop is to be irrigated. The soil should be irrigated sufficiently to bring the soil moisture levels close to the maximum water-holding capacity before tillage. It is very important not to irrigate above the maximum water-holding capacity before tillage and planting as this could cause a soil crust to form on the surface that would impede seedling emergence, reduce plant density, and lower seed yields. Because of the small seed size, seeding depth is 1 to 1.5 inches, or to moisture. Seeding rate for proso millet is 8 to 15 pounds of pure live seed per acre; for foxtail and Japanese millet it is 6 pounds per acre planted with a seed drill. If millet is to be grown for forage it can be broadcast seeded at 25 to 30 pounds per acre. The higher seeding rates help to reduce competition from weeds, shorten plant heights, and reduce lodging for both seed and forage production. A late planting date of the third week in May is recommended to avoid the possibility of a late spring frost. Using certified seed is strongly recommended. Certified seed has strict limits on the maximum content of weed seeds and diseased seeds, and must meet a minimum percent germination. This helps to ensure good germination and emergence and reduces weed and disease infestations.

Like small grains, irrigation should begin again after the crop has reached about 50% emergence to avoid any problems with emergence from too hard a crust on the surface. Thereafter, a good range of irrigation plus precipitation is around 0.5 to 1 inch per week. Irrigation should continue until the crop has reached the 50% headed growth stage.

Using IPM techniques, assess each field for all pests (weeds, diseases, and insects) and plan control measures accordingly. Weed control in millet is extremely important. Millet seedlings are small, thin, and do not compete well with weeds. Weed control is a combination of mechanical and chemical fallow performed the summer before planting to reduce the number and species of weeds for the following season and proper fertilization and seeding rates. To eliminate all weeds with chemical fallow, a broad-spectrum, nonselective, post-emergence herbicide such as glyphosate (Roundup) can be used. Because many millet varieties and types are quite sensitive to herbicides, no one chemical is effective for weed control for all varieties. Millet is relatively free from diseases and none have been found on varieties grown in Alaska. The same insect pests that attack small grains also attack millet although to lesser degrees. The most serious insect pests are aphids (family Aphididae) and grasshoppers, including the lesser migratory grasshopper (*Melanoplus sanguinipes* Fabricias), the northern grasshopper (*Melanoplus borealis* Fieber), and the clear-winged grasshopper (*Camnula pellucida* Scudder). If insect population levels and damage have been determined to be too high through IPM practices, then the application of an insecticide may be warranted. Insecticide sprays or baits can help control heavy infestations if applied at the nymph growth stage. Always remember to read the pesticide label to be sure the crop is specified and follow the directions on mixing, application, and disposal. Contact your local Cooperative Extension Service for more information on pest control (see Appendix 1 for addresses and contact information).

Millet, like canarygrass, is grown specifically for use as birdseed, and because of its later planting date, the crop may still be in the fields when waterfowl begin fall migrations. Millet seed is highly susceptible to head shatter when ripe and can be easily eaten by waterfowl. Large flocks can also cause serious lodging while they are trying to get at the seed. Using a propane scare cannons designed to swivel in different directions and go off at uneven time intervals is recommended to keep migratory waterfowl away. Check with and inform the neighbors before setting up cannons.

Closeup of Japanese millet (Echinochloa sculenta) *in bud. Photo by David Fenwick, taken at Boringdon Park, Plympton, Plymouth, Devon, England*

For more information on wildlife control in agricultural fields, contact the local office of the Alaska Department of Fish and Game.

All millet varieties have some yield losses due to head shatter. Harvest should therefore begin when the seeds at the top of the head are mature and ripe. The lower seeds should have lost their green color but should be in the dough stage. The leaves and stems of proso millet are still green at this stage. Proso millet is susceptible to lodging when ripe. Because the straw of all millet varieties is high in moisture when the seed is ready to harvest, millet should be swathed to dry the straw in windrows before harvest. This also reduces the amount of loss due to head shatter when combined. Millet is killed with the first light frost, so field combining and accepting a higher seed loss from head shatter may be the only option. The same combine settings used to harvest canarygrass should be used to harvest millet. For proper threshing, reduce cylinder speeds to slow the feeding rate. Reduce airflow settings (similar to those for flax) because of the small seed size. Run augers at full capacity or slow them down to reduce the incidence of seed dehulling. Because of the small seed size, all cracks and holes in the combine, augers, trucks, and bins should be sealed to prevent seed loss during handling. Because birdseed acceptance standards only allow 4% dehulled seed, it is important to check continually for dehulled or cracked seeds and adjust combining methods. Any seed lot not meeting the higher birdseed grades is purchased at lower feed prices. Optimum moisture content for safe, long-term storage of millet is 10% to 12%. Typical grain dryers have perforated floor openings that are too large for the small seeds. A 5-mesh nylon sheet over the floor prevents seed loss. On-farm cleaning and sizing of the seed lot to birdseed standards before shipment results in higher prices paid to the producer. Clean-outs can be used on farm or sold as lower-grade seed.

There are many problems in producing millet in Alaska. Even though it is a short-season crop that does well in semi-arid regions, it is a warm-season crop that needs warm soil to germinate and it is highly susceptible to light frosts. This necessitates late planting and early harvest. Light frosts, which would cause total crop failure, can occur at any time during the Alaska growing season. It does not compete well with spring weeds and can be completely shaded out in bad years. Harvest is difficult and losses due to head shatter and predation by migratory waterfowl are high. At present in Alaska, there are no birdseed processing facilities or elevators set up to accept millet. Although a large niche market for imported, prepackaged birdseed for both wild and caged birds commands a high price for producers outside Alaska, high production costs and the unlikelihood of consistently producing a large, high-value crop make millet economically unviable for Alaska. Due to these cultural problems, no varieties of millet are generally recommended. However, just because there was a crop failure for this study does not mean that it might not be successfully grown somewhere within the state. Therefore, the reader is not discouraged from trying any of the millet varieties not recommended, but the probability of success in attempting to produce these crops will likely be low.

Yields and Quality by Location for Proso, Foxtail, and Japanese Millet

Millet seed, as is all birdseed, is bought and sold by weight. Similar to small grains, there is a standard test weight for millet that is used as the legal unit for purchase or sale of the crop. This standard test weight for clean, dry, and undamaged millet is 50 pounds per bushel. The highest prices are paid to the producer for these niche crops but only if they meet the quality criteria mentioned previously. In addition to test weights, other on-farm samples should be taken to determine quality. Any seed lots not meeting high-quality birdseed standards should be used as lower feed grades. It is important then for the producer to clean and size all seed lots before delivery to a niche market. Test weights are used here as a measure of seed quality to determine maturity. Yields are expressed here in pounds per acre and bushels per acre. Determine bushels per acre by dividing the yield of any specific cultivar by the standard test weight.

Tables 61 and 63 list yields and quality measurements for millet varieties for 2 test locations: Fairbanks and Delta Junction. All sites in the Delta Junction area have been combined into the Delta dryland site (Table 63). No irrigation studies were done for millet. Each table also contains information on seed type, the source or the location of where it was bred, and the years it was tested at each location. Maturity in this study was defined as when 50% of the heads for each plot were at the hard dough stage (the seed did not dent when pressed with a thumbnail). Growing degree days (GDD) for average maturity were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. The low temperature point for millet in this report is the freezing point of water, 32°F. The GDD calculations for each day were then added to the preceding GDD value to determine the date at which the specific variety had reached 50% maturity. Maturity was not reached for most varieties due to severe weed competition and seasonal frosts and is represented by N/D (No Data) in the tables. Because there are no standard varieties for millet in Alaska, there were only comparisons among varieties.

Tables 62 and 64 list the animal feed quality analyses of the forage, on a dry weight basis, for select millet varieties for the Fairbanks and Delta Junction dryland test locations. They are presented here without statistical differences and solely for the reader's benefit. More detailed information and explanation about the industry standards for forage and birdseed grade millet that follow can be obtained from E.A. Oelke and others (1990). A detailed explanation of the feed analysis that follows, as well as laboratory procedures, can be obtained from J. Schroeder (1994) and G.J. Michaelson and others (1987). As with the yield tables, all sites in the Delta Junction area have been combined together.

Percent crude protein is calculated from the total percent nitrogen analysis of the seed multiplied by a constant of 6.25. Crude protein is made up of amino acids, which are 16% nitrogen as well as other, non-protein portions of the plant, and so percent crude protein is not a measure of true protein. Industry standards for all millet grown for forage are between 12% and 20%. Higher values have greater nutritional value, but too high a value (>20%) is a possible indicator of high levels of nitrates in the forage. Forage samples should also be analyzed for nitrate (NO_3^-) concentrations. Any samples of 0.44% or higher can be potentially toxic to livestock. For the millet varieties, %P and %K were not measured.

Table 61. Average yields and quality measurements for all millet varieties from test plots in the Fairbanks area.

Millet Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Lodging (%)	Average Maturity Date	Average Maturity (GDD)*
Proso birdseed, spring							
Abarr	Colorado	1	0	0	0	N/D	N/D
Big Red	Nebraska	1	0	0	0	N/D	N/D
Common White	Colorado	1	0	0	0	21-Sep	3272
Dawn	Nebraska	1	0	0	0	N/D	N/D
Leonard	Colorado	1	0	0	0	N/D	N/D
Turgahi	Japan	1	0	0	0	N/D	N/D
Foxtail birdseed, spring							
Golden German	Colorado	1	0	0	0	21-Sep	3272
Manta	South Dakota	1	0	0	0	N/D	N/D
Japanese birdseed, spring							
Japanese	Japan	1	0	0	0	21-Sep	3272

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature; N/D = No Data.

Table 62. Average forage quality measurements for select millet varieties from test plots in the Fairbanks area.

Millet Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)
Forage Industry Standards			**12-20%**	**0.4-0.6%**	**0.4-0.6%**
Proso birdseed, spring					
Common White	Colorado	1	26.51	N/D	N/D
Foxtail birdseed, spring					
Golden German	Colorado	1	22.85	N/D	N/D
Japanese birdseed, spring					
Japanese	Japan	1	22.63	N/D	N/D

Analysis done on whole plant biomass (seed and stems) at maturity; N/D = No Data.

Table 63. Average yields and quality measurements for all millet varieties from test plots in the Delta Junction area, dryland.

Millet Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Lodging (%)	Average Maturity Date	Average Maturity (GDD)*
Proso birdseed, spring							
Abarr	Colorado	1	0	0	0	N/D	N/D
Big Red	Nebraska	1	0	0	0	N/D	N/D
Common White	Colorado	1	0	0	0	23-Sep	3281
Dawn	Nebraska	1	0	0	0	N/D	N/D
Leonard	Colorado	1	0	0	0	N/D	N/D
Turgahi	Japan	1	0	0	0	N/D	N/D
Foxtail birdseed, spring							
Golden German	Colorado	1	0	0	0	23-Sep	3281
Manta	South Dakota	1	0	0	0	N/D	N/D
Japanese birdseed, spring							
Japanese	Japan	1	0	0	0	23-Sep	3281

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature; N/D = No Data.

Table 64. Average forage quality measurements for select millet varieties from test plots in the Delta Junction area, dryland.

Millet Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)
Forage Industry Standards			**12-20%**	**0.4-0.6%**	**0.4-0.6%**
Proso birdseed, spring					
Common White	Colorado	1	19.12	N/D	N/D
Foxtail birdseed, spring					
Golden German	Colorado	1	18.41	N/D	N/D
Japanese birdseed, spring					
Japanese	Japan	1	18.36	N/D	N/D

Analysis done on whole plant biomass (seed and stems) at maturity; N/D = No Data.

Buckwheat

Large and Small Seed Buckwheat

Buckwheat has been grown in Alaska since European colonization, but never in large acreages. There are 2 distinct types of buckwheat differentiated by the size of the triangular seeds. The large-seed diploid, common or Japanese buckwheat (*Fagopyrum esculentum* Moench), and the small-seed tartary or mountain buckwheat (*Fagopyrum tataricum* Gaertn.).

*An example of the large-seeded common buckwheat (*Fagopyrum esculentum *Moench) in bloom, growing in the Karlsruhe Botanical Gardens in Germany. Photo from Wikimedia, taken by H. Zell, CC BY-SA 3.0 license*

Buckwheat, an annual broad-leaved plant with many branches that grows 2 to 5 feet tall. As such, it is considered a pseudo-cereal rather than a true cereal, which are members of the grass family. The stems are succulent and highly susceptible to both late spring and early fall frost damage. It is also highly susceptible to lodging and seed shatter, especially after severe fall frosts. The growth habit is indeterminate, with small clumps of flowers continuously opening about 4 weeks after seeding until the first killing frost. If harvested for seed, buckwheat requires either swathing or field drying after a killing frost so that the plants can dry for efficient combining. Ripe seed, green seed, and flowers are present, increasing the moisture content at harvest and necessitating seed drying before storage.

Buckwheat is usually handled as a grain crop. After dehulling, seed from the common, large-seed varieties can be processed into a baking flour, while the small-seed tartary varieties are usually used for animal feeds. According to E.S. Oplinger and others (1989) buckwheat contains 11% to 13% crude protein, 10% to 12% fiber, and 80-90% dry matter. Although buckwheat flour is higher in lysine than other small grains used for flour, it is lower in glutens, which limits its use to pancake flours, buckwheat cakes, and health food niche markets.

The average flour return for buckwheat is 70%. The remaining hulls (20%) and shorts (10%) are removed in the milling process. Since most of the inner portions of the buckwheat kernel have gone into the production of flour, the hull and shorts will have a very high concentration of crude protein (25% to 30%) and fiber (10% to 12%). Buckwheat flour is generally darker than wheat flour because some hull is processed with the flour. If pure white flour is desired, the average flour return is only 52%. Individuals allergic to the proteins in buckwheat can develop skin rashes if they consume large amounts of the flour. This problem can also show up in white-haired animals, like swine, exposed to high levels of sunlight. Buckwheat is less palatable than other grains and can be fed whole in poultry diets, but for livestock the seed is dehulled and fed along with the shorts from the milling process. However, due to the potential for skin reactions in white or light-colored areas of hair on swine, buckwheat should only be fed in a mix of 2 parts grain to 1 part buckwheat (E.S. Oplinger and others 1989 and G. Hollis 1999). Secondary uses for buckwheat are as a green manure cover crop in rotations before planting potatoes, as a smother crop to reduce weeds, and as an annual crop for honey production. Buckwheat honey has a strong, dark flavor that many people do not like, which limits its value. Bees do not usually use the tartary type of buckwheat for nectar collection.

Fertilization, tillage practices, and seeding depths are identical to those for small grains. Because buckwheat is extremely efficient at obtaining mineral nutrients, due in part to its fast-growing, shallow-rooted growth habit, it is often seeded in unfertilized ground. Its response to fertilizers is less than that of small grains, and it can produce well on infertile, acidic, poorly tilled silt loams, although better competition with weeds and higher seed yield is obtained with fertilizer application. Soils with moderate to low levels of available nutrients should receive a complete fertilizer blend of nitrogen, phosphorus, potassium, sulfur, and boron. Buckwheat may require a higher level of phosphorus in the fertilizer blend with a 1:2:1:0.5 ratio of N, P_2O_5, K_2O, and S due to the acidic pH levels of many Alaska soils. With irrigation, the ratio should be reduced to about 0.5:1:0.5:0.25. Boron helps to induce flowering and should be applied at 0.5 pound per acre. Actual percentages of each nutrient and the application rate vary according to specific soil test results. The fertilizer should be broadcast before spring tillage. Excess nitrogen fertilizer should be avoided because it can induce lodging and delay maturity, especially if the crop is grown under irrigation.

To conserve soil moisture, minimum tillage is recommended for incorporating fertilizer material and plant residue and preparing the seedbed. Pulling a packer behind the tillage implement and using a seed drill equipped with press wheels ensures that the seed is in contact with moist soil during the time needed for germination. This is especially true if the crop is to be irrigated. The soil should be irrigated sufficiently to bring the soil moisture levels to close to the maximum water-holding capacity before tillage. It is very important not to irrigate above the maximum water-holding capacity before tillage and planting as this could cause a soil crust to form on the surface that would impede seedling emergence, reduce plant density, and lower seed yields. Seeding depth is the same as that for small grains at 1.5 to 2.5 inches, or to moisture. Seeding rate is 40 to 60 pounds of pure live seed per acre with the higher rates used for cover or green manure crops. Lower seeding rates of 24 pounds per acre are used for the tartary varieties. Late seeding is recommended to avoid the possibility of serious damage from late spring frosts. Date-of-planting studies by F.J. Wooding (1980) and C.W. Knight (1994) found that average planting dates of around the third week of May have produced reasonable yields in Alaska. Certified seed is strongly recommended. Certified seed has strict limits on maximum content of weed seeds and diseased seed and must meet a minimum percent germination. This helps to ensure good germination and emergence and reduces weed and disease infestations.

*Seeds of tartary buckwheat (*Fagopyrum tataricum *(L.) Gaertn.) at close magnification. Public domain photo, USDA, NRCS. 2013. The PLANTS Database (http://plants.usda.gov, 2 August 2013). National Plant Data Team, Greensboro, NC 27401-4901*

Similar to small grains, irrigation should begin again after the crop has reached about 50% emergence to avoid any problems from too hard a crust on the surface. Thereafter, a good range of irrigation plus precipitation is around 0.5 to 1 inch per week. Irrigation should continue until the crop has reached the 50% flowering growth stage.

Using IPM techniques, assess each field for all pests (weeds, diseases, and insects) and plan control measures accordingly. There are no herbicides registered for use on buckwheat in Alaska. The best weed control method is to seed heavily and let the crop shade out other plants. Also, weed control should use mechanical and chemical fallow in the previous season to reduce the number and species of weeds for the following season. To eliminate all weeds with chemical fallow, a broad-spectrum, nonselective, post-emergence herbicide such as glyphosate (Roundup) can be used. The most difficult weeds to control are knotweed (*Polygonum aviculare*) and wild buckwheat or field bindweed (*Polygonum convolvlus* L.) because they are all in the same family as commercial buckwheat. They all have the same triangular seed shape, although knotweed seed is much smaller and easier to clean out of a seed lot before planting. There are few disease or insect pests that attack buckwheat. If the crop lodges severely in the fall, there may be enough time before harvest for various molds to form on the seeds. Prompt harvest and on-farm drying can reduce mold formation. Contact your local Cooperative Extension Service for more information on pest control (see Appendix 1 for addresses and contact information).

Buckwheat seeds are mature when they are a dark brown and in the hard dough stage (the seed can't be dented when pressed with a thumbnail). Because buckwheat is an indeterminate plant, there are ripe seeds, green seeds, and flowers until the first frost. The seed is susceptible to shatter after a severe frost. To reduce seed loss from shatter, it may be better to swath when 75% of the seeds have reached maturity. Buckwheat has succulent stems that, unless dry when combined, can present problems at harvest, such as wrapping up in the pick-up reels, feed augers, and cylinders. This reduces threshing efficiency and could necessitate shutting down the combine to clean out plant residues. Therefore, soon after a killing frost buckwheat should be either swathed or allowed to field dry, if it does not lodge, for efficient combining. There are no desiccants registered for use on buckwheat. The seed continues to fill in the windrow for about 3 days after swathing. Combine settings are the same as for small grains. Cylinder speed and concave settings need to be properly set to reduce the amount of cracked seed. Continual checking for cracked seeds and adjusting combining methods is important because food-grade seed only allows 4% cracked hulls. The mixture of mature seed, green seed, and flowers increases the moisture content at harvest, requiring seed drying to 16% moisture content before storage. Only high-quality, large-seeded varieties are purchased by millers for food-grade buckwheat, which can't contain any diseased kernels, other crops, or foreign material. Any seed lot not meeting the higher food grades is purchased at lower feed-grade prices. On-farm cleaning and sizing of the seed lot to food-grade standards before shipment results in higher prices paid to the producer. Clean-outs can be used on farm or sold as feed grade.

Buckwheat has a limited market in Alaska. Although there are a number of small-scale, on-farm mills in Alaska, there are no large-scale mills to produce food-grade flour, and no elevators are set up to accept buckwheat. In Alaska it is used primarily as a green manure crop with limited secondary use by honey producers for dark specialty honey.

Recommended Variety Descriptions for Buckwheat

Note: See Appendix 1 for the addresses of seed suppliers.

'CM-15' is an early-maturing (to 75% mature seed), uniform, high-yielding, small-seed experimental line developed by the Agriculture and Agri-Food Canada Research Centre at Morden, Manitoba. Its small seed makes it less acceptable as a milling-grade buckwheat, but its uniformity and early maturing characteristics have produced consistently high yields. It is about equal with 'Pennquad' in maturity and yield on good sites but outproduces 'Pennquad' on poorer sites. Since this is an older variety, seed sources may be difficult to find. Direct inquiries about seed sources to the Agriculture and Agri-Food Canada Morden Research Station, Manitoba.

'Pennquad' is an early-maturing (to 75% mature seed), uniform, high-yielding, large-seed, tetraploid variety developed in 1966 by the USDA plant breeding program at the Pennsylvania State University Agricultural Experiment Station in University Park, Pennsylvania. Its uniformity and high-yielding characteristics make it an acceptable milling variety. This was the standard variety against which all other buckwheat varieties were compared in this report. Since this is an older variety, seed sources may be difficult to find. Direct inquiries about seed sources to Pennsylvania State University.

Yields and Quality by Location for Buckwheat

Buckwheat seed is bought and sold by weight. Similar to small grains, a standard test weight is used as the legal unit for crop sales. Standard test weight for clean, dry, and undamaged buckwheat is 48 pounds per bushel. The highest prices are paid to the producer for these niche crops only if they meet the quality criteria mentioned previously. In addition to test weights, other on-farm samples should be taken to determine quality. Any seed lots not meeting food-grade buckwheat standards should be used as feed grade. It is important, then. for the producer to clean and size all seed lots before delivery to any market. Test weight differs among cultivars and can change within a single cultivar depending on cultural practices, weather conditions, and location where grown. It is used here as a measure of grain quality to determine maturity. Yields are expressed here in pounds per acre and bushels per acre. Determine bushels per acre by dividing the yield of any specific cultivar by the standard test weight.

Tables 65, 67, and 69 list yields and quality measurements for buckwheat varieties for 3 test locations: Fairbanks, Eielson, and Delta Junction. All sites in the Delta Junction area have been combined into the Delta dryland site (Table 69). There were no irrigation studies done with buckwheat. Each table also contains information on seed type (large or small), the source or the location of where it was bred, and the years it was tested at each location. Maturity in this study was considered to be when 75% of the heads for each plot were at the hard dough stage (seed color was light to dark brown and the seed did not dent when pressed with a thumbnail). Growing degree days (GDD) for average maturity were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. The low temperature point for buckwheat in this report is the freezing point of water, 32°F. The GDD calculations for each day were then added to the preceding GDD value to determine the date at which the specific variety had reached 50% maturity. All varieties were compared with 'Pennquad' large-seed buckwheat as

Closeup of large-seed buckwheat flowers (Fagopyrum esculentum Moench*) from a plant growing in the Netherlands. From Wikimedia, photo taken by Rob Hille, Creative Commons Attribution-Share Alike 3.0 Unported license.*

the standard variety. Yield as a percent of 'Pennquad' was determined by dividing the average yield of each variety by the average yield of 'Pennquad'. Maturity vs. Std. (Standard variety) is the number of days each variety reached 50% maturity either before or after the number of days that 'Pennquad' reached 50% maturity.

Tables 66, 68, and 70 list the quality analyses of the seed for select buckwheat varieties for the Fairbanks, Eielson, and Delta Junction dryland test locations. They are presented here without statistical differences and solely for the reader's benefit. More detailed information and explanation about the industry standards for food-grade buckwheat that follow can be obtained from E.S. Oplinger and others (1989). Detailed explanation of the feed analysis that follows, as well as laboratory procedures, can be obtained from J. Schroeder (1994) and G.J. Michaelson and others (1987). As in the yield tables, all sites in the Delta Junction area have been combined.

Percent crude protein is calculated from the total percent nitrogen analysis of the seed multiplied by a constant of 6.25. Crude protein is made up of amino acids, which are 16% nitrogen, as well as other, non-protein portions of the plant, and so percent crude protein is not a measure of true protein. Industry standards for buckwheat are between 11% and 13%. Higher values have greater nutritional food value, but too high a value (>13%) is an indicator of immature green seed, which makes a lower-grade flour because it turns rancid quicker. In a standard feed analysis, other major nutrient mineral concentrations commonly measured are percent phosphorus (%P) and potassium (%K).

Table 65. Average yields and quality measurements for all buckwheat varieties from test plots in the Fairbanks area.

Buckwheat Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test Weight (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Small seed, spring										
CM-15	Manitoba	4	1502	31	68	43	85	6-Sep	-11	3063
Large seed, spring										
Botan Soba	Japan	1	564	12	26	40	80	25-Sep	8	3308
Common	Minnesota	1	1356	28	61	40	85	25-Sep	8	3308
Common	New York	1	1344	28	61	40	85	25-Sep	8	3308
Shumway Japanese	Illinois	1	1408	29	64	40	80	25-Sep	8	3308
Mancan	Manitoba	2	554	12	25	37	80	17-Sep	0	3224
Manor	Manitoba	1	247	5	11	38	80	17-Sep	0	3224
PA Composite	Pennsylvania	1	868	18	39	40	85	25-Sep	8	3308
PA-158	Pennsylvania	1	708	15	32	40	85	25-Sep	8	3308
Pennquad	Pennsylvania	4	2205	46	100	40	80	17-Sep	0	3224
Tempest	Canada	1	1096	23	50	40	75	25-Sep	8	3308
Tokyo	Canada	1	1388	29	63	40	75	25-Sep	8	3308
Winsor Royal	Minnesota	3	825	17	37	34	85	17-Sep	0	3224

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. All varieties were compared with 'Pennquad' large seed buckwheat as the standard variety.

Table 66. Average quality measurements for select buckwheat varieties from test plots in the Fairbanks area.

Buckwheat Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)
Flour Industry Standards			**11-13%**	**0.3-0.5%**	**0.5-0.7%**
Large seed, spring					
Mancan	Manitoba	2	14.69	0.36	0.65
Manor	Manitoba	1	14.81	0.33	0.58
Pennquad	Pennsylvania	4	14.04	0.35	0.59
Winsor Royal	Minnesota	3	11.88	0.26	0.69

Analysis done on mature, ripe seed. All varieties were compared with 'Pennquad' large seed buckwheat as the standard variety.

Table 67. Average yields and quality measurements for all buckwheat varieties from test plots in the Eielson area.

Buckwheat Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test Weight (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Large seed, spring										
Mancan	Manitoba	1	131	3	6	25	25	21-Sep	4	3286
Manor	Manitoba	1	103	2	5	29	30	21-Sep	4	3286
Winsor Royal	Minnesota	3	517	11	23	36	35	11-Sep	-6	3155

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. All varieties were compared with 'Pennquad' large seed buckwheat from the Fairbanks area as the standard variety.

Table 68. Average quality measurements for select buckwheat varieties from test plots in the Eielson area.

Buckwheat Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)
Flour Industry Standards			11-13%	0.3-0.5%	0.5-0.7%
Large seed, spring					
Mancan	Manitoba	1	7.81	0.30	0.57
Manor	Manitoba	1	6.93	0.32	0.54
Winsor Royal	Minnesota	3	9.75	0.38	0.63

Analysis done on mature, ripe seed. All varieties were compared with 'Pennquad' large seed buckwheat from the Fairbanks area as the standard variety.

Table 69. Average yields and quality measurements for all buckwheat varieties from test plots in the Delta Junction area, dryland.

Buckwheat Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test Weight (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Small seed, spring										
CM-15	Manitoba	4	1093	23	199	43	10	5-Sep	0	2805
Large seed, spring										
Botan Soba	Japan	1	160	3	29	40	10	5-Sep	0	2805
Common	Minnesota	1	296	6	54	40	10	5-Sep	0	2805
Japanese	Illinois	1	784	16	143	40	10	5-Sep	0	2805
Mancan	Manitoba	2	653	14	119	38	10	1-Sep	-4	2744
Manor	Manitoba	1	132	3	24	38	10	1-Sep	-4	2744
PA Composite	Pennsylvania	1	192	4	35	40	10	5-Sep	0	2805
PA-158	Pennsylvania	1	208	4	38	40	10	5-Sep	0	2805
Pennquad	Pennsylvania	4	549	11	100	40	10	5-Sep	0	2805
Tempest	Canada	1	432	9	79	40	10	5-Sep	0	2805
Tokyo	Canada	1	336	7	61	40	10	5-Sep	0	2805
Winsor Royal	Minnesota	3	100	2	18	40	10	5-Sep	0	2805

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. All varieties were compared with 'Pennquad' large seed buckwheat as the standard variety.

Table 70. Average quality measurements for select buckwheat varieties from test plots in the Delta Junction area, dryland.

Buckwheat Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)
Flour Industry Standards			11-13%	0.3-0.5%	0.5-0.7%
Large seed, spring					
Mancan	Manitoba	2	7.87	0.26	0.58
Manor	Manitoba	1	5.05	0.30	0.55
Pennquad	Pennsylvania	4	8.63	0.26	0.57
Winsor Royal	Minnesota	3	11.88	0.26	0.69

Analysis done on mature, ripe seed. All varieties were compared with 'Pennquad' large seed buckwheat as the standard variety.

Quinoa

Grain Quinoa

Quinoa (*Chenopodium quinoa* Willd.) is an annual pseudo-cereal, broad-leaved plant that is used as a high-protein grain and leafy vegetable. It is related to, and closely resembles, the introduced weed lambsquarters (*Chenopodium album* L.). Like lambsquarters, quinoa requires cool soil and air temperatures and short day length for best growth. It does well on marginal but well-drained soil. Quinoa can grow anywhere from 1.5 to 6.5 feet in height and comes in a range of colors including white, yellow, pink, dark red, purple, green, and black. It has a fairly extensive root system that makes the plant better adapted to drought conditions. The seed is similar in size to millet and can be black, red, pink, orange, yellow, or white. These colors are the result of the resinous outer coating that contains 2% to 6% saponin. The saponin is very bitter-tasting and is a mild gastrointestinal irritant or laxative that must be removed by washing before the grain can be eaten. According to E.A. Oelke and others (1992), the protein and amino acid content is equal to or greater than that of wheat grain (11% to 15% crude protein), but the fat content is higher (5% to 6%). Quinoa is around 3% to 5% fiber and 80% to 90% dry matter. The grain can be eaten whole, ground into flour, or cooked like rice. The leaves can be harvested when the plant is immature and either eaten raw in salads or cooked like spinach. As the plant matures, the oxalic acid content in the leaves increases, making them bitter and unpalatable. There is a limited health food niche market for quinoa, mostly for grain-producing varieties.

Quinoa inflorescence. Photo from Wikimedia, taken by Kurt Stueber, Creative Commons Attribution-Share Alike 3.0 Unported license

Fertilization and tillage practices are similar to those used for small grain production. It is a marginal competitor against weeds, especially lambsquarters, and can tolerate light frosts. Quinoa responds well to higher levels of available nitrogen to produce an acceptable grain crop and it can grow better under arid conditions. However, higher levels of phosphorus have no effect on yields. Soils with moderate levels of available nutrients should receive a complete fertilizer blend of nitrogen, phosphorus, potassium, and sulfur at a ratio of 1:1:0.5:0.5 N, P_2O_5, K_2O, and S. With irrigated-farming practices, the ratio should be reduced to about 0.5:0.5:0.25:0.25. Boron helps to induce flowering and should be applied at 0.5 pound per acre. Actual percentages of each nutrient and the application rate vary according to the specific soil test results. The fertilizer can be broadcast before spring tillage or portions can be banded at planting. If quinoa follows summer fallow, fertilization may not be required. Avoid excess nitrogen fertilizer because it can delay maturity and increase lodging, especially if applied during irrigation.

To conserve soil moisture, minimum tillage is recommended for incorporating fertilizer material and plant residue and preparing the seedbed. Seedbed preparation is extremely important as a firm seedbed is needed to ensure seed contact with moist soil. Pulling a packer behind the tillage implement and using a seed drill equipped with press wheels ensures that the seed is in contact with moist soil while it is germinating. This is especially true if the crop is to be irrigated. The soil should be irrigated sufficiently to bring the soil moisture levels close to the maximum water-holding capacity before tillage. It is very important not to irrigate above the maximum water-holding capacity before tilling and planting as this could cause a soil crust to form on the surface that would impede seedling emergence, reduce plant density, and lower seed yields. Because quinoa seeds are small, regular grain drills must have the drill speed reduced with a reducer sprocket. Other options would be to use a grass seed attachment or a horticultural vegetable seeder. Seeding depth is 0.5 to 1 inch with a seeding rate of 0.50 to 0.75 pounds of pure live seed per acre. Higher seeding rates help reduce competition from weeds. Because of the plant's wide branching growth habit, row spacing should be at least twice that of small grains, 14 to 20 inches. Grain drills can be used to plant quinoa by blocking off the appropriate opening in the seed box. The seed box should be kept full to account for the effect of seed weight on the flow through the drill. Certified seed is strongly recommended. Certified seed has strict limits on maximum content of weed seeds and diseased seed and must meet a minimum percent germination. This helps to ensure good germination and emergence and reduces weed and disease infestations.

Similar to small grains, irrigation should begin again after the crop has reached about 50% emergence to avoid any problems that might be caused by too hard of a crust on the surface. Thereafter, a good range of irrigation, plus precipitation, is around 0.5 to 1.0 inch per week. Irrigation should continue until the crop has reached the 50% flowering growth stage.

Using IPM techniques, assess each field for all pests (weeds, diseases, and insects) and plan control measures accordingly. Weed control in quinoa is extremely important as the plants grow slowly during the first 2 weeks after emergence, which allows the weeds to get a head start in the spring. Lambsquarters come on later in the spring but catch up quickly and look identical to quinoa, making them very difficult to weed out. This could lead to potential reductions in crop quality: Johnson and Croissant (1990) have found possible hybrids between quinoa and lambsquarters in Colorado, and Risi and Galwey (1998) have found that there is a potential for 10% to 15% cross pollination in quinoa. Therefore, best weed control is a combination of mechanical and chemical summer fallow to reduce the number and species of weeds for the following year. To eliminate all weeds with chemical fallow, a broad-spectrum, nonselective, post-emergence herbicide such as glyphosate (Roundup) can be used. Quinoa is relatively free from diseases and none have been found on varieties grown in Alaska. The larval stage of the red turnip beetle (*Entomoscelis americana* Brown) has been found on both lambsquarters and quinoa in Alaska. The larva feed on the leaves of quinoa in late May to early June, often causing total defoliation. The adult beetle is bright red with 3 black stripes down the back and a black patch behind the head. There are no pesticides registered for quinoa in Alaska. Contact your local Cooperative Extension Service for more information on pest control (see Appendix 1 for addresses and contact information). There is very little bird or wildlife predation of quinoa because of the oxalic acid content in the leaves and the saponin in the seed coats, which make them bitter and unpalatable.

Quinoa greens. Photo from Wikimedia, taken by Christian Gautier, Creative Commons Attribution 2.0 Generic licence.

The lower leaves of quinoa start to turn pale yellow or red and curl and drop off as the plant reaches maturity. It is at this stage that mature seed is present. A killing fall frost followed by sufficient good weather to dry the plant is usually required for combine harvesting. Combine ground speed should be slower than for small grains and concave clearances should be opened larger to accommodate the greater amount of plant material. Reduce cylinder speeds and air flow and use smaller screens to avoid seed loss. All cracks and holes in the combine, augers, trucks, and bins should be sealed to prevent seed loss during handling. Optimum moisture content for safe, long-term storage of quinoa is 10% to12%. Typical grain dryers have perforated floor openings that are too large for the small seeds. A 5-mesh nylon sheet over the floor prevents seed loss. On-farm cleaning of the seed before shipment results in higher prices paid to the producer.

Before quinoa seed can be used in food processing, the bitter-tasting saponins in the seed coat must be removed. This process usually requires either soaking in clean water for a couple of hours, then rinsing and resoaking in more clean water for another couple of hours, or continual rinsing in clean, running water for 1 to 2 hours. A mechanical method is to use a grain dehuller identical to that used to abrade the hulls off feed barley and oats before they can be consumed by humans. Once the saponins have been removed the seed must be dried back to 10% to 12% for storage or it will germinate in 24 hours.

Grain color variation in quinoa (Chenopodium quinoa)*, INIA Genebank (Instituto de Investigaciones Agropecuarias), Juliaca, Peru. Photo from Wikimedia, taken by Michael Hermann, courtesy of www.cropsforthefuture.org.*

Quinoa grain production in Alaska is problematic. It does not compete well with spring weeds and can potentially hybridize with common lambsquarters. Harvest is difficult because of the large amount of plant material and small seed size. Also, the seed coats must have the bitter-tasting saponins removed before consumption by humans. There is a small health food niche market for quinoa seed and flour products that commands a high price paid to producers. However, high production costs and the unlikelihood of consistently producing a high-quality, high-value crop make it economically unviable for Alaska. Because of these cultural problems, no varieties of quinoa are generally recommended. However, just because there was a crop failure for this study does not mean that it might not be successfully grown somewhere within the state. Therefore, the reader should not be discouraged from trying any of the quinoa varieties not recommended, but the probability of success in attempting to produce these crops will likely be low.

Yields and Quality by Location for Grain Quinoa

Quinoa seed is bought and sold by weight. The standard test weight for quinoa is used as the legal unit for crop sales. This standard test weight for clean, dry, undamaged seed is 50 pounds per bushel. The highest prices are paid to the producer for these niche crops, but only if they meet the quality criteria mentioned previously. In addition to test weights, samples should be taken on farm to determine quality. Any seed lots not meeting high quality standards should be used as lower feed grades. It is important, then, for the producer to clean and size all seed lots before delivery to a niche market. Test weights are used here as a measure of seed quality to determine maturity. Yields are expressed here in pounds per acre and bushels per acre. Determine bushels per acre by dividing the yield of any specific cultivar by the standard test weight.

Table 71 shows yields and quality measurements for quinoa varieties for the Fairbanks test location. There were no irrigation trials done on quinoa. The table also contains information on the source or the location of where it was bred and the years it was tested at this location. Maturity in this study was defined as when 50% of the seed for each plot was at the hard dough stage (the seed did not dent when pressed with a thumbnail). Growing degree days (GDD) for average maturity were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. The low temperature point for quinoa in this report is the freezing point of water, 32°F. The GDD calculations for each day were then added to the preceding GDD value to determine the cumulative value for the date at which the specific variety had reached 50% maturity. As there are no standard varieties for quinoa in Alaska, there were no comparisons other than among varieties. However, since it is related to the introduced weed lambsquarters (*Chenopodium album* L.), yield data from a study done by B. Van Veldhuizen and C. Knight (2006) is presented here for comparison. In that study, 20 different plant species (both wild and introduced) were examined for their agronomic potential as high-energy birdseed crops. More information on this study ("Dragonhead mint (*Dracophalum parviflorum* Nutt.) as a potential agronomic crop for Alaska," Miscellaneous Publication 2006-01) can be found online at the SNRE publications website, www.uaf.edu/snre/research/publications.

Closeup of the underside of a leaf of lambsquarters, showing the characteristic mealy-like quality common to the goosefoot relatives. Photo from Wikimedia, taken by Matt Lavin in Bozeman, Montana, Creative Commons Attribution-Share Alike 2.0 Generic license

A native lambsquarters species, Chenopodium berlandieri, *or pitseed goosefoot, growing at Wind Cave National Park, South Dakota. It is native to Alaska and south throughout North America, and was once a domesticated crop, similar to the closely related quinoa* C. quinoa. *Photo from Wikimedia, taken by Jim Pisarowicz; National Park Service.*

Table 72 lists the animal feed quality analysis of the seed for select quinoa varieties for the Fairbanks test location. Feed analysis data for lambsquarters from the previously mentioned study are also presented for comparison. They are presented here without statistical differences and solely for the reader's benefit. More detailed information and explanation about the industry standards for food-grade quinoa that follow can be obtained from E.A. Oelke and others (1992). Detailed explanation of the feed analysis that follows as well as laboratory procedures can be obtained from J. Schroeder (1994) and G.J. Michaelson and others (1987).

Percent crude protein is calculated from the total percent nitrogen analysis of the seed multiplied by a constant of 6.25. Crude protein is made up of amino acids, which are 16% nitrogen, as well as other, non-protein portions of the plant, and so percent crude protein is not a measure of true protein. Industry standards for quinoa are between 11% and 15%. Higher values have greater nutritional food value, but too high a value (>15%) is an indicator of immature green seed, which makes a lower-quality flour because it turns rancid quicker. In a standard feed analysis, other major nutrient mineral concentrations commonly measured are percent phosphorus (%P) and potassium (%K).

Percent crude fat (%Fat) is a measure of the amount of oil contained in the plant. These fats contribute some of the essential fatty acids and energy needed in animal diets. High levels of plant-based oils can supply more energy, but they also dilute mineral nutrient concentrations.

Percent dry matter (%DM) is the amount of plant biomass left after the water has been driven off in an oven at 140°F. The actual time that it takes to dry to a constant weight at 140°F varies from a few days to a week or more, depending on the type of plant matter. The nutrient concentrations are always expressed on a dry-weight basis because it allows for better comparisons between different types of plants.

Percent neutral detergent fiber (%NDF) is a measure of the percentage of partially digestible plant material (lignin, hemicellulose, and cellulose). Lower levels of NDF usually result in a higher animal intake of the feed. It is also used to calculate the dry matter intake (DMI), where DMI = 120 ÷ %NDF. This value is later used to determine the relative feed value.

Percent acid detergent fiber (%ADF) is a measure of the highly indigestible plant material (lignin and cellulose). Higher levels of ADF usually indicate a low digestibility of the plant material. It is also used to calculate the digestible dry matter (DDM), where DDM = 88.9 - (0.779 x %ADF). This value is also later used to determine the relative feed value.

The relative feed value (RFV) is a unitless index that combines the nutritional factors of the dry matter intake and the digestible dry matter of the plant material, where RFV = (DDM x DMI) ÷ 1.29. Plant material with an ADF of 41% and a NDF of 53% has a RFV of 100. All other plant material is compared to this value. Lower ADF and NDF values will cause the RFV to increase. The higher the RFV, the lower the overall quality of the feed.

Percent cellulose (%Cellulose) is a measure of partially digestible plant material. Percent lignin (%Lignin) is a measure of highly indigestible plant material. Both percentages are determined from %ADF and %NDF. Higher %ADF and %NDF result in higher percentages of indigestible plant material (%Lignin), which usually lead to lower feed intake and animal performance.

Table 71. Average yields and quality measurements for all quinoa varieties from test plots in the Fairbanks area.

Quinoa Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Test Weight (lbs/bu)	Lodging (%)	Average Maturity Date	Average Maturity (GDD)*
Yellow seed grain, spring								
C0407-78	Colorado	1	234	5	35	0	21-Sep	3272
C0407-06	Colorado	1	156	3	36	0	21-Sep	3272
C0407-260	Colorado	1	209	4	34	0	21-Sep	3272
Lambsquarter, spring^								
Lambsquarter	Alaska	1	56	1	32	0	21-Sep	3272

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature.

^Lambsquarter plot size was considerably smaller than that for the quinoa variety trials, so there is a greater possibility of error for yield estimates on a per acre basis.

Table 72. Average quality measurements for select quinoa varieties from test plots in the Fairbanks area.

Quinoa Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)	Crude Fat (%)	Dry Matter (%DM)	NDF (%)	ADF (%)	Relative Feed Value	Cellulose (%)	Lignin (%)
Flour Industry Standards			**11-15%**	**0.3-0.5%**	**0.5-0.7%**	**5-6%**	**80-90%**	**40-50%**	**25-35%**	**<161**	**20-26%**	**6-9%**
Yellow seed grain, spring												
C0407-78	Colorado	1	15.34	0.34	0.75	6.10	83.98	N/D	N/D	N/D	N/D	N/D
C0407-06	Colorado	1	14.78	0.34	0.80	6.00	89.23	N/D	N/D	N/D	N/D	N/D
C0407-260	Colorado	1	14.75	0.31	0.78	6.05	89.06	N/D	N/D	N/D	N/D	N/D
Lambsquarter, spring												
Lambsquarter	Alaska	1	18.44	0.47	1.58	7.34	94.87	26.88	18.09	259	13.71	4.39

Analysis done on mature, ripe seed. Seed coats were not removed before analysis. N/D = No Data.

Amaranth

Amaranth (*Amaranthus cruentus* L.) is an annual, pseudo-cereal, broad-leaved plant that is used as a high-protein grain, leafy vegetable, or forage crop. It closely resembles the introduced weed lambsquarters (*Chenopodium album* L.). Amaranth is drought-tolerant if there is enough soil moisture to establish the crop after planting. Warm growing conditions, including soil temperatures of 65° to 75°F for germination, are necessary for the best growth. It also requires a long growing season to fully mature and produce a high seed yield. Amaranth produces large colorful seed heads (green, red, or purple) at the top of leafy, thick stems 5 to 7 feet tall. The seed is tiny (less than 0.1 inch diameter) and white or tan. Amaranth grain has 12% to 17% protein, is higher in the essential amino acid lysine than small grains, high in fiber, and low in saturated fats. The grain can be ground into a baking flour, popped like popcorn, or flaked like oatmeal. The leaves can be harvested when the plant is immature and either eaten raw in salads or cooked like spinach. Varieties have been specifically developed for either grain production or leafy vegetable and forage production. If harvested before flowering, amaranth makes an acceptable livestock forage. However, D.H. Putnam and others (1989) found that amaranth can accumulate high levels of nitrates in the leaves and should be fed sparingly. If the fertilization rate for nitrogen is too high or there are droughty growing conditions, nitrates can build up in the plant tissue. Forage with levels of 0.44% or higher can cause growth and health problems if fed to livestock. There is a limited health food niche market for amaranth, mostly for grain-producing varieties.

*Red amaranth (*Amaranthus cruentus *L.) growing at the Henri-Gaussen Botanical Garden, Toulouse, France. Photo from Wikimedia, taken by user Traumrune, Creative Commons Attribution-Share Alike 3.0 Unported, 2.5 Generic, 2.0 Generic and 1.0 Generic license*

Fertilization and tillage practices are similar to those for small grain production. Amaranth, however, requires lower levels of available nitrogen to produce an acceptable grain crop and it can grow better under arid conditions. It is a good competitor against weeds, has light frost tolerance, and produces high grain yields when sufficient nutrients are present. Soils with moderate levels of available nutrients should receive a complete fertilizer blend of nitrogen, phosphorus, potassium, and sulfur at a ratio of 1:1:0.5:0.5 N, P_2O_5, K_2O, and S. With irrigated farming practices, the ratio should be reduced to about 0.5:0.5:0.25:0.25. Boron helps to induce flowering and should be applied at 0.5 pound per acre. Actual percentages of each nutrient and the application rate vary according to specific soil test results. The fertilizer can be broadcast before spring tillage or portions can be banded at planting. Amaranth does not usually respond to high levels of available nutrients, especially under dryland conditions. However, if it is grown for forage, a higher amount of nitrogen is required for higher-quality forage at a ratio of 1.5:1:0.5:0.5 N, P_2O_5, K_2O, and S. Irrigation is recommended for complete nutrient use in forage production. If amaranth follows summer fallow, fertilization may not be required. Avoid excess nitrogen fertilizer because it can delay maturity and potentially increase nitrate levels, especially if applied during irrigation.

To conserve soil moisture, minimum tillage is recommended for incorporating fertilizer material and plant residue and preparing the seedbed. Seedbed preparation is extremely important as a firm seedbed is needed to ensure seed contact with moist soil. Pulling a packer behind the tillage implement and using a seed drill equipped with press wheels ensures that the seed is in contact with moist soil during germination. This is especially true if the crop is to be irrigated. The soil should be irrigated sufficiently to bring the soil moisture levels to close to the maximum water-holding capacity before tillage.

It is very important not to irrigate above the maximum water-holding capacity before tilling and planting as this could cause a soil crust to form on the surface that would impede seedling emergence, reduce plant density, and lower seed yields. Because of the tiny size of amaranth seed, regular grain drills must have the drill speed reduced with a reducer sprocket. Other options would be to use a grass seed attachment or horticultural vegetable seeders. Because of the tiny seed size, seeding depth is only 0.25 to 0.5 inch. The seeding rate for amaranth is 1.0 to 2.0 pounds of pure live seed per acre. Higher seeding rates help reduce competition from weeds. Because of the wide-branching growth habit of amaranth, the row spacing should be at least twice that of small grains, 14 to 20 inches. Grain drills can be used to plant amaranth by blocking off the appropriate opening in the seed box. The seed box should be kept full to account for the effect of seed weight on the flow through the drill. A late planting date of the third week in May is recommended to avoid any late spring frost. Certified seed is strongly recommended. Certified seed has strict limits on maximum content of weed seeds and diseased seed, and must meet a minimum percent germination. This helps to ensure good germination and emergence and reduces weed and disease infestations.

Amaranth (A. cruentus L.). Photo from Wikimedia, taken by user Kallerna, Creative Commons Attribution-Share Alike 3.0 Unported license

Similar to small grains, irrigation should begin again after the crop has reached about 50% emergence to avoid any problems that might result from too hard of a crust on the surface. Thereafter, a good range of irrigation, plus precipitation, is around 0.5 to 1.0 inch per week. Irrigation should continue until the crop has reached the 50% flowering growth stage.

Using IPM techniques, assess each field for all pests (weeds, diseases, and insects) and plan control measures accordingly. Weed control in amaranth is extremely important. Amaranth germination requires warm soil temperatures, which give weeds a head start in the spring. Therefore, the best weed control is a combination of mechanical and chemical summer fallow to reduce the number and species of weeds for the following year; wait for any weeds to germinate in the spring, then perform seedbed tillage and use proper fertilization and seeding rates. To eliminate all weeds with chemical fallow, a broad-spectrum, nonselective, post-emergence herbicide such as glyphosate (Roundup) can be used. There are no herbicides registered for amaranth in Alaska. Amaranth is relatively free from diseases and none have been found on varieties grown in Alaska. There are also no known major insect pests that attack amaranth in Alaska. Contact your local Cooperative Extension Service for more information on pest control (see Appendix 1 for addresses and contact information).

The stems and leaves of amaranth are thick and high in moisture, even late into the season. Lower leaves start to turn brown and curl as the plant reaches maturity, while the upper portion of the plant (including the seed head) remains green. At this stage there is mature seed present. A killing fall frost followed by sufficient good weather to dry the plant is usually required for combine harvesting. Because of the thick stems, combine ground speed should be slower than for small grains. Concave clearances should be opened to accommodate the thicker stems. Reduce cylinder speeds and air flow to avoid seed loss. Use clover or alfalfa screens for maximum separation of seed from dirt and chaff. Because the remaining chaff and other plant residues will attract moisture, molds, and insects, remove it using an alfalfa scarifier before drying grain. All cracks and holes in the combine, augers, trucks, and bins should be sealed to prevent seed loss during handling. Optimum moisture content for safe, long-term storage of grain amaranth is 10% to 12%. Typical grain dryers have perforated floor openings that are too large for the small seeds. A 5-mesh nylon sheet over the floor prevents seed loss. Improper seed cleaning or drying leaves undesirable flavors in milled flour (from other plant residues and molds). On-farm cleaning of the seed before shipment results in higher prices paid to the producer.

Amaranth grain production in Alaska is problematic. It is a warm-season crop that needs warm soil to germinate and it requires a long growing season. This necessitates a late planting date and an even later harvest date. It does not compete well with spring weeds and can be completely shaded out in bad years. Harvest is difficult because of the thick plant material and tiny seed size. There is a small health food niche market for amaranth seed that commands a high price paid to producers. However, high production costs and the unlikelihood of consistently producing a high-quality, high-value crop make it economically unviable for Alaska. Due to these cultural problems, no varieties of grain amaranth are generally recommended. However, just because there was a crop failure with this study does not mean that it might not be successfully grown somewhere within the state. Therefore, the reader should not be discouraged from trying any of the grain amaranth varieties not recommended, but the probability of success in attempting to produce these crops will likely be low.

*Foxtail amaranth (*A. cruentus *L.) growing at the VanDusen Botanical Garden in Vancouver, British Columbia, Canada. This amaranth and the closely related love-lies-bleeding (*A. caudatus *L.) serve as important food crops in Central and South America. Photo from Wikimedia, taken by Stan Shebs and offered under a Creative Commons Attribution-Share Alike 3.0 Unported license*

Yields and Quality by Location for Grain and Forage Amaranth

Grain amaranth seed is bought and sold by weight. As with other small grains, there is a standard test weight for grain amaranth that is used as the legal unit for purchase or sale of the crop. This standard test weight for clean, dry, and undamaged seed is 63 pounds per bushel. The highest prices are paid to the producer for these niche crops, but only if they meet the quality criteria mentioned previously. Other than test weights, additional samples should be taken on-farm to determine quality. Any seed lots not meeting high quality standards should be used as lower feed grades. It is important, then, for the producer to clean and size all seed lots before delivery to a niche market. Test weights are used here as a measure of seed quality to determine maturity. Yields are expressed here in pounds per acre and bushels per acre. Determine bushels per acre by dividing the yield of any specific cultivar by the standard test weight.

Table 73 shows yields and quality measurements for grain amaranth varieties for the Fairbanks test location. No irrigation trials on grain amaranth were conducted. The table also contains information on the source or the location of where it was bred, biomass yields, and the years it was tested at this location. Maturity in this study was considered to be when 50% of the seed for each plot were at the hard dough stage (the seed did not dent when pressed with a thumbnail). Growing degree days (GDD) for average maturity were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. The low temperature point for amaranth in this report is the freezing point of water, 32°F. The GDD calculations for each day were then added to the preceding GDD value to determine the the date at which the specific variety had reached 50% maturity. However, maturity was not reached for every variety because of severe weed competition and seasonal frosts. In this case, the lack is represented by N/D (No Data) in the table. As there are no standard varieties for grain amaranth in Alaska, the only comparison is among varieties.

Table 74 lists the animal feed quality analysis of the forage, on a dry weight basis, for select grain amaranth varieties for the Fairbanks test location. It is presented here without statistical differences and solely for the reader's benefit. More detailed information and explanation about the industry standards for forage grade amaranth that follow can be obtained from D.H. Putnam and others (1989). Detailed explanation of the feed analysis that follow as well as laboratory procedures can be obtained from J. Schroeder (1994) and G.J. Michaelson and others (1987).

Percent crude protein is calculated from the total percent nitrogen analysis of the seed multiplied by a constant of 6.25. Crude protein is made up of amino acids, which are 16% nitrogen, as well as other, non-protein portions of the plant, and so percent crude protein and is not a measure of true protein. Industry standards for all amaranth grown for forage are between 24% and 30%. Higher values have greater nutritional value, but too high a value (>30%) is a possible indicator of high nitrate levels in the forage. Forage samples should also be analyzed for nitrate (NO_3^-) concentrations. Any samples of 0.44% or higher can be potentially toxic to livestock. For the amaranth varieties %P and %K were not measured.

Table 73. Average yields and quality measurements for all grain amaranth varieties from test plots in the Fairbanks area.

Amaranth Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Test Weight (lbs/bu)	Biomass Yield (lbs/acre)	Lodging (%)	Average Maturity Date	Average Maturity (GDD)*
Grain & forage, spring									
1011	Nebraska	2	5	0	34	6026	0	25-Sep	3308
477914	Nebraska	2	0	0	N/D	5213	0	N/D	N/D
K343	Pennsylvania	2	0	0	N/D	5739	0	N/D	N/D
R158	Pennsylvania	2	0	0	N/D	4400	0	N/D	N/D

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature; N/D = No Data.

Table 74. Average forage quality measurements for select grain amaranth varieties from test plots in the Fairbanks area.

Amaranth Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)
Forage Industry Standards			**24-30%**	**0.3-0.5%**	**0.5-0.7%**
Grain & forage, spring					
1011	Nebraska	2	18.69	N/D	N/D
477914	Nebraska	2	18.38	N/D	N/D
K343	Pennsylvania	2	12.38	N/D	N/D
R158	Pennsylvania	2	24.63	N/D	N/D

Field Peas

Green and Yellow Dry Field Peas

For many years, field peas (*Pisum sativum* L.) have been successfully grown in Alaska as a forage crop. They are a cool-season, late-maturing pulse crop that can survive late frosts, but they become stressed under high temperatures. A pulse crop is defined as any annual leguminous crop; the name is taken from the Latin "puls," meaning porridge. As legumes, peas are capable of fixing atmospheric nitrogen and produce high forage yields with high protein concentrations without high levels of nitrogen fertilizer. Field peas are an annual herbaceous plant with slender succulent stems 2 to 4 feet long. Field peas can be divided into 2 types. The normal type has 1 to 3 pairs of leaflets with terminal-branched tendrils, and the semi-leafless (or tare-leafed) type has tendrils instead of the leaflets. The semi-leafless varieties intertwine for better lodging resistance and faster crop drying at harvest, and they yield better under droughty conditions. Both types can be further divided into green-seed types having green seed coats and cotyledons and yellow-seed types having yellow or white seed coats and yellow cotyledons. The seeds can be round, angular, smooth, or wrinkled. There is no specific distinction between garden peas and field peas, other than garden peas tend to be sweeter and more wrinkled. Seeds are contained in pods averaging 3 inches long and bearing 4 to 9 seeds.

Field pea seed is used for human and livestock consumption. For human consumption it is sold primarily as split peas. Split peas have had the outer seed coat and inner embryo removed and separated in a burr mill. The

*Field peas (*Pisum sativum L.*) cultivated by Bryce Wrigley in the Delta Junction area* seed coat and embryo can be combined with other whole peas and ground for livestock feed and fed either whole or mixed with other grains. Field pea is a low-cost protein and energy source for swine diets, especially when combined with canola meal. Peas and pea byproducts are a popular feed for caged pigeons.

Field peas can be used for forage. Forage quality is maximized if peas are harvested after the pods are well formed, but before they reach maturity. Field peas are often interseeded with barley or oats to produce a more nutritionally balanced forage. The cereal grain stems also help to support the pea vines, making the forage easier to harvest. A.L. Brundage and others (1979) found that seed yields of both peas and oats grown in Alaska declined in oat/pea intercropping compared to either oats or peas grown alone. However, the nutritive composition (crude protein and nutritive minerals) of the oat/pea forage was higher than in either oats or peas grown separately as forage. S.H. Begna and others (2011) also found that an oat/pea intercrop grown in Interior Alaska can improve the forage quality (higher crude protein) over that of peas or oats grown alone. This study also found that growing oats and peas together lowers the weed competition by shading the soil, which reduces the total number of germinating weeds as well as the size of the weeds that do manage to germinate. Field peas can also be grown as a green manure crop to be turned under before the pods reach maturity. Field pea plant residues break down faster than small grain straw or canola plant residues. This high-quality plant matter increases subsequent nitrogen availability and improves soil tilth and organic matter content. Research in Alaska by S.D. Sparrow and others (1995 and 2001) indicates that this effect can be highly variable depending on weather and soil conditions in subsequent years. The best response was on succeeding years when there was sufficient soil moisture and warmer soil temperatures. However, mechanical fallowing the year before often produced the same yields as turning under a pea crop, most likely because of the conservation of soil moisture and warming soil. Yields on crops following peas are potentially higher if the pea crop is turned under while still green (before maturity) as a green manure crop. However, this would not allow any harvest of biomass for forage or seed. Also, because soil temperatures for most crop-producing areas of Alaska are cold, the organic mineralization rates are slower. This results in a slower release of plant-available mineralized forms of nitrogen 2 or more years after incorporation of the pea green manure crop.

Except for nitrogen, fertilization requirements for field peas are similar to those for small grains. Soils with moderate to high levels of available nutrients should receive a complete fertilizer blend of nitrogen, phosphorus, potassium, and sulfur at a ratio of 1:2:1:0.5 N, P_2O_5, K_2O, and S. With irrigated farming practices, the ratio should be reduced to about 0.5:1:0.5:0.25. In ideal growing conditions, a properly inoculated field pea can obtain most of its nitrogen requirement from atmospheric nitrogen, with the remaining requirement met by available soil nitrogen. Nitrogen-fixing nodules on the plant roots are sensitive to soil-based nitrogen sources. As available soil nitrogen increases, nodule formation and nitrogen fixation decrease. Nodule reduction occurs when the available soil nitrogen level is around 25 to 35 pounds per acre or higher. On the other hand, if available soil nitrogen levels are less than about 10 pounds per acre, then early plant growth is limited because of the nitrogen deficiency. This is because it can take 10 days to 2 weeks for the root nodules to begin functioning efficiently. This can be corrected at planting by adding a small amount of starter nitrogen, such as monoammonium phosphate. Avoid excess nitrogen fertilizer, especially if grown under irrigation, which can induce lodging and delay maturity.

Field peas require a relatively large amount of phosphorus and potassium to promote root and nodule development. Phosphorus and potassium also improve disease resistance and tolerance for frost and drought. Alaska soils are generally acidic, which tends to make phosphorus unavailable for plant uptake. Banding the phosphorus carrier with or next to the seed at planting increases the available phosphorus. The safe maximum level of phosphorus that can be banded with the seed is 15 pounds per acre.

Sulfur and boron are needed by field peas to promote flowering and seed set. Soils low in available sulfur should have sulfur in the form of sulfate broadcast with nitrogen as ammonium sulfate or with the potassium as potassium sulfate. Application rates of 0.5 to 1.0 pound per acre of actual boron can be sufficient to correct most soil deficiencies. Actual percentages of all nutrients and the application rates vary according to specific soil test results. All fertilizer can be broadcast before spring tillage or portions can be banded at planting.

To conserve soil moisture, minimum tillage is recommended for incorporating fertilizer material and plant residue and preparing the seedbed. Pulling a packer behind the tillage implement and using a seed drill equipped with press wheels ensure that the seed is in contact with moist soil during germination. This is especially true if the crop is to be irrigated. The soil should be irrigated sufficiently to bring the soil moisture levels to close to the maximum water-holding capacity before tillage. It is very important not to irrigate above the maximum water-holding capacity before tilling and planting as this could cause a soil crust to form on the surface that would impede seedling emergence, reduce plant density, and lower seed or forage yields. Seeding depth is the same as that for small grains, 1.5 to 2.5 inches, or to moisture. Seeding rates depend on seed size. Generally, recommended rates are 45 to 180 pounds per acre of pure live seed for the small-seed types and 80 to 180 pounds per acre for the large-seed types. Lighter seeding rates are recommended when field peas are interseeded with small grains for forage and in areas of low soil moisture. Early planting dates are recommended to utilize as much of the short growing season as possible. However, planting into seedbeds that are too cold or wet delays germination and promotes fungal attacks on the seed. Seed treatment with a fungicide helps to reduce losses due to fungal attack. Care must be taken in choosing the appropriate fungicide to ensure that there is no adverse effect with the inoculant. Certified seed is strongly recommended. Certified seed has strict limits on maximum content of weed seeds and diseased seed and must meet a minimum percent germination. This helps to ensure good germination and emergence and reduces weed and disease infestations.

Similar to small grains, irrigation should begin again after the crop has reached about 50% emergence to avoid any problems resulting from too hard of a crust on the surface. Thereafter, a good range of irrigation plus precipitation is around 0.5 to 1.0 inch per week. Irrigation should continue until the crop has reached the 50% pod set growth stage.

To induce nodule formation, field peas should be inoculated before planting with the appropriate strain of *Rhizobium* bacteria (*Rhizobium leguminsarium*). Inoculants are highly sensitive to high temperatures, drying winds, direct sunlight, some seed-applied fungicides, and granular fertilizer. Treat the inoculant and the inoculated seed with care and plant the seed as soon after treatment as possible. *Rhizobium* bacteria can live in the soil for a number of years and can thus infect successive field pea crops. However, the most efficient bacteria may not be the ones that survive, so fresh inoculant should be used each year.

Using IPM techniques, assess each field for all pests (weeds, diseases, and insects) and plan control measures accordingly. If weed populations are enough to cause a potential loss in yield or quality of the crop, application of herbicides may be warranted. Weed control in field peas is a combination of mechanical and chemical summer fallow to reduce the number and species of weeds for the following season and an application of a post-emergence herbicide when needed as determined through IPM practices. Field peas, especially the semi-leafless types, are poor competitors against weeds, particularly in the early growth stages. The best broad-leaved weed control can be with the broadleaf-selective herbicide MCPA (which is labeled for use on peas) applied before the field peas are in the 5-node stage; later applications result in crop injury. To eliminate grassy weeds with chemical fallow, a broad-spectrum, post-emergence herbicide such as glyphosate (Roundup) can be used. Gray molds (*Botrytis* spp.) can infect field peas late in the season when the canopy has closed and the crop lodges. High precipitation and low temperatures in late summer are not enough to completely dry the crop, creating an environment ideal for gray molds. However, gray molds do not usually occur in high enough concentrations to warrant treatment during every growing season. Grasshoppers, including the lesser migratory grasshopper (*Melanoplus sanguinipes* Fabricias), the northern grasshopper (*Melanoplus borealis* Fieber), and the clear-winged grasshopper (*Camnula pellucida* Scudder), can attack young field peas, often severely enough to seriously affect yield, sometimes completely consuming entire fields. If insect population levels and damage have been determined to be too high through IPM practices, then the application of an insecticide may be warranted. Insecticide sprays or baits can help control heavy infestations if applied at the nymph growth stage. Always remember to read the pesticide label to be sure the crop is specified and follow the directions on mixing, application, and disposal. Contact your local Cooperative Extension Service for more information on pest control (see Appendix 1 for addresses and contact information).

In the fall, large flocks of pigeons and migratory waterfowl can seriously reduce yield and cause serious lodging while trying to get at the seed. Propane scare cannons, designed to swivel in different directions and go off at uneven time intervals, are recommended to keep birds away. Check with and inform the neighbors before setting up cannons.

Large ungulates like moose and bison can also cause serious damage to the crop. A single moose or a cow and calf pair usually don't cause much damage to large fields but can wipe out small-scale plots over the summer. They are attracted to newly emerging plants and will keep coming back through the season to graze. In the Delta Junction area, bison congregate in large herds that don't usually cause serious damage until their fall migrations north of the Alaska Highway. This migration occurs during the time when the peas are mature, ripe, and ready for harvest. The bison may eat large portions of the crop, and a large herd walking through or bedding down in the field can flatten the crop into the ground, making harvest impossible. It is illegal to harass wildlife in Alaska so the only control is to erect large (6 feet or higher), stout, highly visible fencing that can direct the animals around the fields. For more information on wildlife control in agricultural fields, contact the local office of the Alaska Department of Fish and Game.

Field pea ripening progresses from the bottom of the plant up. The seed is ripe when it can't be dented with a thumbnail. The crop should be swathed when the bottom 30% of the pods are ripe, the middle 40% of the pods are yellow, and the upper 30% of the pods are turning yellow. Before combining, the seed must be at 18% to 20% moisture. To thresh properly during field combining, the crop must be at full maturity. Green, wet vines can become wrapped up in the pickup reels, the feed augers, and the cylinders. This reduces threshing efficiency and could necessitate shutting down the combine to clean out plant residues. For easier harvest of the tangled crop, equip combines with vine lifters and pickup reels, especially for the intertwining, semi-leafless varieties. Dry field pea pods can shatter or crack easily when very dry. Use lower reel and cylinder speeds than for small grains and set the concave openings to just larger than the seed size, with a larger opening in the front. To reduce cracked seed, run augers full or at lower speeds. Because food grade standards only allow 4% cracked seed, continual checking for cracked seeds and adjusting combining methods is important. Food-grade field peas can't contain any other crops or foreign material and only 2% bleached seed. Bleached seed is caused by high humidity, bright sunshine, and warm temperatures. This is most important on the green-seed types. When moisture conditions cause soil to stick to the seed during harvest, dirty seed, or "earth tag" results. Any seed lot not meeting higher food grades is purchased at lower feed prices. On-farm cleaning and sizing to food grade standards before shipment results in higher prices paid to the producer. Clean-outs can be used on farm or sold as lower grade feed seed. Moisture content of field pea seed for safe, long-term storage is 16%. Dry on farm any crop harvested at higher moisture conditions. To avoid reduced germination of seed, drying heat should not exceed 110°F. For feed, temperatures at or below 160°F can be used.

Most field peas in Alaska are grown for forage either alone or interseeded with oats. A limited acreage is grown for seed production. All field pea production is intended for on-farm use as a protein supplement in livestock feed diets. Although there is a small health food niche market in Alaska for processed whole or split peas, at present there are no processing facilities or elevators in Alaska set up to accept field peas. The cost of importing certified field pea seed into Alaska is high due to seed weight. Older, deregistered varieties are constantly being replaced by newer registered varieties, making seed supplies for older varieties much harder to find. Therefore, another small niche market exists for certified seed, but it is difficult to consistently produce a mature, evenly dry seed crop.

Recommended Variety Descriptions for Green and Yellow Dry Field Pea

Note: See Appendix 1 for the addresses of seed suppliers.

'Carneval' is an early-maturing, short, semi-leafless, strong-stemmed, high-yielding, yellow-seed field pea developed by the Swedish company Svalof Weibull AB in Alberta. 'Carneval' has superior stem strength and standability. It is suitable for seed and forage production with high yields and high protein content. This variety is protected by Canadian plant breeders' rights. Producers may save seed for their own use on their own farms, but sale or transfer of seed is prohibited without written permission and a payment of royalties to the breeder. Since this is an older variety, seed sources may be difficult to find. Direct inquiries about seed sources to Viterra, Inc. in Regina, Saskatchewan.

'Express' is an early-maturing, short, high-yielding, semi-leafless, yellow-seed field pea registered in 1978 in Canada. It is suitable for seed and forage production with high yields and high protein content. This was the standard variety against which all other field pea and chickpea varieties were compared. This variety has been deregistered and is now in the public domain. Since this is an older variety, seed sources may be difficult to find. Direct inquiries about seed sources to the Crop Diversification Centre South, in Brooks, Alberta.

'SW Midas' is an early-maturing, short, semi-leafless, strong-stemmed, high-yielding, yellow-seed field pea developed by the Swedish company Svalof Weibull (SW) AB in Alberta. 'SW Midas' has superior stem strength and standability. It is suitable for seed and forage production with high yields and high protein content. This variety is protected by Canadian plant breeders' rights. Producers may save seed for their own use on their own farms, but sale or transfer of seed is prohibited without written permission and a payment of royalties to the breeder. Direct inquiries about seed sources to Pulse USA.

Yields and Quality by Location for Green and Yellow Dry Field Pea

All field peas (green and yellow seed) are bought and sold by weight. The standard test weight for field peas is used as the legal unit for crop sales. The standard test weight for clean, dry, and undamaged field peas is 60 pounds per bushel. The highest prices are paid to the producer for niche crop markets only if they meet the quality criteria mentioned previously. Other than test weights, additional samples should be taken on farm to determine quality. Because seed lots not meeting high-quality standards should be used as lower feed grades, it is important for the producer to clean and size all seed lots before delivery to a niche market. Test weights are used here as a measure of seed quality to determine maturity. Yields are expressed here in pounds per acre and bushels per acre. Determine bushels per acre by dividing the yield of any specific cultivar by the standard test weight.

Tables 75, 77, 79 and 80 list yields and quality measurements for field pea varieties at 3 test locations: Fairbanks, Eielson, and Delta Junction. All sites in the Delta Junction area have been combined into either the Delta dryland site (Table 79) or, if grown under irrigation, the Delta irrigated site (Table 80). Each table also contains information on seed type (green or yellow, normal-leafed or semi-leafless), biomass yield on a dry weight basis as a forage crop, canopy heights, and the years it was tested at each location. Maturity in this study was considered to have occurred when 50% of the pods in each plot were yellow and the seed could not be dented with a thumbnail. Growing degree days (GDD) for average maturity were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. The low temperature point for field peas in this report is the freezing point of water, 32°F. The GDD calculations for each day were then added to the preceding GDD value to determine the date at which the specific variety had reached 50% maturity. All varieties were compared with 'Express' yellow-seed, semi-leafless field pea as the standard variety. Yield as a percent of the standard variety 'Express' was determined by dividing the average yield of each variety by the average yield of 'Express'. Maturity vs. Std. (Standard variety) is the number of days it took for each variety to reach 50% maturity either before or after the number of days that 'Express' reached 50% maturity.

Tables 76 and 78 list the animal feed quality analysis of the forage, on a dry weight basis, for select field pea varieties for the Fairbanks and Eielson test locations. It is presented here without statistical differences and solely for the reader's benefit. Industry standards for each of the pea forage quality measures can be highly variable. B. Thaler and H. Stein (2003) report that white-flowered pea varieties have higher levels of energy and amino acid availability than the colored flowered varieties and that round seed types have more mineral nutrition than wrinkled seed types. Therefore, average values are presented for the industry standards instead of a range of potential values. Detailed explanation of the feed analysis that follows as well as laboratory procedures can be obtained from J. Schroeder (1994) and G.J. Michaelson and others (1987).

Percent crude protein is calculated from the total percent nitrogen analysis of the seed multiplied by a constant of 6.25. Crude protein is made up of amino acids, which are 16% nitrogen, as well as other non-protein portions of the plant, and so percent crude protein is not a measure of true protein. Industry standards for field pea forage are set for a range between 10% and 20% crude protein. Higher values have greater nutritional food value. In a standard feed analysis, other major nutrient mineral concentrations that are commonly measured are percent phosphorus (%P), potassium (%K), calcium (%Ca), and magnesium (%Mg). Minor animal nutrient concentrations that are measured in parts per million include copper (ppm Cu), zinc (ppm Zn), manganese (ppm Mn), and iron (ppm Fe).

Percent crude fat (%Fat) is a measure of the amount of oil contained in the plant. Plant-based oils contribute some of the essential fatty acids and energy needed in animal diets. High levels of these oils can supply more energy but they also dilute mineral nutrient concentrations.

Percent dry matter (%DM) is the amount of plant biomass left after the water has been driven off in an oven at 140°F. The actual time that it takes to dry to a constant weight at 140°F varies from a few days to a week or more, depending on the type of plant matter. The nutrient concentrations are always expressed on a dry-weight basis as it allows for better comparisons between different types of plants.

Percent neutral detergent fiber (%NDF) is a measure of partially digestible plant material (lignin, hemicellulose, and cellulose). Lower levels of NDF usually result in a higher animal intake of the feed. It is also used to calculate the dry matter intake (DMI), where DMI = 120 ÷ %NDF. This value is later used to determine the relative feed value.

Percent acid detergent fiber (%ADF) is a measure of the highly indigestible plant material (lignin and cellulose). Higher levels of ADF usually indicate a low digestibility of the plant material. It is also used to calculate the digestible dry matter (DDM), where DDM = 88.9 - (0.779 x %ADF). This value is also used later to determine the relative feed value.

The relative feed value (RFV) is a unitless index that combines the nutritional factors of the dry matter intake and the digestible dry matter of the plant material, where RFV = (DDM x DMI) ÷ 1.29. Plant material with an ADF of 41% and a NDF of 53% has a RFV of 100. All other plant material is compared to this value. Lower ADF and NDF values will cause the RFV to increase. The higher the RFV, the lower the overall quality of the feed.

Percent cellulose (%Cellulose) is a measure of partially digestible plant material. Percent lignin (%Lignin) is a measure of highly indigestible plant material. Both percentages are determined from %ADF and %NDF determinations. Higher %ADF and %NDF result in higher percentages of indigestible plant material (%Lignin), which usually leads to lower feed intake and animal performance.

Table 75. Average yields and quality measurements for all field pea varieties from test plots in the Fairbanks area.

Field Pea Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test Weight (lbs/bu)	Biomass Yield (lbs/acre)	Lodging (%)	Canopy Height (in)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Yellow seed normal-leaf, spring												
CPB Concorde	United Kingdom	1	0	0	0	0	7391	75	14	4-Aug	1	2355
Discovery	United Kingdom	1	0	0	0	0	8824	50	24	8-Aug	5	2464
Endeavor	United Kingdom	1	0	0	0	0	8145	50	22	6-Aug	3	2411
Grande	Sweden	2	3316	55	204	62	9812	25	26	6-Aug	3	2411
Yellow seed semi-leafless, spring												
Anno	Denmark	2	1986	33	122	63	10,398	50	20	4-Aug	1	2355
Baroness	United Kingdom	2	1715	29	106	62	7922	25	22	9-Aug	6	2490
Carneval	Sweden	3	2813	47	173	62	9433	25	23	11-Aug	8	2541
CDC Yorkton	Saskatchewan	1	0	0	0	0	10,825	50	26	1-Aug	-2	2273
Celeste	France	3	2677	45	165	62	11,084	50	18	6-Aug	3	2411
Century	Canada	1	0	0	0	0	N/D	50	30	23-Aug	20	2808
Choque	France	2	2882	48	177	64	7307	25	22	7-Aug	4	2438
Express	Sweden	3	1625	27	100	63	9286	50	18	3-Aug	0	2328
Fluo	France	2	2913	49	179	63	11,395	25	17	5-Aug	2	2383
Highlight	Sweden	3	2968	49	183	52	7472	50	20	6-Aug	3	2411
Impala	Netherlands	2	524	9	32	63	9405	25	17	8-Aug	5	2464
LU-1-209	Canada	1	0	0	0	0	10,432	75	21	8-Aug	5	2285
Miranda	Canada	1	1224	20	75	62	N/D	75	11	9-Aug	6	2490
Montana	Netherlands	2	2479	41	153	61	10,742	50	17	5-Aug	2	2383
Mustang	Denmark	1	0	0	0	0	8680	25	20	28-Jul	-6	2162
Orb	United Kingdom	2	2654	44	163	62	N/D	50	17	29-Jul	-5	2189
Profi	Denmark	2	0	0	0	0	11,171	50	23	4-Aug	1	2355
Ricardo	Canada	1	1847	31	114	62	N/D	75	11	10-Aug	7	2515
Scorpio	Netherlands	2	2610	44	161	64	10,963	75	16	4-Aug	1	2355
Spitfire	United Kingdom	1	0	0	0	0	11,554	50	22	5-Aug	2	2383
Spring D	Denmark	1	2839	47	175	63	N/D	0	21	5-Aug	2	2383
Stehgolt	Canada	1	1897	32	117	63	N/D	50	19	8-Aug	5	2464
SV C 37133	Sweden	1	0	0	0	0	8145	50	22	8-Aug	5	2464
SV C 61414	Sweden	1	0	0	0	0	8824	50	24	8-Aug	5	2464
SV E 12226	Sweden	1	0	0	0	0	10,766	50	21	8-Aug	5	2464
SV 0 32440	Sweden	1	0	0	0	0	11,270	50	17	8-Aug	5	2464
SW Midas	Sweden	1	0	0	0	0	N/D	100	25	17-Aug	14	2588
Trump	Ontario	1	1521	25	94	62	N/D	75	10	9-Aug	6	2490
Voyager	Sweden	1	0	0	0	0	10,766	50	20	5-Aug	2	2383
Green seed normal-leaf, spring												
Clipper	Czech Republic	1	0	0	0	0	10,432	75	21	3-Aug	0	2328
Patriot	Sweden	2	1987	33	122	63	N/D	50	15	31-Jul	-3	2244

Table 75 (continued). Average yields and quality measurements for all field pea varieties from test plots in the Fairbanks area.

Field Pea Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test Weight (lbs/bu)	Biomass Yield (lbs/acre)	Lodging (%)	Canopy Height (in)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Green seed semi-leafless, spring												
Ascona	Canada	2	0	0	0	0	6499	25	19	14-Aug	11	2616
CDC Sage	Saskatchewan	1	0	0	0	0	N/D	100	25	17-Aug	14	2588
CPB Phantom	United Kingdom	1	0	0	0	0	9861	50	18	4-Aug	1	2355
Danto	Denmark	2	1896	32	117	62	12,379	25	19	7-Aug	4	2438
Keoma	Alberta	2	2239	37	138	62	9299	50	18	8-Aug	5	2464
Majoret	Sweden	3	1835	31	113	62	10,816	25	23	13-Aug	10	2592
Promar	Denmark	2	1532	26	94	63	8006	50	17	10-Aug	7	2515
Radley	Canada	1	2395	40	147	63	N/D	25	22	7-Aug	4	2438
SW Parade	Sweden	2	0	0	0	0	N/D	75	13	17-Aug	14	2493
Totem	Sweden	1	0	0	0	0	11,270	50	17	8-Aug	5	2464

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. N/D = No Data. All varieties were compared with 'Express' yellow-seed, semi-leafless field pea as the standard variety

Field pea blossoms, photographed in the Netherlands. Photo taken by user Rasbak and placed on Wikimedia with a Creative Commons Attribution-Share Alike 3.0 Unported license.

Field pea pod. Field peas are one of the oldest domesticated crops, grown for at least 7,000 years. Color of bloom and shape of seed may be related to nutritional content, with white flowers and round seeds being more nutritious. (Thaler and Stein 2003). Photo taken by user Rasbak and placed on Wikimedia under a Creative Commons Attribution-Share Alike 3.0 Unported license.

Table 76. Average forage quality measurements for select field pea varieties from test plots in the Fairbanks area.

Field Pea Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)	Total Ca (%)	Total Mg (%)	Total Cu (ppm)	Total Zn (ppm)	Total Mn (ppm)	Total Fe (ppm)	Crude Fat (%)	Dry Matter (%DM)	NDF (%)	ADF (%)	Relative Feed Value	Cellulose (%)	Lignin (%)
Forage Industry Standards			**17.0**	**0.44**	**1.05**	**0.82**	**1.42**	**7**	**39**	**120**	**56**	**1.3**	**88.10**	**37.10**	**30.70**	**163**	**23.10**	**6.40**
Yellow seed normal-leaf, spring																		
CPB Concorde	United Kingdom	1	12.55	0.13	1.39	2.98	0.51	3	28	84	145	1.30	94.09	41.52	28.81	149	22.96	5.85
Discovery	United Kingdom	1	8.44	0.12	0.91	1.77	0.28	4	20	50	117	0.93	94.80	45.69	31.83	131	26.42	5.40
Endeavor	United Kingdom	1	13.71	0.12	1.28	2.13	0.32	2	19	40	125	1.00	94.38	41.83	24.47	155	20.36	4.11
Grande	Sweden	2	10.02	0.11	1.08	1.48	0.27	3	21	28	93	1.18	94.79	32.24	21.47	208	17.90	3.56
Yellow seed semi-leafless, spring																		
Anno	Denmark	2	9.29	0.11	1.02	1.71	0.30	3	33	76	102	0.87	94.79	35.78	22.77	185	19.33	3.43
Baroness	United Kingdom	2	9.74	0.11	1.04	1.56	0.26	2	22	42	100	0.99	95.01	41.35	28.05	151	22.68	5.37
Carneval	Sweden	3	12.37	0.13	1.30	2.23	0.36	1	15	34	137	0.83	94.50	34.52	24.00	189	19.59	4.41
CDC Yorkton	Saskatchewan	1	10.23	0.10	0.94	1.84	0.35	3	39	71	94	1.06	94.73	31.09	19.81	220	15.96	3.84
Celeste	France	3	10.24	0.11	1.24	2.36	0.41	3	22	90	87	1.42	94.59	38.63	26.27	165	22.25	4.02
Choque	France	2	12.82	0.11	1.33	2.17	0.32	3	21	41	117	0.93	94.62	44.23	30.61	137	25.84	4.77
Express	Sweden	3	12.25	0.11	1.07	2.29	0.36	4	29	68	188	0.99	94.56	45.85	30.55	132	25.43	5.13
Fluo	France	2	14.70	0.12	1.74	2.37	0.39	5	95	95	245	1.31	94.43	34.77	22.81	190	20.10	2.71
Highlight	Sweden	3	11.19	0.08	1.17	2.59	0.47	3	39	192	160	0.81	94.37	34.64	24.01	189	20.68	3.33
Impala	Netherlands	2	11.12	0.12	1.12	2.76	0.45	3	22	40	103	0.87	93.90	40.94	26.64	155	21.02	5.62
LU-1-209	Canada	1	15.39	0.16	1.60	2.21	0.38	5	45	80	90	0.74	94.58	45.30	29.40	136	24.91	4.50
Montana	Netherlands	2	13.41	0.12	1.25	2.11	0.35	6	47	55	121	1.48	94.82	43.47	34.22	133	29.47	4.75
Mustang	Denmark	1	13.25	0.12	1.09	2.21	0.35	3	28	61	127	1.02	93.92	32.59	20.11	209	17.79	2.32
Profi	Denmark	2	12.37	0.14	1.29	1.87	0.34	4	58	202	101	0.88	94.47	36.79	24.47	177	20.87	3.59
Scorpio	Netherlands	2	13.93	0.13	1.27	2.33	0.37	3	33	45	136	1.06	94.27	34.52	22.13	193	19.56	2.57
Spitfire	United Kingdom	1	14.11	0.12	1.57	2.53	0.37	5	53	99	157	1.08	94.35	32.72	22.77	202	19.20	3.57
SV C 37133	Sweden	1	13.71	0.12	1.28	2.13	0.32	2	19	40	125	1.00	94.38	41.83	24.47	155	20.36	4.11
SV C 61414	Sweden	1	8.44	0.12	0.91	1.77	0.28	4	20	50	117	0.93	94.80	45.69	31.83	131	26.42	5.40
SV E 12226	Sweden	1	12.78	0.13	1.54	2.71	0.40	3	55	171	163	1.12	94.39	37.51	25.55	171	22.20	3.36
SV 0 32440	Sweden	1	18.14	0.18	1.68	2.18	0.40	7	47	47	147	1.12	94.42	36.87	25.09	175	21.51	3.58
Voyager	Sweden	1	12.78	0.13	1.54	2.71	0.40	3	55	171	163	1.12	94.39	37.51	25.55	171	22.20	3.36
Green seed normal-leaf, spring																		
Clipper	Czech Republic	1	15.39	0.16	1.60	2.21	0.38	5	45	80	90	0.74	94.58	45.30	29.40	136	24.91	4.50

Green seed semi-leafless, spring																		
Ascona	Canada	2	15.96	0.12	1.73	2.49	0.36	5	15	61	183	1.25	94.36	39.39	25.67	163	22.30	3.37
CPB Phantom	United Kingdom	1	12.49	0.13	1.50	2.01	0.36	5	77	139	166	1.10	94.55	40.89	28.57	152	23.58	4.99
Danto	Denmark	2	13.09	0.13	1.84	1.88	0.41	5	77	96	99	1.20	95.05	45.95	33.81	127	28.69	5.12
Keoma	Alberta	2	14.07	0.14	1.43	2.72	0.46	5	40	125	204	1.27	94.19	38.22	21.87	175	18.69	3.18
Majoret	Sweden	3	12.02	0.12	1.44	2.40	0.46	3	78	169	119	1.27	94.13	29.67	20.31	229	19.67	2.84
Promar	Denmark	2	19.14	0.16	1.96	2.35	0.45	7	41	51	185	1.23	94.35	39.16	27.41	161	21.46	5.95
Totem	Sweden	1	18.14	0.18	1.68	2.18	0.40	7	47	47	147	1.12	94.42	36.87	25.09	175	21.51	3.58

Analysis done on whole plant biomass (seed and stems) when pods were still green. All varieties were compared with 'Express' yellow-seed, semi-leafless field pea as the standard variety.

Table 78. Average forage quality measurements for select field pea varieties from test plots in the Eielson area.

Field Pea Variety Name	Source	Years Tested	Crude Protein (%)	Total P (%)	Total K (%)	Total Ca (%)	Total Mg (%)	Total Cu (ppm)	Total Zn (ppm)	Total Mn (ppm)	Total Fe (ppm)	Crude Fat (%)	Dry Matter (%DM)	NDF (%)	ADF (%)	Relative Feed Value	Cellulose (%)	Lignin (%)
Forage Industry Standards			**17.0**	**0.44**	**1.05**	**0.82**	**1.42**	**7**	**39**	**120**	**56**	**1.3**	**88.10**	**37.10**	**30.70**	**163**	**23.10**	**6.40**
Yellow seed normal-leaf, spring																		
CPB Concorde	United Kingdom	1	12.31	0.12	0.62	2.75	0.88	2	16	20	88	1.09	93.42	42.13	26.02	152	21.76	4.27
Discovery	United Kingdom	1	14.90	0.15	0.67	2.98	0.97	4	33	40	115	1.12	93.15	39.07	25.23	165	21.78	3.45
Endeavor	United Kingdom	1	17.59	0.15	0.78	3.04	0.88	2	20	23	76	0.73	93.11	41.32	21.24	163	17.23	4.01
Grande	Sweden	2	11.37	0.13	0.66	2.80	0.97	3	27	44	109	1.14	92.86	38.34	24.82	169	21.50	3.31
Yellow seed semi-leafless, spring																		
Anno	Denmark	2	17.31	0.17	0.94	2.65	0.72	2	30	20	148	0.92	93.87	40.86	25.30	158	21.15	4.16
Baroness	United Kingdom	2	11.50	0.14	0.68	2.84	0.96	2	28	31	129	1.20	92.99	40.73	28.15	153	22.39	5.75
Carneval	Sweden	3	19.24	0.24	0.91	2.99	0.92	3	26	31	104	0.60	93.36	37.19	21.14	181	18.05	3.09
CDC Yorkton	Saskatchewan	1	12.58	0.13	0.60	3.51	1.27	6	24	42	115	1.05	92.95	37.97	23.15	174	20.09	3.06
Celeste	France	3	18.07	0.25	0.83	2.46	0.75	3	18	22	93	1.09	93.57	41.31	26.68	153	22.17	4.51
Century	Canada	1	24.55	0.38	1.01	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Choque	France	2	15.08	0.11	0.64	3.85	1.27	2	14	31	96	1.43	92.47	35.51	22.76	186	19.65	3.12
Express	Sweden	3	15.79	0.13	0.53	3.52	1.23	3	22	24	113	1.06	92.66	31.35	21.67	214	18.64	3.03
Fluo	France	2	17.46	0.20	0.77	2.63	0.76	3	29	28	135	1.22	93.09	39.40	21.92	170	18.79	3.13
Highlight	Sweden	3	19.88	0.24	0.89	4.23	1.14	4	21	35	114	1.43	92.41	30.33	18.14	229	16.03	2.10
Impala	Netherlands	2	15.17	0.18	0.66	2.63	0.99	3	30	38	126	0.91	92.68	37.22	20.14	183	18.32	1.82
LU-1-209	Canada	1	10.39	0.11	0.64	3.86	1.13	3	28	38	128	0.95	92.72	43.67	26.33	146	22.03	4.30
Montana	Netherlands	2	18.35	0.18	0.80	2.93	0.95	4	26	26	103	1.48	92.99	38.67	22.95	171	19.61	3.34
Mustang	Denmark	1	14.79	0.14	0.58	3.06	1.01	2	17	26	80	0.95	92.96	39.27	24.39	166	20.85	3.54
Profi	Denmark	2	19.20	0.23	0.86	4.04	1.16	3	20	27	94	1.12	92.92	38.22	22.68	173	19.49	3.19
Scorpio	Netherlands	2	16.79	0.16	0.78	3.40	1.00	6	30	30	105	1.32	92.70	36.31	18.73	190	16.59	2.13
Spitfire	United Kingdom	1	12.74	0.14	0.59	3.33	1.25	2	24	38	126	1.08	92.24	38.66	24.39	168	18.97	5.42
SV C 37133	Sweden	1	17.59	0.15	0.78	3.04	0.88	2	20	23	76	0.73	93.11	41.32	21.24	163	17.23	4.01
SV C 61414	Sweden	1	14.90	0.15	0.67	2.98	0.97	4	33	40	115	1.12	93.15	39.07	25.23	165	21.78	3.45
SV E 12226	Sweden	1	17.21	0.16	0.70	2.99	1.01	3	23	34	113	1.05	92.95	37.99	21.89	176	18.61	3.27

SV 0 32440	Sweden	1	15.62	0.12	0.72	3.81	1.09	4	28	29	114	0.65	92.81	36.62	22.60	181	20.04	2.56
Voyager	Sweden	1	17.21	0.16	0.70	2.99	1.01	3	23	34	113	1.05	92.95	37.99	21.89	176	18.61	3.27
Green seed normal-leaf, spring																		
Clipper	Czech Republic	1	10.39	0.11	0.64	3.86	1.13	3	28	38	128	0.95	92.72	43.67	26.33	146	22.03	4.30
Green seed semi-leafless, spring																		
Ascona	Canada	2	21.57	0.27	0.91	3.77	1.03	3	31	31	132	0.97	93.03	37.86	19.13	182	16.23	2.91
CPB Phantom	United Kingdom	1	11.73	0.10	0.63	5.36	1.52	2	35	59	158	1.17	92.15	34.83	19.52	197	16.05	3.48
Danto	Denmark	2	14.50	0.15	0.74	3.39	0.97	8	29	42	104	1.20	93.08	41.85	26.93	151	22.92	4.01
Keoma	Alberta	2	15.98	0.10	0.68	4.03	1.12	1	24	35	119	1.08	92.65	33.08	20.53	205	15.23	5.30
Majoret	Sweden	3	20.74	0.26	0.84	3.64	1.21	4	22	33	151	1.29	92.90	33.96	21.65	197	18.48	3.17
Promar	Denmark	2	12.56	0.13	0.73	3.29	0.95	16	31	29	136	1.20	93.06	38.90	21.55	172	18.36	3.19
Totem	Sweden	1	15.62	0.12	0.72	3.81	1.09	4	28	29	114	0.65	92.81	36.62	22.60	181	20.04	2.56

Analysis done on whole plant biomass (seed and stems) when pods were still green. N/D = No Data. All varieties were compared with 'Express' yellow-seed, semi-leafless field pea as the standard variety.

Table 77. Average yields and quality measurements for all field pea varieties from test plots in the Eielson area.

Field Pea Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test Weight (lbs/bu)	Biomass Yield (lbs/acre)	Lodging (%)	Canopy Height (in)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Yellow seed normal-leaf, spring												
CPB Concorde	United Kingdom	1	4468	74	132	58	10,937	75	24	13-Aug	-8	2599
Discovery	United Kingdom	1	6780	113	200	58	19,746	50	32	16-Aug	-5	2670
Endeavor	United Kingdom	1	4027	67	119	59	14,550	75	32	14-Aug	-7	2624
Grande	Sweden	2	4867	81	143	57	14,183	75	24	19-Aug	-2	2737
Yellow seed semi-leafless, spring												
Anno	Denmark	2	3334	56	98	60	10,027	75	25	20-Aug	-1	2757
Baroness	United Kingdom	2	4473	75	132	60	11,544	25	31	21-Aug	0	2778
Carneval	Sweden	3	3766	63	111	56	19,426	25	36	19-Aug	-2	2737
CDC Yorkton	Saskatchewan	1	5679	95	167	58	22,006	75	28	15-Aug	-6	2647
Celeste	France	3	3396	57	100	56	12,948	75	22	22-Aug	1	2798
Century	Canada	1	442	7	13	45	N/D	25	35	25-Aug	4	2858
Choque	France	2	3068	51	90	60	12,605	50	31	19-Aug	-2	2737
Express	Sweden	3	3396	57	100	58	17,055	50	22	21-Aug	0	2778
Fluo	France	2	3285	55	97	60	13,873	50	21	17-Aug	-4	2693
Highlight	Sweden	3	3328	55	98	57	17,386	50	31	25-Aug	4	2858
Impala	Netherlands	2	3054	51	90	58	20,273	75	24	22-Aug	1	2798
LU-1-209	Canada	1	4364	73	129	57	18,514	75	30	22-Aug	1	2798
Miranda	Canada	1	1402	23	41	60	N/D	75	16	20-Aug	-1	2757
Montana	Netherlands	2	3996	67	118	59	10,377	50	24	16-Aug	-5	2670
Mustang	Denmark	1	4195	70	124	58	15,940	50	33	12-Aug	-9	2574
Orb	United Kingdom	2	2281	38	67	60	N/D	75	20	16-Aug	-5	2670
Yellow seed semi-leafless, spring, continued												
Profi	Denmark	2	3098	52	91	56	16,478	50	36	18-Aug	-3	2716
Ricardo	Canada	1	1607	27	47	61	N/D	50	17	31-Aug	10	2973
Scorpio	Netherlands	2	3116	52	92	60	11,707	75	21	11-Aug	-10	2548
Spitfire	United Kingdom	1	6055	101	178	58	16,301	75	32	17-Aug	-4	2693
Spring D	Denmark	1	2433	41	72	60	N/D	25	24	22-Aug	1	2798
Stehgolt	Canada	1	1783	30	53	62	N/D	25	21	28-Aug	7	2918
SV C 37133	Sweden	1	4027	67	119	59	14,550	75	32	28-Aug	7	2918
SV C 61414	Sweden	1	6780	113	200	58	19,746	50	32	28-Aug	7	2918
SV E 12226	Sweden	1	5876	98	173	58	13,038	50	31	28-Aug	7	2918
SV 0 32440	Sweden	1	5073	85	149	56	15,988	50	29	28-Aug	7	2918
Trump	Ontario	1	1481	25	44	59	N/D	50	16	27-Aug	6	2899
Voyager	Sweden	1	5876	98	173	58	13,038	50	31	18-Aug	-3	2716

Green seed normal-leaf, spring												
Clipper	Czech Republic	1	4364	73	129	57	18,514	75	30	13-Aug	-8	2599
Patriot	Sweden	2	2310	39	68	60	N/D	0	26	16-Aug	-5	2670
Green seed semi-leafless, spring												
Ascona	Canada	2	4382	73	129	56	16,258	50	30	21-Aug	0	2778
CPB Phantom	United Kingdom	1	4699	78	138	58	11,531	50	27	17-Aug	-4	2693
Danto	Denmark	2	3954	66	116	59	13,178	50	27	21-Aug	0	2778
Keoma	Alberta	2	3506	58	103	60	13,009	50	27	22-Aug	1	2798
Majoret	Sweden	3	2628	44	77	58	14,241	25	30	23-Aug	2	2818
Promar	Denmark	2	2968	49	87	59	13,943	25	23	25-Aug	4	2858
Radley	Canada	1	2036	34	60	59	N/D	25	22	11-Aug	-10	2548
Totem	Sweden	1	5073	85	149	56	15,988	50	29	22-Aug	1	2798

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. N/D = No Data. All varieties were compared with 'Express' yellow-seed, semi-leafless field pea as the standard variety.

Table 79. Average yields and quality measurements for all field pea varieties from test plots in the Delta Junction area, dryland.

Field Pea Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test Weight (lbs/bu)	Biomass Yield (lbs/acre)	Lodging (%)	Canopy Height (in)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Yellow seed normal-leaf, spring												
Grande	Sweden	2	796	13	317	64	N/D	0	20	10-Aug	0	2313
Korando	North Dakota	1	410	7	100	60	N/D	90	18	21-Aug	11	2533
Yellow seed semi-leafless, spring												
Anno	Denmark	2	700	12	279	64	N/D	25	18	8-Aug	-2	2265
Baroness	United Kingdom	2	426	7	170	63	N/D	25	15	5-Aug	-5	2191
Carneval	Sweden	4	591	10	236	62	N/D	25	26	11-Aug	1	2337
Celeste	France	2	597	10	238	64	N/D	25	11	7-Aug	-3	2241
Choque	France	2	823	14	328	61	N/D	25	14	6-Aug	-4	2217
Express	Sweden	6	251	4	100	62	N/D	25	15	10-Aug	0	2289
Fluo	France	2	663	11	264	64	N/D	50	10	4-Aug	-6	2165
Highlight	Sweden	2	584	10	233	62	N/D	0	15	5-Aug	-5	2190
Impala	Netherlands	2	312	5	124	64	N/D	25	15	13-Aug	3	2383
LU-1-209	Canada	1	0	0	0	0	N/D	50	15	8-Aug	-2	2165
Miranda	Canada	1	299	5	119	63	N/D	50	9	6-Aug	-4	2217
Montana	Netherlands	2	715	12	285	63	N/D	25	13	8-Aug	-2	2265
Orb	United Kingdom	2	544	9	217	62	N/D	25	13	13-Aug	3	2383
Ricardo	Canada	1	503	8	201	65	N/D	25	12	4-Aug	-6	2165
Scorpio	Netherlands	2	458	8	183	63	N/D	25	13	6-Aug	-4	2217
Spring D	Denmark	1	782	13	312	63	N/D	0	16	6-Aug	-4	2217
Stehgolt	Canada	1	439	7	175	63	N/D	25	13	7-Aug	-3	2241
SV C 37133	Sweden	1	0	0	0	0	N/D	50	12	7-Aug	-3	2241
SV C 61414	Sweden	1	0	0	0	0	N/D	50	12	7-Aug	-3	2241

SV E 12226	Sweden	1	0	0	0	0	N/D	50	11	7-Aug	-3	2241
SV 0 32440	Sweden	1	0	0	0	0	N/D	50	19	7-Aug	-3	2241
Yellow seed semi-leafless, spring, continued												
SW Midas	Sweden	2	213	4	100	60	N/D	45	20	20-Aug	10	2419
Trump	Ontario	1	472	8	188	65	N/D	25	13	5-Aug	-5	2190
Green seed normal-leaf, spring												
Patriot	Sweden	3	584	10	233	62	N/D	25	14	9-Aug	-1	2289
Green seed semi-leafless, spring												
Ascona	Canada	3	0	0	0	0	N/D	0	15	11-Aug	1	2237
CDC Sage	Saskatchewan	2	0	0	0	0	N/D	100	19	11-Aug	1	2419
Danto	Denmark	1	717	12	286	62	N/D	0	14	5-Aug	-5	2190
Keoma	Alberta	2	436	7	174	65	N/D	25	15	8-Aug	-2	2165
Majoret	Sweden	2	510	8	203	63	N/D	25	15	8-Aug	-2	2265
Promar	Denmark	2	402	7	160	62	N/D	25	13	5-Aug	-5	2190
Radley	Canada	1	693	12	276	62	N/D	0	12	5-Aug	-5	2190
SW Parade	Sweden	2	0	0	0	0	N/D	48	15	11-Aug	1	2409

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. N/D = No Data. All varieties were compared with 'Express' yellow-seed, semi-leafless field pea as the standard variety.

Table 80. Average yields and quality measurements for all field pea varieties from test plots in the Delta Junction area, irrigated.

Field Pea Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test Weight (lbs/bu)	Biomass Yield (lbs/acre)	Lodging (%)	Canopy Height (in)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Yellow seed normal-leaf, spring												
Korando	North Dakota	1	1010	17	474	61	N/D	90	20	24-Aug	-4	2608
Yellow seed semi-leafless, spring												
Carneval	Sweden	2	0	0	0	0	N/D	25	32	18-Aug	-10	2489
Express	Sweden	1	0	0	0	0	N/D	75	19	28-Aug	0	2677
SW Midas	Sweden	1	778	13	366	62	N/D	90	17	25-Aug	-3	2621
Green seed normal-leaf, spring												
Patriot	Sweden	1	0	0	0	0	N/D	75	16	27-Aug	-1	2660
Green seed, semi-leafless, spring												
SW Parade	Sweden	2	0	0	0	0	N/D	75	14	11-Aug	-17	2409

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. N/D = No Data. All varieties were compared with 'Express' yellow-seed, semi-leafless field pea as the standard variety.

Chickpeas

Kabuli (Garbanzo bean)

Chickpeas (*Cicer arietinum* L.) are an annual legume pulse crop. They mature later than field peas and require a long, warm growing season. Like field peas, chickpeas are capable of fixing atmospheric nitrogen and produce high yields with high protein concentrations without high levels of nitrogen fertilizer. Chickpeas are an annual plant resembling a small bush about 10 to 12 inches tall with multiple branches. They are classified into 2 main types based on seed size, color, thickness, and shape of the seedcoat. Dezi types have smaller seeds with a thick, irregular-shaped seedcoat that can range in color from a light tan to black. Kabuli types (garbanzo beans) have larger seeds with a thin seedcoat and are white to light tan in color. There are 2 leaf types: the fern leaf, with multiple leaflets attached to a leaf stem, and the unifoliate, or single-leaf type, that is found on some kabuli types. Chickpeas are indeterminate, meaning that they will continue to flower and set seed pods all summer long. Dezi types have purple or red flowers and kabuli types white flowers, reflecting the seed colors. Seed pods are formed on the main stem through the third branch. They are round in shape and contain 1 seed in kabuli types and 2 seeds in dezi types.

Chickpea seed is used for human and livestock consumption. For human consumption, dezi types must have the outer seedcoat mechanically removed. Compared with field peas, chickpeas have a higher nutrient composition with proportionately more protein, carbohydrates, and unsaturated fatty acids. They are ground for livestock to be fed either whole or mixed with

White and green chickpeas, representing two different types (kabuli on the left, dezi on the right). Photo by Sanjay Acharya, from Wikimedia under a Creative Commons Attribution-Share Alike 3.0 Unported license other grains. Unfortunately, they also contain a higher concentration of non-reducing sugars, which produces greater flatulence.

Except for nitrogen, fertilization practices for chickpeas are similar to those for field peas. Soils with moderate to high levels of available nutrients should receive a complete fertilizer blend of nitrogen, phosphorus, potassium, and sulfur at a ratio of 1:2:1:0.5 N, P_2O_5, K_2O, and S. With irrigation farming practices, the ratio should be reduced to about 0.5:1:0.5:0.25. Properly inoculated chickpeas can obtain most of the nitrogen requirement from atmospheric nitrogen, with the remaining requirement coming from available soil nitrogen. Nitrogen-fixing nodules on the plant roots are sensitive to soil-based nitrogen sources. As available soil nitrogen increases, nodule formation and nitrogen fixation decreases. It can take 10 days to 2 weeks after planting for the root nodules to begin functioning efficiently. This can be corrected at planting by adding a small amount of starter nitrogen, such as monoammonium phosphate. Avoid excess nitrogen fertilizer (above 18 pounds per acre), because it can induce lodging and delay maturity, especially if grown under irrigation.

Chickpeas require a relatively high amount of phosphorus and potassium to promote root and nodule development. These nutrients also improve disease resistance and tolerance for frost and drought. Alaska soils are generally acidic, which tends to make phosphorus unavailable for plant uptake. Banding the phosphorus carrier with or next to the seed at planting increases the available phosphorus. The safe maximum level of phosphorus that can be banded with the seed is 15 pounds per acre.

Sulfur and boron are needed by chickpeas to promote flowering and seed set. Soils low in available sulfur should have sulfur in the form of sulfate, broadcast with nitrogen as ammonium sulfate, or with the potassium as potassium sulfate. An application rate of 0.5 pound per acre of actual boron can be sufficient to correct most soil deficiencies. Actual percentages of all nutrients and application rates vary according to the specific soil test results. All fertilizer can be broadcast prior to spring tillage or portions can be banded at planting.

To conserve soil moisture, minimum tillage is recommended for incorporating fertilizer material and plant residue and preparing the seedbed. Pulling a packer behind the tillage implement and using a seed drill equipped with press wheels ensures that the seed is in contact with moist soil during germination. This is especially true if the crop is to be irrigated. The soil should be irrigated sufficiently to bring the soil moisture levels to close to the maximum water-holding capacity before tillage. Seeding should only begin when the soil temperature at 2 to 3 inches deep is at least 40°F. Seeding depth is the same as that for field peas, 1.5 to 2.5 inches, or to moisture. Seeding rate depends on seed size. Generally, the recommended rate is 80-95 pounds per acre of pure live seed for dezi types and 120-140 pounds per acre for the kabuli types. Seed treatment with a fungicide helps to reduce losses from fungal attack. Care must be taken in choosing the appropriate fungicide to ensure that there is no adverse effect with the inoculant. Certified seed is strongly recommended. Certified seed has strict limits on maximum content of weed seeds and diseased seed, and must meet a minimum percent germination. This helps to ensure good germination and emergence and reduces weed and disease infestations.

To induce nodule formation, chickpeas should be inoculated prior to planting with the appropriate *Cicer* strain of *Rhizobium* bacteria (*Rhizobium leguminsarium*). Inoculants are highly sensitive to high temperatures, drying winds, direct sunlight, some seed-applied fungicides, and granular fertilizer. Treat the inoculant as well as the inoculated seed with care and plant the seed as soon after treatment as possible. *Rhizobium* bacteria can live in the soil for a number of years and can thus infect successive crops. However, while some inoculant bacteria may return each summer, the most efficient bacteria may not be the ones that survive, so fresh inoculant should be used each year.

Irrigation should begin again after the crop has reached about 50% emergence to avoid any problems resulting from too hard of a crust on the surface. Thereafter, a good range of irrigation plus precipitation is around 0.5 to 1.0 inch per week. Irrigation should continue until the crop has reached the 50% pod set growth stage.

Using IPM techniques, assess each field for all pests (weeds, diseases, and insects) and plan control measures accordingly. If weed populations are high enough to cause a potential loss in yield or quality of the crop, herbicides may be warranted. Chickpeas are poor competitors against weeds, particularly in the early growth stages. The best broad-leaved and grassy weed control has been with mechanical or chemical fallow, a broad-spectrum, nonselective, post-emergence herbicide such as glyphosate (Roundup) used the season before. Grasshoppers, including the lesser migratory grasshopper (*Melanoplus sanguinipes* Fabricias), the northern grasshopper (*Melanoplus borealis* Fieber), and the clear-winged grasshopper (*Camnula pellucida* Scudder), can attack young plants, often severely enough to seriously affect yield, sometimes completely consuming entire fields. If insect population levels and damage have been determined to be too high through IPM practices, then the application of an insecticide may be warranted. Insecticide sprays or baits can help control heavy infestations if applied at the nymph growth stage. Always remember to read the pesticide label to be sure the crop is specified and follow the directions on mixing, application, and disposal. Contact your local Cooperative

Extension Service for more information on pest control (see Appendix 1 for addresses and contact information).

In the fall, large migratory waterfowl can significantly reduce yield and cause serious lodging while trying to get at the seed. Propane scare cannons, which are designed to swivel in different directions and go off at uneven time intervals, are recommended to keep birds away. Check with and inform the neighbors before setting up cannons. For more information on control of wildlife in agricultural fields, contact the local office of the Alaska Department of Fish and Game.

Seed color in chickpeas is the most important factor in determining when to harvest. For kabuli types, the upper pods, stems, and seed should be a light yellow; dezi types will have the same plant color but seed color is dependent on variety type. The seed is ripe when it can't be dented with a thumbnail. Seedcoats that are dark or discolored are rejected for food grade. The crop should be swathed or combined when the seed is between 18% and 20% moisture. To thresh properly during field combining, the crop must be at full maturity. Green, wet plants can get wrapped up in the pick-up reels, the feed augers, and the cylinders. This reduces threshing efficiency and could necessitate shutting down the combine to clean out plant residues. Use lower reel and cylinder speeds than for small grains and set the concave openings to just larger than the seed size, with a larger opening in the front. Chickpea seed has a small, protruding beak-like structure that must not be damaged during harvest and handling. To reduce the amount of damaged and cracked seed, run augers full or at lower speeds. Because food grade standards only allow 4% damaged or cracked seed, continual checking for damaged seeds and adjusting combining methods is important. Food-grade chickpeas can't contain any other crops or foreign material and must have less than 0.5% green seed. Green seed is caused by the indeterminate growth habit of chickpeas. The crop will still be flowering into harvest with many unripe pods. Green pods that are frozen will produce green seed. To improve the quality of the seed lot, producers should harvest around portions of the field with a high percentage of green pods. Any seed lot not meeting standards for higher food grades is purchased at lower feed prices. On-farm cleaning and sizing to food grade standards prior to shipment results in higher prices paid to the producer. Kabuli types are sized according to the hole diameter of a specific screen. "Jumbo" seeds are those that remain on a 22/64-inch screen, "large" are seeds that remain on a 20/64-inch screen, and "medium" are seeds that remain on top of an 18/64-inch screen. Clean-outs can be used on the farm or sold as lower-grade feed. Moisture content of chickpea seed for safe, long-term storage is 15%. Dry on farm any crop harvested at higher moisture conditions.

Chickpea production in Alaska is problematic. It does not compete well with spring weeds and requires a long, warm growing season. Harvest is difficult because of the large amount of plant material, and there can be very little damage on harvested seed to meet food grade standards. There is a small health food niche market for chickpeas that commands a high price paid to producers. However, high production costs and the unlikelihood of consistently producing a high-quality, high-value crop make it economically unviable for Alaska. Because of these cultural problems, no varieties of chickpea are generally recommended. However, just because there was a crop failure for this study does not mean that chickpeas cannot be successfully grown somewhere within the state. Therefore, the reader should not be discouraged from trying any of the chickpea varieties not recommended, but the probability of success in attempting to produce these crops will likely be low.

Chickpea growing at the Berlin Botanical Gardens Berlin-Dahlem, showing the typical multiple or fern-like leaf type. Note white blossoms typical of garbanzo beans. Photo by user BotBin, from Wikimedia under the Creative Commons Attribution-Share Alike 3.0 Unported license

Yields and Quality by Location for Chickpea

All chickpeas (dezi and kabuli) are bought and sold by weight. The standard test weight for field peas is used as the legal unit for crop sales. This standard test weight for clean, dry, undamaged chickpeas is 60 pounds per bushel. The highest prices are paid to the producer for niche crop markets but only if they meet the quality criteria mentioned previously. Other than test weights, additional samples should be taken on farm to determine quality. Because seed lots not meeting high quality standards should be used as lower feed grades, it is important for the producer to clean and size all seed lots before delivery to a niche market. Test weights are used here as a measure of seed quality to determine maturity. Yields are expressed here in pounds per acre and bushels per acre. Determine bushels per acre by dividing the yield of any specific cultivar by the standard test weight.

Table 81 lists yields and quality measurements for chickpea varieties for the Fairbanks location. In the case of chickpeas, only 1 variety was tested, and for only 1 year. The table also contains information on seed type and the year it was tested at this location. There were no irrigation studies done on chickpeas. Maturity in this study was defined as when 50% of the pods for each plot were yellow and the seed could not be dented with a thumbnail. Growing degree days (GDD) for average maturity were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. The low temperature point for chickpeas in this report is the freezing point of water, 32°F. The GDD calculations for each day were then added to the preceding GDD value to determine the date at which the specific variety had reached 50% maturity. The specific variety was compared with 'Express' yellow-seed, semi-leafless field pea in lieu of the standard variety. Yield as a percent of the standard variety 'Express' was determined by dividing the average yield of each variety by the average yield of 'Express'. Maturity vs. Std. (Standard variety) is the number of days the variety reached 50% maturity either before or after the number of days that 'Express' reached 50% maturity. There was no animal feed nutritional analysis done on chickpea seed.

Table 81. Average yields and quality measurements for CDC Xena chickpea from test plots in the Fairbanks area.

Chickpea Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Seed Test Weight (lbs/bu)	Lodging (%)	Canopy Height (in)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Kabuli - Garbanzo, spring											
CDC Xena	Saskatchewan	1	0	0	0	0	0	20	28-Sep	56	3380.9

*Growing degree days (GDD) for average maturity were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. .All varieties were compared with 'Express' yellow seed, semi-leafless field pea as the standard variety.

Canola

Spring Edible and Industrial Canola Oilseed

Rapeseed and canola are closely related oilseed crops; rape is the term used for forage varieties. Rapeseed (from the Latin *rapum*, meaning turnip) is an annual or biennial industrial oilseed crop specifically developed for the lubrication and biofuel markets. Rapeseed contains between 35% and 40% oil by weight. This oil is made up of major fatty acids, some of which are considered essential fatty acids since they can't be synthesized by the body and must come from the diet. The Canola Council of Canada (2000) reports ranges of these major fatty acids for rapeseed as: 3% to 4% palmitic acid, 20% to 35% oleic, an omega-9 fatty acid, 10% to 20% linoleic, an omega-6 fatty acid, and 5% to 10% linolenic, an omega-3 fatty acid. The oil also contains high levels of nonessential fatty acids such as erucic acid (30% to 60%), which can cause heart lesions, and high levels of glucosinolates (30 to 40 micromoles per gram), which can cause goiters when fed to animals. Rapeseed oil is valuable as a biofuel and as a lubricant for underwater applications and on steam-washed surfaces, but it is unsuitable for food and feed markets because of the high levels of erucic acid and glucosinolates. Rapeseed (and canola) oil can be used after extraction as a biofuel either directly or after a chemical refining process that uses methanol and potassium hydroxide to remove water and glycerol from the oil. There are 2 types of rapeseed, Polish, or turnip, rape (*Brassica rapa* or *Brassica campestris* L.) and Argentine rape (*Brassica napus* L.).

Bee on canola blossom

Canola is an edible oilseed crop specifically selected and bred from both Polish and Argentine rapeseed to be low in erucic acid (2% or less) and glucosinolates (less than 30 micromoles per gram). The principle breeder is the Canadian Oilseed Association. To differentiate this new edible oil from the industrial oilseed rapeseed, the association used the first few letters of its name, Can+Ol+A, or canola. Canola seed, like rapeseed, contains between 35% and 40% oil by weight. The Canola Council of Canada (2000) states that canola oil has higher levels of major essential fatty acids compared to rapeseed oil, with ranges of 3% to 4% palmitic acid, 40% to 60% oleic, an omega-9 fatty acid, 20% to 30% linoleic, an omega-6 fatty acid, and 10% to 15% linolenic, an omega-3 fatty acid. Canola oil is also lower in saturated fats at 6% than any other vegetable oil and has a favorable mix of mono- and polyunsaturated fats, making it a high-value cooking oil. Canola and rapeseed oil are obtained by a combination of expressing and extraction with a solvent. The best of the commercial oilseed presses is only capable of extracting about half of the oil contained in the canola seed, about 20% by weight. Small-scale commercial presses and kitchen-scale presses can only get about one-quarter of the oil in the seed, or about 10% to 11% by weight. The remaining half to three-quarters of the oil that remains in the meal is extracted with a hexane solvent process. The solvent is then removed from the oil, which is blended in with the pressed oil and everything is run through a filtration and cleaning process. Canola oil for the edible market can't contain more than 2% green seed. Green seed are immature seed, which contain chlorophyll that imparts a green color to the oil and shortens the shelf life by turning rancid quickly. The canola meal that remains after processing is a high-protein supplement for animal diets. Canola plant residues (straw) contain high levels of glucosinolates of around 5 to 20 micromoles per gram. As mentioned previously, these glucosinolates can cause palatability and nutritional problems if fed to livestock or poultry. However, these glucosinolates have a positive allelochemical effect that inhibits growth of some species of weeds, nematodes, insects, and soil-borne plant diseases in the field the following year.

Polish canola is a mid-tall (1.5 to 3 feet) multibranched, annual, spring or winter, cool-season, broad-leaved oilseed plant. It is earlier maturing than the Argentine type by 2 to 3 weeks and requires about the same length growing season as barley. It is more resistant to early spring frosts, outproduces Argentine varieties under drought conditions, and is more resistant to shattering at harvest. It is almost completely open-pollinated, so seed producers can't grow 2 different varieties within a mile of any other variety (the distance insect pollinators such as honeybees would travel from their hive to a nectar and pollen source). Cross-pollination would result from any 2 varieties grown closer together. Seed from cross-pollination would contain characteristics of both parents. It would not be true to either original type and could not be sold as either original variety. The small seed (about 1/16 inch diameter and about half the size of Argentine varieties) ranges from reddish brown to black when mature.

Argentine canola is a tall (2.5 to 4 feet) multibranched, broad-leaved oilseed plant. It is a long-season crop that matures in about the same period as wheat. It is more susceptible than the Polish type to early and late spring frosts and shatters readily when ripe. It outyields the Polish varieties by 15% to 20% under adequate soil moisture conditions. Argentine canola is only about 30% cross-pollinated, but seed producers should still not plant 2 varieties close together. The seed is large (about one-eighth inch diameter) and ranges from dark brown to black when mature.

There is also a Polish/Argentine hybrid canola that was developed to have the early maturity and shatter resistance of Polish canola types and the high yields and large seeds of the Argentine types. These are conventional open-pollinated hybrids where 100% of the cross is between 2 parents with the seed harvested from just the female line. It is a tall, multibranched, annual, cool-season, broad-leaved oilseed plant similar to the Argentine parent. In maturity, it is a mid-season crop that matures in about the same period as oats. The seed is large (about one-eighth inch in diameter) and dark brown to black when mature with yields somewhere between the Polish and Argentine types.

Fertilization practices for canola are similar to those for small grains. Because proper fertilization is important for producing high yields of high-quality canola, soil should be tested to determine which plant nutrients are limiting and how to correct for those deficiencies. Test soil in the fall in the field in which next year's crop will be grown. In general, all soils should receive a complete mix of nitrogen, phosphorus, potassium, sulfur, and boron. Complete fertilizer blends consisting of ammonium sulfate, urea, monoammonuim phosphate, triple superphosphate, potassium chloride or potassium sulfate, and sodium borate work well in the soil conditions described previously. If ammonium sulfate is not available, a substitution of potassium sulfate for potassium chloride would work to provide the needed sulfur. Canola requires more nitrogen than any other nutrient. Nitrogen is essential for increased leaf production, which increases yield if sufficient soil moisture is present during the growing season. With proper soil moisture conditions, a maximum of 20 pounds per acre of nitrogen can be banded with the seed. Because soil moisture conditions are rarely sufficient in Alaska unless irrigation is used, most if not all nitrogen carriers should be broadcast applied. In low soil-moisture conditions, germinating seeds and seedlings can be injured by nitrogen fertilizers. Avoid excess nitrogen fertilizer because it can induce lodging, delay maturity, and cause an increased risk of fungal attacks at harvest especially if grown under irrigation. About half of the available soil nitrogen is removed with the seed at harvest. If plant residues are incorporated with tillage the next spring, a large amount of nitrogen remaining in the straw and stubble is returned and becomes available.

Canola requires relatively moderate to high phosphorus and potassium levels, which improve disease resistance and tolerance for frost and drought. Because Alaska soils are generally acidic, they tend to fix phosphorus, making it unavailable for plant uptake, so banding the phosphorus carrier with or next to the seed at planting would not help increase available phosphorus. Canola's small seed is planted shallowly, where soil moisture is usually less than optimum, which renders the phosphorus unavailable for plant use. Thus, phosphorus and potassium fertilizers should be broadcast with the nitrogen fertilizers. About two-thirds of the phosphorus and one-third of the potassium are removed with the seed. If plant residues are incorporated with tillage next spring, a large amount of potassium remaining in the straw and stubble is returned and becomes available for crops.

Sulfur and boron are needed by canola to promote flowering and seed set. Soils low in available sulfur should have a sulfate form of sulfur broadcast as ammonium sulfate or as potassium sulfate. Studies done by F.J. Wooding (1985) found that boron application rates of 0.5 to 1.0 pounds per acre of actual boron are sufficient to correct most soil deficiencies. About half of the available soil sulfur is removed with the seed at harvest. If plant residues are incorporated with tillage the next spring, a large amount of sulfer remaining in the straw and stubble becomes available. A ratio of 3:2:1:0.5 of N, P_2O_5, K_2O, and S have produced acceptable yields of canola. With irrigated farming practices, the ratio should be reduced to about 1.5:1:0.5:0.25. Actual percentages of all nutrients and application rates vary according to specific soil test results. All fertilizer must be broadcast before spring tillage.

Choice of the field for canola production is important. It should not have been cropped to canola in the previous 3 years. Studies conducted by L. Harrison and others (1997) in Canada concluded that some canola diseases can survive on canola plant residues for more than 5 years. Canola production should follow a year of summer fallow to help reduce the likelihood of plant disease, broad-leaved weeds, and volunteer canola, or be planted in a rotation following a grain crop like barley. This also increases available soil

Row of canola at the Fairbanks Experiment Farm, June 15, 2011 moisture and reduces the amount of fertilizer required. To conserve soil moisture, minimum tillage is recommended for incorporating fertilizer material and plant residue and preparing the seedbed. Pulling a packer behind the tillage implement and using a seed drill equipped with press wheels ensures that the seed is in contact with moist soil during germination. If the crop is to be grown under irrigation, the soil should be irrigated sufficiently to bring the soil moisture levels close to the maximum water-holding capacity before tillage. It is very important not to irrigate above the maximum water-holding capacity before tilling and planting as this could cause a soil crust to form on the surface that would impede seedling emergence, reduce plant density, and lower seed yields. Seeding depth is shallow, 0.5 to 1.5 inches, or to moisture. Seeding deeper than 2 inches may result in delayed germination and emergence. Seeding rate depends on seed size. Generally, 6 to 12 pounds per acre of pure live seed for the larger Argentine types and slightly less than or equal to that rate (6 to 10 pounds per acre) for the smaller-seed Polish types is recommended. Heavier seeding rates produce thick stands that ripen more uniformly and reduce the possibility of green seeds at harvest. Lighter seeding rates compensate in yields because side branches develop, thicker and stronger stems reduce lodging, and better air movement through the canopy reduces fungal attack. However, lighter seeding increases the risk of competition with weeds for available nutrients and soil moisture, so proper weed control during the summer fallow rotation is important. Planting as early as possible to avoid loss of important soil moisture and utilize as much of the short growing season as possible is recommended. Certified seed is strongly recommended; it often comes pretreated with a seed protectant of fungicides and insecticides to help ensure uniform seed germination and seedling survival. This treated seed will include a colored dye (blue or grey) to differentiate it from untreated seed so that it isn't used as feed or edible oil. Certified seed has strict limits on maximum content of weed seeds and diseased seed, and must meet a minimum percent germination. This helps to ensure good germination and emergence and reduces weed and disease infestations.

Like small grains, irrigation should begin again after the crop has reached about 50% emergence to avoid any problems resulting from too hard of a crust on the surface. Thereafter, a good range of irrigation plus precipitation is around 0.5 to 1.0 inch per week. Irrigation should continue until the crop has reached the 50% pod set growth stage.

Using IPM techniques, assess each field for all pests (weeds, diseases, and insects) and plan control measures accordingly. Weed control in canola is extremely important. Canola needs warm soil to germinate and when young does not compete well with weeds. Wild mustard (*Sinapsis arvensis*), chickweed (*Stellaria media* L.), corn spurry (*Spergula arvensis* L.), hawksbeard (*Crepis tectorum* L.), lambsquarter (*Chenopodium album* L.), Pennsylvania smartweed (*Polygonum pensylvanicum* L.), knotweed (*Polygonum aviculare*), shepherd's purse (*Capsella bursa-pastoris* (L.) Medic.), tansy mustard (*Descurainia sophioides* Fisch.), wild buckwheat or field bindweed (*Polygonum convolvlus* L.), and volunteer canola or mustards of different varieties are the biggest broadleaf weed problems in canola seed production for Alaska. Common grassy weeds are bluejoint reed grass (*Calamogrostis canadensis* (Michx.) Beauv.), foxtail barley (*Hordeum jubatum* L.), quackgrass (*Agropyron repens* (L.) Beauv.), and wild oats (*Avena fatua* L.). The best weed control is a combination of mechanical and chemical summer fallow to reduce the number and species of weeds for the following season. In the spring, wait for weeds to germinate, then perform seedbed tillage using proper fertilization and seeding rates. There are no herbicides registered for use on canola in Alaska. Many of the Canadian spring and fall-seeded varieties have been bred to be herbicide resistant. Without a spring tillage treatment to reduce weeds for these varieties, herbicide spraying is required. To eliminate both grassy and broad-leaved weeds, a broad-spectrum, nonselective, post-emergence herbicide such as glyphosate (Roundup) can be used. Varieties with resistance to Roundup are termed "Roundup Ready" or "RR." There are also varieties that have been developed to be resistant to triazine or atrazine herbicides which are termed "TTC." Triazine herbicides are used to control wild mustards and other cruciferous weeds in the same plant family (mustards) as canola. All varieties developed with these traits have been Argentine types, which are more susceptible to late spring and early fall frosts than Polish types. Also, all Argentine types are later-maturing with reduced yields and a higher percentage of green seed at harvest than the Polish types. None of the herbicide-resistant Argentine varieties are recommended for Alaska.

Several fungal diseases attack canola seed and seedlings, causing damping-off (*Peronospora parasitica*) and root rot. These diseases cause seed decay and seedling blight with delayed emergence and eventual uneven stands. Cool, wet soil conditions in the spring favor development of seed-borne fungal attacks. Using treated seed with any one of a number of seed protectants and fungicides helps prevent loss from seed-borne fungal attacks. Blackleg (*Leptosphaeria maculans*) is a serious fungal disease in western Canada that is caused by infected seed or crop residues. It can affect all plants at any time during any growth stage, reducing plant vigor and yield. Using clean certified seed or resistant varieties can prevent its appearance before it becomes a serious problem in Alaska. Alternaria black spot (*Alternaria brassicae)* is a serious fungal disease that has been found on canola in Alaska. Small, dark lesions that occur on leaves and seed pods throughout the growing season cause a reduced

Robert Van Veldhuizen using a metal bar to push over the canola stems in an experimental drying treatment

photosynthetic ability of the leaves, premature pod drying, and seed shatter. It can be controlled by using a registered fungicide such as carboxin (Vitavax) applied to the seed and planting certified seed. Sclerotinia, or white mold fungus (*Sclerotinia sclerotiorum*), infects the base of the plant, causing wilt. This fast-acting disease often takes only 4 to 7 days from the first appearance of symptoms to complete wilting. Cool, wet soil conditions in the spring and infected plant residue from the previous year favor development of this fungal disease. It can spread from plant contact and through airborne spores. Control using crop rotation and certified seed, which often comes pretreated with a fungicide such as Vitavax RS. Sunflowers, camelina, and mustards are also susceptible to this disease and should not be used in the crop rotation.

Canola is susceptible to many different kinds of insect pests; these pests can cause serious yield losses and thus require control measures. Flea beetles (*Phyllotreta cruciferae* Goeze) are small, shiny black insects that jump when disturbed. They can seriously damage the newly emerging crop by eating small holes in the leaves. Control using certified seed that comes pretreated with a registered insecticide such as lindane (Vitavax RS), that also contains the fungicide carboxin. The cabbage root maggot, or cutworm (*Hylemya brassicae* Bouche), is the larval stage of a fly. It infests the base and roots of canola in the seedling, flowering, and mature growth stages. Infestations of just 3 or more maggots can eventually girdle a plant. Also, their feeding creates wounds that can later serve as entry sites for fungal diseases. Polish canola is more susceptible than the Argentine varieties. Heavier seeding rates may help by reducing the size of the main stem, possibly because smaller stems are less attractive to egg-laying females or because there are more stems to choose from and the crop as a whole is less affected. Another control measure that works well is increasing the number of years between canola crops in the same fields. The red turnip beetle (*Entomoscelis americana* Brown) has recently become a pest in Alaska. The adult beetle is bright red with 3 black stripes down the back and a black patch behind the head. The larvae feed on the leaves in late May to early June and the adults feed on the leaves in late June to early July, often causing total defoliation in years of heavy infestation. After feeding for several weeks, the beetle burrows into the soil and becomes inactive for a 2-week summer hibernation period. The beetles re-emerge in August and continue feeding until killed by early frosts. If insect population levels and damage have been determined to be too high, then the application of an insecticide may be warranted. Insecticide sprays can help control heavy infestations when sprayed at the first outbreak (larval or maggot stage). Cultural practices such as tilling under volunteer canola and tansy mustard (*Descurainia sophioides* Fisch.), which is an alternate host, are also recommended to reduce red turnip beetle populations. Always remember to read the pesticide label to be sure the crop is specified and follow the directions on mixing, application, and disposal. Contact your local Cooperative Extension Service for more information on pest control (see Appendix 1 for addresses and contact information).

Even though canola is used as a high-energy food source in bird seed mixes, song birds and migratory waterfowl don't cause much damage to the crop. This is because the seeds are held inside a pod until after harvest, unless there is significant pod shatter in the field. Argentine canola is more susceptible to pod shatter than Polish canola.

Canola ripens from the bottom of the plant to the top. When 40% to 50% of the seeds near the bottom have turned brown or black, harvest can begin. There are still green seeds in the pods near the tips of the side branches and at the top of the plant. Average seed moisture content at this stage is 35% to 45%. Use seed color and not pod color as an indicator of maturity, because some varieties can have ripe seeds in green pods. Canola is usually swathed before combining because seed continues to mature in the windrow and can change color by 5% per day with enough heat and low humidity. Swathing also helps dry both the canola plants and any green weeds before harvest, making combining easier and reducing shatter loss. After heavy precipitation, standing canola dries better than swathed canola in windrows. Swathing too early reduces overall yields and oil content, while swathing too late increases shatter loss. Windrows of Polish canola become very lightweight as the crop dries down. These light windrows can then be blown around by even a slight breeze, spreading the plants out and shattering seed pods, causing significant yield reduction.

In an effort to find a solution to these harvest problems, M. Zhang and B. Van Veldhuizen (2010a and 2010b) conducted an experiment on 2 pre-harvest treatments based on what Canadian producers were doing with Argentine canola. The first treatment is a modification of the pushing method described by B. Irvine (2003). This treatment was to push over the main stem of the canola plant with a metal bar that was suspended about 6 to 8 inches off the ground. This effectively crimped, or in some cases broke off, the main stem, stopping the translocation of water and nutrients to the plant. The second treatment is based on a method described by Saskatchewan Agriculture, and updated by B. Flaten and others (2010), of spraying canola with either a glyphosate herbicide (4% concentration of the 480 g/L formulation) or a plant desiccant such as Reglone. Glyphosate works to slowly dry down the canola, which will continue to ripen mature seed. In addition, glyphosate will kill any perennial weeds in the crop. In comparison, a desiccant such as Reglone, which is a contact herbicide, will kill the plant on contact and doesn't hasten crop dry down or allow it to ripen mature seed. If desiccants are sprayed too early, then any green seed will remain green. Because the percent green seed in all Alaska grown canola has been at 2% or higher until the end of harvest season, waiting to spray with a desiccant would not be a viable option. Therefore, the second treatment, a pre-harvest spray with a 1.5% solution of glyphosate (Roundup-Ultra) weed control herbicide, was used to kill the canola plant and any associated perennial and annual weeds. (Note: gylphosate is registered in Canada as a pre-harvest treatment for edible canola, but it is not registered by the EPA for that use in the United States.) Glyphosate degrades fairly quickly when it contacts the soil, usually 4 to 7 days after spraying. The recommended pre-harvest interval, which is the time between spray application and crop harvest, is 7 to 10 days. Because of the colder soil temperatures in Alaska, this degradation is slower, so the pre-harvest interval was extended to 2 to 3 weeks.

The pushing and spraying treatments were designed to dry down the canola plant to make combine harvesting easier and quicker, continue to ripen seed during the dry-down period, and reduce the percent green seed content to 2% or lower. Both treatments were done in mid-August when 30% or more of the seed in the lower pods was turning brown or black (also at 30% or less moisture in the seed). Everything was then combined about 2 to 3 weeks later when the untreated canola had close to 50% or more of the seed turning brown to black and the percent moisture was around 10%.

This study was replicated and conducted over a 3-year period at both the Fairbanks and Delta Junction dryland locations using 4 Polish canola varieties: 'AC Sunbeam', 'Hysyn 110', 'Maverick', and 'Reward' as the standard variety. Each treatment (direct combining, pushing, and spraying) area was 0.02 acres in size at each location and conducted on crops planted on fallow ground each year. The untreated or direct combining treatment produced results that were similar to what has been measured over the past years for Polish canola: average yields with an average of 4% green seed at Fairbanks and 5% at Delta Junction. The pushed treatment had significantly lower yields because a high number of the pods shattered on contact with the metal bar, increasing seed loss. This loss of ripe seed produced 2 important results. The first was that the percent green seed remained close to that of the direct combined treatment, for an average of 4% green seed at Fairbanks and 3% at Delta Junction. The second was a very high number of volunteer canola growing the following year. Spraying with 1.5% glyphosate solution treatment produced higher than average yields with an average of 1% green seed at both locations. Combining dry canola from this treatment was faster compared with combining the other 2 treatments. Also, the seed cleaned out better at harvest, which reduced the amount of additional drying needed to get the seed at optimum percent moisture for long-term storage. Tests of the harvested canola seed showed no differences in oil content, protein, mineral nutrients, or germination ability for any of the treatments, indicating that none of these treatments had an adverse effect on the quality of the seed.

An additional aspect of this study is control of both annual and perennial weeds. Even though the 1.5% glyphosate treatment killed all annual and perennial weeds, it made very little difference on the amount or type of annual weeds that occurred on the plot area the following season compared with the other 2 treatments. Annual weed seed collected at harvest from lambsquarter (*Chenopodium album* L.), knotweed (*Polygonum aviculare*), shepherd's purse (*Capsella bursa-pastoris* (L.) Medic.), and wild buckwheat, or field bindweed (*Polygonum convolvlus* L.), showed no difference in seed counts (yields) or germination ability for any of the treatments. This indicates that these annual weeds will still be a problem in succeeding years. However, populations of perennial weedy grass species such as bluejoint reed grass (*Calamogrostis canadensis* (Michx.) Beauv.), foxtail barley (*Hordeum jubatum* L.), and quackgrass (*Agropyron repens* (L.) Beauv.) were reduced in following seasons with the 1.5% glyphosate treatment. The glyphosate killed the aboveground portions of these perennial weeds, stopping the translocation of nutrients to the roots and rhizomes. This effectively eliminated or reduced the number of plants that could resprout and grow the following spring. This result was expected because this treatment (although at a higher concentration for fallow ground) is recommended on the glyphosate herbicide label for control of perennial weeds.

Further research is needed to study the 1.5% glyphosate pre-harvest treatment method to improve the yield and quality of canola seed. Continued use of this pre-harvest treatment on canola variety trials indicates that during cool, wet growing seasons, the percent green seed may not be reduced to 2% or lower. This is most likely because the plants were not mature enough by mid-August (from the cooler temperatures), so the seed was not quite at 30% brown or black stage (greater than 30% moisture). Spraying when the plants are immature could stop any further seed

Closeup of ripe canola pods

filling, resulting in a higher percentage of green seed with lower yields and test weights. Also, this treatment could potentially increase the risk of excess residues remaining on the plant because there isn't enough time for complete chemical breakdown during the cooler temperatures before fall harvest. It is important to remember that this method is still in a research phase and is not recommended as a pre-harvest treatment for commercial producers. None of the gylphosate herbicides that are registered by the EPA in the U.S. are allowed for a pre-harvest spraying of edible canola.

Combining either the swathed or standing canola can begin when the seed has around 10% moisture content. Reduce cylinder speeds to one-half or two-thirds of that used for small grains. Concave clearance should be about 1 inch at the front and 0.5 inch at the back. Reduce these settings to reduce the chance of overthreshing and thereby causing cracked seeds and excess plant material in the hopper. Reduce the fan speed to about three-quarters of that used for small grains to avoid blowing the seed out with the chaff. The cleaning action for canola relies more on shaking action than on airflow. Top screens should be between one-quarter and one-third inch and the bottom screens between one-eighth and one-quarter inch, depending on seed size. Care must be taken to seal up all small holes and cracks in the combine, augers, trucks, and bins as canola seed is small and round in shape and thus leaks out easily. Equip the combine with a straw chopper and spreader to evenly distribute the plant material. Canola straw is not a good animal feed because it contains high levels of glucosinolates that can cause goiters. These glucosinolates can also have an allelochemical effect that can potentially reduce seed germination in the following year's crop.

Typical grain dryers have perforated floor openings that are too large for the small seeds. A 5-mesh nylon sheet over the floor prevents seed loss. Canola should be recleaned, dried to about 8-9% moisture and cooled to between 60°F and 40°F before storage. Any green or moist material can cause molds to form, reducing the quality of the oil and the germination ability of the seed. Aeration from the bottom up through the bin with supplemental heat to drive off excess moisture is the usual first step. Do not heat the seed above 110°F; higher temperatures will reduce germination. Canola seed should be cooled immediately after drying to between 60°F and 40°F. Temperatures and moisture content of the seed in the bin should be checked every day for a week after harvest, then every week after that. Repeat the aeration and drying if needed, because canola seed can spoil quickly in storage. The limit for green seed in the edible canola market is only 2% or less. Green seed and clean-outs can be used on farm as an animal feed. When the crop is used as a supplement for animal diets, there is no limit to the amount of green seed, whole seed, or canola meal that can be used, but it should be added to diet formulations on an energy basis rather than as a protein replacement. If total oil extraction is used, then the residual meal will contain around 35% to 40% protein. The straw should not be used as a feed supplement or as bedding because of the high levels of glucosinolates. However, ruminants are less susceptible to the effects than non-ruminants.

Spring Forage Rape

Forage rape is the same species as Argentine canola and rapeseed, (*Brassica napus* (L.)). It is a tall, multi-branched, broad-leaved, biennial, spring forage crop very similar in appearance to Argentine canola except that the leaves are succulent and much larger—4 inches wide by 12 inches long. The plants are usually harvested or grazed when the plant is young (up to a foot tall). The plant will regrow to be harvested a second time in more temperate climates. Forage rape is used as an annual forage for small ruminants like sheep and goats or in limited amounts for beef cattle. It should not be fed to dairy animals as it can change the flavor of the milk. The leaves contain low levels of gluocosinolates (5 to 20 micromoles per gram), which can cause palatability and nutritional problems if fed in large amounts to livestock. Forage rape is over 80% water, so dry matter yields of 16% to 20% are much lower than for grain forages, but it does contain 17% to 20% crude protein and 13% to 16% fiber.

Forage rape needs a higher rate of nitrogen for optimum leaf production than does oilseed canola. The fertilizer rate for forage rape is a ratio of 2:1:1:0.5 of N, P_2O_5, K_2O, and S. With irrigated farming practices, the ratio should be reduced to about 1:0.5:0.5:0.25. Actual percentages of all nutrients and the application rates vary according to the specific soil test results. All fertilizer must be broadcast prior to spring tillage. The seeding rate is also different than for oilseed canola. Rates of 5 to 15 pounds of pure live seed per acre are recommended for good forage production. The higher seeding rates help to reduce weed competition through shading by the large leaves. The seeding depths are the same as for oilseed canola. All other crop production parameters, such as tillage practices, field choice, planting, irrigation practices, weed, disease, and insect control, are the same as for oilseed canola.

Since forage rape is very high in moisture, it is harvested as a silage rather than as a dry forage like hay or forage grains. Other options would be to graze livestock when the crop is about a foot tall. Care must be taken when feeding forage rape because the leaves contain low levels of gluocosinolates, which can cause palatability and nutritional problems if fed in large amounts.

Because of the problems of harvesting and feeding a high-moisture, low-quality forage such as forage rape, no varieties are generally recommended for Alaska. However, just because there was a crop failure for this study does not mean that forage rape might not be successfully grown somewhere within the state. Therefore, the reader should not be discouraged from trying any of the forage rape varieties not recommended, but the probability of success in attempting to produce these crops will likely be low.

Recommended Variety Descriptions for Spring Polish Canola

Note: See Appendix 1 for the addresses of seed suppliers.

'AC Sunbeam' is an early-maturing, mid-tall, high-yielding, low erucic acid, low glucosinolate, edible oil, spring Polish canola developed by Agriculture and Agri-Food Canada in Beaverlodge, Alberta in 1996. 'AC Sunbeam' matures 2 days earlier than 'Reward'. It has higher yields and lower percent green seed than 'Reward'. 'AC Sunbeam' has moderate lodging resistance. Direct inquiries about seed sources to Fenton Seed Farm, Ltd.

'Colt' is an early-maturing, mid-tall, high-yielding, low erucic acid, low glucosinolate, edible oil, spring Polish canola developed by the the Swedish company Svalof Weibull AB in Alberta in 1988. 'Colt' matures 2 days earlier than 'Reward'. It yields better than 'Reward' and has higher oil and crude protein concentrations. Lodging resistance and percent green seed content are similar to 'Reward'. This variety has been deregistered and is now in the public domain. Seed sources may be difficult to obtain. Direct inquiries about seed sources to Bonis and Company, Ltd.

'Eldorado' is an early-maturing, mid-tall, high-yielding, low erucic acid, low glucosinolate, edible oil, spring Polish canola developed at the University of Alberta in 1991. It has a slightly higher yield than 'Reward' and matures about 4 days earlier. Lodging resistance and green seed percentage are similar to 'Reward' and shatter resistance is fair. This variety has been deregistered and is now in the public domain. Seed sources may be difficult to obtain. Direct inquiries about seed sources to the University of Alberta.

'Horizon' is an early-maturing, mid-tall, high-yielding, low erucic acid, low glucosinolate, edible oil, spring Polish canola developed by the Swedish company Svalof Weibull AB in Alberta in 1988. 'Horizon' matures about 2 days earlier than 'Reward'. It has a better yield than 'Reward' with higher oil and crude protein content with similar green seed percentage. 'Horizon' has slightly better lodging resistance than 'Reward'. This variety has been deregistered and is now in the public domain. Seed sources may be difficult to obtain. Direct inquiries about seed sources to Bonis and Company, Ltd.

'Hysyn 110' is an early-maturing, mid-tall, high-yielding, low erucic acid, low glucosinolate, edible oil, spring Polish canola developed by Advanta Seeds, of Yorkton, Saskatchewan in 1994. It is a synthetic hybrid from 2 Polish canola parents. A synthetic hybrid is a conventional cross-pollinated hybrid. It contains 25% of parent 1 (female line), 25% of parent 2 (male line) and 50% of the characteristics of the cross between the 2 parents. A regular conventional cross-pollinated hybrid is 100% of the cross between 2 parents with the seed harvested from just the female line. 'Hysyn 110' matures about 1 day later than 'Reward'. It has the same yield as 'Reward' but lower oil content and green seed percentage. 'Hysyn 110' has poorer lodging resistance than 'Reward'. Direct inquiries about seed sources to Zeneca Seeds.

'Maverick' is an early-maturing, mid-tall, high-yielding, low erucic acid, low glucosinolate, edible oil, spring Polish canola developed by the Swedish company Svalof Weibull AB in Alberta in 1994. It matures 4 days earlier than 'Reward'. 'Maverick' has greater lodging resistance, higher yields, and lower green seed percentage than 'Reward'. This variety has been deregistered and is now in the public domain. Seed sources may be difficult to obtain. Direct inquiries about seed sources to Bonis and Company, Ltd.

'Reward' is an early-maturing, mid-tall, high-yielding, low erucic acid, low glucosinolate, edible oil, spring Polish canola developed at the University of Manitoba in 1991. It has high yields with high oil and crude protein content and a low percentage of green seed. Lodging resistance is moderate under normal soil fertility conditions. This was the standard variety against which all other canola, rapeseed, mustards, camelina, crambe, and borage varieties were compared in this report. This variety has been deregistered and is now in the public domain. Seed sources may be difficult to obtain. Direct inquiries about seed sources to the SeCan Association.

Winter Edible and Industrial Canola Oilseed

Most canola is planted as a spring annual to be harvested after the first frost. Studies conducted by S.D. Sparrow, J.S. Conn, and C.W. Knight (1990) have determined that tilling of a canola crop after fall harvest results in a fairly high amount of volunteer canola the following season. This is because shatter losses are fairly high, seed buried in the soil over the winter survives, and spring soil moisture levels are higher in the untilled soil. If sufficient stubble and surface plant residues remain after fall tillage, trapped snow results in increased spring soil moisture, reduced erosion, and minimal soil crusting. This provides an even better environment for volunteer canola germination in the spring. Canadian research into this phenomenon has led to the development of fall-seeded, or winter canola, varieties. Fertilization rates, tillage practices, seeding depths, irrigation practices, weed and insect control, harvesting, cleaning, and storage are the same as for spring canola.

There are 2 different types of winter canola. The first type has the seed treated with a polymer that prevents fall germination and breaks down over the winter to ensure an early spring germination. This type of canola is planted in very late fall just before freezeup to remain dormant in the soil until spring, when it grows similarly to spring-planted canola. Two experimental lines, 1 Polish and 1 Argentine, of polymer-coated, fall-seeded winter canola from the oilseed breeding program of Agriculture, Food and Rural Development in Lacombe, Alberta have been tried in Alaska for 2 years without success. Soil temperature and moisture conditions in early spring are often too cold or wet for uniform germination or regrowth. Plant vigor is reduced, often leading to total crop failure before the formation of the first true leaves.

The second type is more similar to winter grains. The seed is planted in early to mid-August, germinating in about 7 to 10 days. The plant forms a low rosette of 2 to 8 leaves with a large tap root before beginning winter dormancy. If the crown does not die during the winter as a result of freezing injury or desiccation, then new growth will begin as soon as soil temperatures reach around 40°F. Two Argentine varieties of this type of fall-seeded winter canola, 'Bridger' and 'Cascade' from the University of Idaho, were also tried without success. Most of the varieties developed with this trait have been edible oil Argentine types (low erucic acid and low glucosinolate content), which are more susceptible to late spring frosts than the Polish types. The larger leaf area of canola provides a greater surface for the establishment of snowmold fungus under the snowpack. The humidity under the snowpack is high and white snowmold fungi (*Sclerotinia borealis*) can attack and kill the plants. These snowmold fungi are present on the plant tissue before winter and only grow and spread in the spring when temperature and moisture conditions are right. Even in temperate climates, fall-seeded winter canola has lower winter survival rates than fall-seeded winter grains. For these reasons, fall-seeded winter canola varieties are not generally recommended for most of Alaska. However, just because there was a crop failure for this study does not mean that winter canola might not be successfully grown somewhere within the state. Therefore, the reader should not be discouraged from trying any of the winter canola varieties not recommended, but the probability of success in attempting to produce these crops will likely be low.

Canola is still considered a marginal crop for Alaska. In good years with adequate soil moisture and GDD, as well as using the 1.5% glyphosate spray pre-harvest treatment, the Polish varieties listed previously can produce close to the 2% green seed requirement, but even in good years there can be uneven ripening resulting in green seed at harvest. This is because any seed killed by frost does not continue to ripen and remains green. Preliminary irrigation studies on canola in the Delta Junction area show a promising increase in average yields and a decrease in average percent green seed. However, it is still not consistently lower than the 2% green seed requirement for any given year. The authors hope that further irrigation and fertility studies may help solve this problem. There is increasing interest in Alaska in producing an oilseed crop for both the edible oil and industrial oil lubricating and biofuel markets. Any seed grown for these markets should be grown on contract with a processing facility since a high-quality seed lot is required. Unfortunately, there is currently no large-scale facility in Alaska to process oil from canola seed for either the edible oil or lubricating and biofuel oil markets. Also, there are no elevators in Alaska currently set up to take canola seed. However, there are a few on-farm, small-scale oilseed presses set up to extract oil without the secondary chemical extraction. All canola presently grown in Alaska is for on-farm use as a biofuel with the meal or whole seed used as a feed supplement in livestock diets.

All Argentine canola varieties mature later than the Polish varieties. As a result, there are no varieties that have been tested in Alaska that produce 2% green seed or less, even when the 1.5% glyphosate spray pre-harvest treatment is used (for those varieties that are not Roundup Ready) or when grown under irrigation. For this reason, no Argentine or Polish/Argentine hybrid canola varieties are recommended. However, just because there was a crop failure for this study does not mean that Argentine canolas might not be successfully grown somewhere within the state. Therefore, the reader should not be discouraged from trying any of the Argentine canola varieties not recommended, but the probability of success in attempting to produce these crops will likely be low.

Yields by Location for Spring Polish and Argentine Canola

Canola and rapeseed (Polish and Argentine) are bought and sold by weight. As for other small grains, there is a standard test weight for canola that is used as the legal unit for purchase or sale of the crop. This standard test weight for clean, dry, and undamaged canola is 50 pounds per bushel. Other than test weights, additional samples should be taken on farm to determine quality. Any seed lots not meeting high quality standards should be used as lower feed grades. It is important then for the producer to clean and size all seed lots before delivery to a niche market. Test weights are used here as a measure of seed quality to determine maturity. Yields are expressed here in pounds per acre and bushels per acre. Determine bushels per acre by dividing the yield of any specific cultivar by the standard test weight.

Tables 82, 86, 88, and 90 list yields and quality measurements for canola varieties for 3 test locations: Fairbanks, Eielson, and Delta Junction. All sites in the Delta Junction area have been combined into either the Delta dryland site (Table 88), or, if grown under irrigation, the Delta irrigated site (Table 90). Each table also contains information on seed type (Polish or Argentine) and the years it was tested at each location. Erucic acid contents for all varieties are listed as low (less than 5%), normal (20-40%), and high (greater than 50%). Glucosinolate contents are listed as either low (less than 30 micromoles/g) or high (30 micromoles/g or higher). Varieties with low levels of both erucic acid and glucosinolates (low E & low G) can be used for the edible oil market. These types of canola are also referred to as double-low or double-zero low-erucic acid rapeseed (00-LEAR). Varieties that are low in erucic acid but high in glucosinolates (low E & high G) can be used as biofuel or sparingly in ruminant animal feeds but not for edible oil. These types of canola are also referred to as single-low or single-zero low-erucic acid rapeseed (0-LEAR). Most of the varieties in this category are older varieties that have been removed from production and are no longer recommended in Canada or the U.S. Varieties that are normal or high in erucic acid and high in glucosinolates (normal E & high G) or (high E & high G) can be used only in the lubricating and biofuel oil markets. These types of canola are also referred to as high-erucic acid rapeseed (HEAR). Most of the newer varieties in this category are high in both erucic acid and glucosinolates for higher quality lubrication oils. Older varieties have been discontinued and are no longer recommended for production.

Maturity in this study was defined as when 50% of the seed for each plot had a brown or black color. Growing degree days (GDD) for average maturity are calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. The low temperature point for all canola in this report is the freezing point of water, 32°F. The GDD calculations for each day are then added to the preceding GDD value to determine the date at which the specific variety had reached 50% maturity. All varieties were compared with 'Reward' Polish canola as the standard variety. Yield as a percent of the standard variety 'Reward' was determined by dividing the average yield of each variety by the average yield of 'Reward'. Maturity vs. Std. (Standard variety) is the number of days it took for each variety to reach 50% maturity either before or after the number of days it took for 'Reward' to reach 50% maturity. Estimated oil yield data is based on extracting about half of the oil contained in the canola seed, or about 20% by weight, through the primary pressing process and not the secondary chemical extraction process. Therefore, the seed yield in pounds per acre times 20% equals the oil yield in pounds per acre. The density of canola oil is 7.81 pounds per gallon. This number is used to convert the oil yield in pounds per acre into gallons of oil per acre. Seed, meal, and forage (on a dry weight basis) quality data (percent oil, percent crude protein, percent green seed, and other nutrients) for Fairbanks (Tables 83-85), Eielson (Table 87), Delta dryland (Table 89), and Delta irrigated (Table 91) are presented without statistical differences and solely for the reader's benefit. More detailed information and explanation about the industry standards for forage grade rape and food grade canola oil that follow can be obtained from H.B. Bartholomew and J.F. Underwood (1992) and the Canola Council of Canada (2000). Detailed explanation of the feed analyses that follow as well as laboratory procedures can be obtained from J. Schroeder (1994) and G.J. Michaelson and others (1987).

Percent green seed is a measure of the maturity of the crop. Seed coat color is not always a good indicator of plant maturity because it can start to turn yellow, brown, or black while the inside is still green and immature. To determine if the inner seed color is still green, collect multiple random samples of 100 seeds after drying and cleaning. Place them on a grid over white paper and crush with a roller. The inner color of any immature seed will then show up as green or yellowish-green blots, which can then be counted. The percent green seed is then determined from the original 100 seed subsample. A high percentage of green seed indicates that the crop is immature. Oil processed from a crop with a high percentage of green seed will go rancid quicker.

Percent crude protein is calculated from the total percent nitrogen analysis of the seed multiplied by a constant of 6.25. Crude protein is made up of amino acids, which are 16% nitrogen, as well as other non-protein portions of the plant, and so percent crude protein is not a measure of true protein. Industry standards of crude protein for canola are set for a range between 35% and 45% for seed, 30% and 45% for meal, and 20% and 25% for forage. Higher values have greater nutritional food value, but too high a value (>45% for seed and meal and >25% for forage) is an indicator of immature green seed at harvest, which makes a lower quality grade oil because it turns rancid quicker.

In a standard feed analysis, other major nutrient mineral concentrations that are measured are percent phosphorus (%P), potassium (%K), calcium (%Ca), and magnesium (%Mg). Minor nutrient concentrations that are measured in parts per million include sodium (ppm Na), copper (ppm Cu), zinc (ppm Zn), manganese (ppm Mn), and iron (ppm Fe).

Percent oil (%Oil) is a measure of the amount of oils contained in the seed. These plant-based oils contribute some of the major essential fatty acids and energy needed in animal diets. High levels of these oils can supply more energy but also dilute mineral nutrient concentrations.

Percent dry matter (%DM) is the amount of plant biomass left after the water has been driven off in an oven at 140°F. The actual time that it takes to dry to a constant weight at 140°F varies from a few days to a week or more, depending on the type of plant matter. The nutrient concentrations are always expressed on a dry weight basis as it allows for better comparisons between different plant types.

The gross energy (GE) contained in the seed or meal is measured in British thermal units (BTUs) and expressed in units of calories per gram of dry matter (cal/g). One BTU is the amount of energy required to raise the temperature of 1 pound of water by 1°F. The higher the BTU values, the more energy that is contained in the plant.

Percent neutral detergent fiber (%NDF) is a measure of the partially digestible plant material (lignin, hemicellulose, and cellulose) of the forage. Lower levels of NDF usually result in a higher animal intake of the forage. It is also used to calculate the dry matter intake (DMI), where DMI = 120 ÷ %NDF. This value is later used to determine the relative feed values.

Percent acid detergent fiber (%ADF) is a measure of the highly indigestible plant material (lignin and cellulose) of the forage. Higher levels of ADF usually indicate a low digestibility of the plant material. It is also used to calculate the digestible dry matter (DDM), where DDM = 88.9 - (0.779 x %ADF). This value is also later used to determine the relative feed values.

The percent in vitro dry matter digestibility (%IVDMD) is a laboratory simulation of plant material digestibility in a rumen of a cow. A known weight of plant material is digested in a simulated rumen for a given period of time. After digestion is complete, the residue that is left is weighed and the difference is the estimated percentage of the plant material that is potentially digestible.

The relative feed value (RFV) is a unitless index that combines the nutritional factors of the dry matter intake and the digestible dry matter of the plant material, where RFV = (DDM x DMI) ÷ 1.29. Plant material with an ADF of 41% and a NDF of 53% has an RFV of 100. All other plant material is compared to this value. Lower ADF and NDF values will cause the RFV to increase. The higher the RFV, the lower the overall quality of the feed.

Table 82. Average yields and quality measurements for all canola varieties from test plots in the Fairbanks area.

Canola Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Oil Yield (gal/acre)	Seed Test Weight (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Polish edible oilseed, spring (Low E & Low G)											
AC Sunbeam	Alberta	3	1432	29	108	37	50	93	5-Aug	-10	2321
AC Sunshine	Alberta	4	1643	33	117	42	48	7	16-Aug	2	2498
Candle	Canada	6	2499	50	164	64	52	59	1-Sep	18	2843
Colt	Sweden	4	1888	38	132	48	49	31	16-Aug	2	2499
Eldorado	Alberta	4	1945	39	116	50	49	53	16-Aug	2	2531
Goldrush	Sweden	1	1821	36	86	47	48	50	21-Aug	7	2450
Horizon	Sweden	4	1901	38	130	49	49	48	16-Aug	2	2494
Hysyn 110	Manitoba	5	1345	27	100	34	48	90	11-Aug	-4	2395
Maverick	Sweden	2	1225	24	113	31	44	66	13-Aug	-2	2387
Reward	Manitoba	9	1522	30	100	39	48	77	14-Aug	0	2470
Tobin	Saskatchewan	10	2046	41	131	52	50	64	23-Aug	9	2538

Table 82 (continued). Average yields and quality measurements for all canola varieties from test plots in the Fairbanks area.

Canola Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Oil Yield (gal/acre)	Seed Test Weight (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Polish industrial oilseed, spring (Low E & High G)											
Span	Saskatchewan	1	1910	38	125	49	44	25	30-Aug	16	2944
Torch	Saskatchewan	3	1570	31	103	40	44	25	30-Aug	16	2944
Polish industrial oilseed, spring (Normal E & High G)											
Echo	Saskatchewan	1	2155	43	142	55	42	25	30-Aug	16	2944
Polish industrial oilseed, spring (High E & High G)											
R-500	Saskatchewan	2	2094	42	138	54	51	80	1-Sep	18	2843
Polish/Argentine hybrid edible oilseed, spring (Low E & Low G)											
43H57 (RR)	Saskatchewan	3	1848	37	143	47	45	91	16-Aug	2	2437
Argentine edible oilseed, spring (Low E & Low G)											
43A56 (RR)	Saskatchewan	3	1420	28	110	36	45	92	16-Aug	2	2432
Altex	Canada	4	1815	36	119	46	45	20	1-Sep	18	2843
Alto	Canada	3	1873	37	115	48	45	12	28-Aug	14	2833
Andor	Canada	1	1366	27	90	35	47	25	1-Sep	18	2843
Delta	Sweden	3	1876	38	114	48	49	23	28-Aug	15	2828
Hyola 357 Magnum (RR)	North Dakota	1	1436	29	68	37	41	100	10-Sep	27	3079
Hyola 401	North Dakota	1	918	18	43	24	48	100	10-Sep	27	3079
Legend	Sweden	3	1481	30	83	38	44	3	29-Aug	15	2849
OAC Trident (TTC)	Ontario	1	1454	29	82	37	44	25	30-Aug	16	2943
OAC Triton (TTC)	Ontario	1	894	18	59	23	40	25	1-Sep	18	2843
Regent	Canada	3	2234	45	147	57	43	22	1-Sep	18	2843
Reston	Canada	1	943	19	62	24	41	25	1-Sep	18	2843
Sprite	Canada	1	0	0	0	0	0	25	4-Sep	21	2578
Tower	Manitoba	4	1883	38	124	48	45	20	1-Sep	18	2843
Westar	Saskatchewan	5	1794	36	112	46	46	26	28-Aug	14	2810
Argentine industrial oilseed, spring (Low E & High G)											
Midas	Saskatchewan	1	2050	41	135	52	42	25	1-Sep	18	2980
Oro	Saskatchewan	1	2065	41	136	53	42	25	1-Sep	18	2980
Zephyr	Saskatchewan	1	1645	33	108	42	42	25	1-Sep	18	2980
Argentine industrial oilseed, spring (Normal E & High G)											
Target	Manitoba	1	1945	39	128	50	42	25	1-Sep	18	2980
Turret	Manitoba	1	1900	38	125	49	42	25	1-Sep	18	2980

*Growing degree days (GDD) for average maturity are calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. E = Erucic acid, G = Glucosinolates, RR = Roundup Ready (glyphosate resistant), TTC = triazine or atrazine resistant, N/D = No Data. All varieties were compared with 'Reward' Polish canola as the standard variety.

Table 83. Average quality measurements for select canola varieties from test plots in the Fairbanks area.

Canola Variety Name	Source	Years Tested	Green Seed (%)	Oil Content (%)	Crude Protein (%)	Total P (%)	Total K (%)	Dry Matter (%)	Oil GE (cal/g)	Meal GE (cal/g)
Edible Oil Industry Standards			**<2%**	**33-45%**	**22-37%**	**0.5-0.8%**	**0.6-0.9%**	**>93%**		
Polish edible oilseed, spring (Low E & Low G)										
AC Sunbeam	Alberta	3	3	31.78	26.69	0.63	0.79	97.56	7596.87	6220.21
AC Sunshine	Alberta	4	5	34.36	26.67	0.66	0.71	97.06	N/D	N/D
Colt	Sweden	4	5	35.15	26.30	0.57	0.66	97.57	N/D	N/D
Eldorado	Alberta	4	2	35.20	26.23	0.61	0.71	97.82	N/D	N/D
Horizon	Sweden	4	4	34.91	26.19	0.60	0.64	97.69	N/D	N/D
Hysyn 110	Manitoba	5	4	30.80	30.94	0.62	0.77	97.65	7461.86	6198.56
Goldrush	Sweden	1	3	31.68	N/D	N/D	N/D	N/D	N/D	N/D
Maverick	Sweden	2	5	33.80	N/D	N/D	N/D	N/D	N/D	N/D
Reward	Manitoba	9	5	34.17	26.17	0.66	0.80	97.96	7423.54	6176.91
Tobin	Saskatchewan	10	3	33.36	26.36	0.66	0.72	97.57	N/D	N/D
Polish industrial oilseed, spring (Low E & High G)										
Span	Saskatchewan	1	N/D	37.00	N/D	N/D	N/D	N/D	N/D	N/D
Torch	Saskatchewan	3	N/D	36.00	N/D	N/D	N/D	N/D	N/D	N/D
Polish industrial oilseed, spring (High E & High G)										
R-500	Saskatchewan	2	N/D	41.80	N/D	N/D	N/D	N/D	N/D	N/D
Polish/Argentine hybrid edible oilseed, spring (Low E & Low G)										
43H57 (RR)	Saskatchewan	3	36	35.16	N/D	N/D	N/D	N/D	N/D	N/D
Argentine edible oilseed, spring (Low E & Low G)										
43A56 (RR)	Saskatchewan	3	37	36.68	N/D	N/D	N/D	N/D	N/D	N/D
Alto	Canada	3	24	34.53	26.83	0.59	0.68	97.17	N/D	N/D
Delta	Sweden	3	31	33.99	27.23	0.60	0.68	96.87	N/D	N/D
Hyola 357 Magnum (RR)	North Dakota	1	41	35.94	N/D	N/D	N/D	N/D	N/D	N/D
Hyola 401	North Dakota	1	48	33.31	N/D	N/D	N/D	N/D	N/D	N/D
Legend	Sweden	3	26	35.64	27.51	0.65	0.72	97.39	N/D	N/D
OAC Trident (TTC)	Ontario	1	N/D	31.02	28.38	0.69	0.70	97.80	N/D	N/D
Regent	Canada	3	N/D	37.10	N/D	N/D	N/D	N/D	N/D	N/D
Tower	Manitoba	4	N/D	33.50	N/D	N/D	N/D	N/D	N/D	N/D
Westar	Saskatchewan	5	21	34.21	27.17	0.59	0.73	97.39	N/D	N/D

E = Erucic acid, G = Glucosinolates, RR = Roundup Ready (glyphosate resistant), TTC = triazine or atrazine resistant, N/D = No Data. All varieties were compared with 'Reward' Polish canola as the standard variety.

Mustard

Edible Yellow, Brown, and Oriental Mustard Oilseed

Yellow mustard (*Sinapis alba*) is a tall (2.5 to 4 feet), multibranched, annual, broad-leaved oilseed plant similar in appearance to Argentine canola. It is a mid- to long-season crop that matures in about the same period as barley or canola and grows best in warm, dry growing conditions. The seed is ground into a paste to make the typical condiment mustard. It is the mildest of the 3 types of mustards and contains about 20% to 27% oil.

Brown and oriental mustards (*Brassica juncea*) are very tall (3 to 5 feet), multibranched, annual, broad-leaved oilseed plants also similar in appearance to Argentine canola. They are also mid- to long-season crops that mature in about the same period as barley or canola but grow better in cool, moist growing conditions. Both of these mustard seed types are hot and spicy. Brown mustard seed is ground into a paste to make Dijon-type condiment mustard or ground into a flour to produce a dry, hot mustard or spice mix and contains about 30% to 40% oil. Oriental mustard seed is used to make spicy cooking oils and has the highest oil content of about 35% to 45%.

The oil in all mustards is made up of major fatty acids, some of which are considered essential fatty acids as they can't be synthesized by the body, but must come from the diet. The Canadian Grain Commission (2010) reports ranges of these major fatty acids for mustards as 20% to 25% oleic, an omega-9 fatty acid; 8% to 25% linoleic, an omega-6 fatty acid; and 8% to 15% linolenic, an omega-3 fatty acid. The oil also contains high levels (20% to 40%) of the nonessential fatty acid, erucic acid. Mustard oils, like canola oil, have about 6% saturated fat content.

Although these mustards, like rapeseed, have high levels of erucic acid and glucosinolates that make them problematic for use as cattle feed, they are not a concern humans since the quantities consumed in the diet are small. The spiciness in all mustard seed is related to the high glucosinolate content. All 3 mustards have concentrations of about 100 to 250 micromoles per gram or more in the seed, with yellow usually having the lowest and oriental having the highest. The plant breeding program of Agriculture and Agri-Food Canada have developed new *Brassica juncea* varieties that have met the low erucic acid and low glucosinolate content requirements of edible canola-quality oil. This was done in an effort to produce an oriental-type mustard cooking oil with the same health benefits as canola oil (2% or less erucic acid and less than 30 micromoles per gram of glucosinolates). None of these varieties have been evaluated yet within this program.

The glucosinolate level in mustard plant tissue is much lower at around 5 to 20 micromoles per gram. There is an enzyme in the plant tissue of all *Brassica* species called myrosinase that reacts with the glucosinolates only when the plant tissue has been crushed and produces the chemical, allyl isothiocyamate (AITC). This chemical inhibits growth of some plant species, nematodes, insects, and soilborne plant diseases in the field and inhibits the growth of molds, yeasts, and many other foodborne pathogens. This positive allelochemical effect is a natural plant-based defense against damage from insects and animals. Because of the higher glucosinolate content and the greater amount of biomass compared to canola, many mustards are grown specifically as a green manure cover crop to be incorporated into the soil either before or directly after seed harvest as a biofumigation control of insects, weeds, and soilborne diseases. This effect is usually short-lived (1 day in warm and moist soil conditions to as long as a week under cool, dry conditions) as organic breakdown of the plant tissue continues.

The seed coat of yellow mustard contains about 25% arabinogalactan, a gelling substance known as mucilage within the processing industry. This material contributes to the emulsification properties, or the texture of the condiment mustard, when the seed is crushed and added to water to make a paste. Varieties of yellow mustard with higher mucilage content make better condiments and bring higher prices to the producer.

Mustard oils are obtained by a combination of expressing and extraction with a solvent. The best of the commercial oilseed presses is capable of extracting only about half of the oil contained in the mustard seed, or about 12% to 20% by weight. Small-scale to kitchen-scale presses can only get about one-quarter of the oil in the seed, or about 6% to 10% by weight. The remaining half to three-quarters of the oil that remains in the meal is extracted with a hexane solvent process. The solvent is then removed from the oil, which is blended in with the pressed oil and everything is run through a filtration and cleaning process. The resulting meal is then dried and reground through finer screens to make mustard powders and spices.

Fertilization practices for mustards are similar to those for canola. Mustards require more nitrogen than any other nutrient, which is essential for increased leaf production and increased yields if sufficient available soil moisture is present during the growing season. With adequate soil moisture conditions, a maximum of 10 pounds per acre of nitrogen can be banded with the seed. Because soil moisture conditions are rarely sufficient in Alaska unless irrigation is used, most if not all nitrogen carriers should be broadcast applied. In low soil moisture conditions, germinating seeds and seedlings can be injured by the banded nitrogen fertilizers. Avoid excess nitrogen fertilizer because it can induce lodging, delay maturity, and cause an increased risk of fungal attacks at harvest, especially if grown under irrigation. Like canola, about half of the available soil nitrogen is removed with the seed at harvest. If plant residues are incorporated with tillage the following spring, a high amount of nitrogen remaining in the straw and stubble is returned to the soil.

Mustards require moderate phosphorus and low potassium levels, which improve disease resistance and tolerance for frost and drought. Because Alaska soils are generally acidic, they tend to fix phosphorus, making it unavailable for plant uptake, so banding the phosphorus carrier with or next to the seed at planting would not help increase the level of available phosphorus. The small seed is planted shallowly, where soil moisture is usually less than optimum, which renders the phosphorus unavailable for plant use. Thus, phosphorus and potassium fertilizers should be broadcast with the nitrogen fertilizers. About two-thirds of the phosphorus and one-third of the potassium are removed with the seed. If plant residues are incorporated with tillage the following spring, a high amount of potassium remaining in the straw and stubble is returned to the soil and becomes available for crops.

Sulfur and boron are needed by mustards to promote flowering and seed set. Soils low in available sulfur should have a sulfate form of sulfur broadcast as ammonium sulfate or as potassium sulfate. An application rate of 0.5 pound per acre of actual boron is sufficient to correct most soil deficiencies. About half of the available soil sulfur is removed with the seed at harvest. If plant residues are incorporated with tillage the following spring, a large amount of sulfur remaining in the straw and stubble becomes available. A ratio of 3:2:1:0.5 of N, P_2O_5, K_2O, and S have produced acceptable yields of all mustard types. With irrigated farming practices, the ratio should be reduced to about 1.5:1:0.5:0.25. Actual percentages of all nutrients and the application rates vary according to the specific soil test results. All fertilizer must be broadcast prior to spring tillage.

Choice of the field for mustard production is important. It should not have been cropped to canola or other *Brassica* species in the previous 3 to 5 years. Mustard production should follow a year of summer fallow to help reduce the likelihood of plant disease, broad-leaved weeds, and volunteers, or planted in a rotation following a grain crop like barley. This also increases available soil moisture and reduces the amount of fertilizer required. To conserve soil moisture, minimum tillage is recommended for incorporating fertilizer and plant residue and preparing the seedbed. Pulling a packer behind the tillage implement and using a seed drill equipped with press wheels ensure that the seed is in contact with moist soil during the time needed for germination. If the crop is to be grown under irrigation, the soil should be irrigated sufficiently to bring the soil moisture levels to close to the maximum water-holding capacity before tillage. It is very important not to irrigate above the maximum water-holding capacity before tillage and planting as this could cause a soil crust to form on the surface that can impede seedling emergence, reduce plant density, and lower seed yields. Seeding depth is shallow, 0.5 to 1.5 inches, or to moisture. Seeding deeper than 2 inches may result in delayed germination and emergence. Seeding rate depends on seed size. Generally, 10 to 14 pounds per acre of pure live seed for the larger yellow mustard types and 6 to 10 pounds per acre for the smaller-seeded brown and oriental types are recommended for seed and oil production. Higher seeding rates of 15 to 20 pounds per acre of pure live seed are recommended for a green manure cover crop for bio-fumigation. Also, heavier seeding rates produce thicker stands that ripen more uniformly and reduce the possibility of green seeds at harvest. Planting as early as possible to avoid loss of important soil moisture and to use as much of the short growing season as possible is recommended. Use of certified seed is strongly recommended. Certified seed has strict limits on maximum content of weed seeds and diseased seed and must meet a minimum percent germination. This helps to ensure good germination and emergence and reduces weed and disease infestations.

Like canola, irrigation should begin again after the crop has reached about 50% emergence to avoid any problems resulting from too hard of a crust on the surface. Thereafter, a good range of irrigation plus precipitation is around 0.5 to 1.0 inch per week. Irrigation should continue until the crop has reached the 50% pod-set growth stage.

Using IPM techniques, assess each field for all pests (weeds, diseases, and insects) and plan control measures accordingly. Weed control in mustards is extremely important. All mustard types need warm soil to germinate and don't compete well with weeds. The same weeds that are a problem for canola also compete with mustards. The most difficult to control are wild mustard (*Sinapsis arvensis*), shepherd's purse (*Capsella bursa-pastoris* (L.) Medic.), tansy mustard (*Descurainia sophioides* Fisch.), and volunteer canola because the seed size and shape are similar to commercial mustard seed. The best weed control is a combination of mechanical and chemical summer fallow to reduce the number and species of weeds for the following season. In the spring, wait for weeds to germinate, then perform seedbed tillage using proper fertilization and seeding rates. There are no herbicides registered for use on mustards in Alaska. To eliminate both grassy and broad-leaved weeds, a broad-spectrum, nonselective, post-emergence herbicide such as glyphosate (Roundup) can be used in the chemical fallow rotation.

The same fungal diseases that attack canola seed and seedlings, causing damping-off, downy mildew (*Peronspora parasitica*), and root rot, also attack all mustards. They cause seed decay and seedling blight with delayed emergence and eventual uneven stands. Cool, wet soil conditions in the spring favor development of seedborne fungal attacks. Control these diseases by using certified seed and registered fungicides such as carboxin (Vitavax) applied to the seed. Sclerotinia, or white mold fungus (*Sclerotinia sclerotiorum*), infects the base of the plant, causing wilt. This fast-acting disease often takes only 4 to 7 days from the first appearance to complete wilting. Cool, wet soil conditions in the spring and infected plant residue from the previous year favor development of this fungal disease. It can spread from plant contact and through airborne spores. Control with crop rotation and certified seed. Sunflowers, canola, and camelina are also susceptible to this disease and should not be used in the crop rotation.

Like canola, all mustard types are susceptible to many different kinds of insect pests, many of which can cause serious yield losses, and thus require control measures. Flea beetles (*Phyllotreta cruciferae* Goeze) are small, shiny, black insects that jump when disturbed. They can seriously damage the newly emerging crop by eating small holes in the leaves. Control using registered insecticide seed treatments such as lindane (Vitavax RS) that also contain the fungicide carboxin. The cabbage root maggot, or cutworm (*Hylemya brassicae* Bouche), is the larval stage of a fly. It infests the base and roots in the seedling to mature growth stages. Just 3 or more cutworms can eventually girdle the plant. However, because of the greater stem size compared to canola, they rarely cause serious damage after the flowering stage. Unfortunately, their feeding creates wounds that can later serve as entry sites for fungal diseases. If insect population levels and damage have been determined to be too high through IPM practices, then the application of an insecticide may be warranted. A control measure that works well is to increase the number of years between *Brassica* crops in the same fields. The red turnip beetle (*Entomoscelis americana* Brown) has recently become a serious pest in Alaska. The adult beetle is bright red with 3 black stripes down the back and a black patch behind the head. The larva feed on the leaves in late May to early June and the adults feed on the leaves in late June to early July, often causing total defoliation in heavy infestation years. After feeding for several weeks, the beetle burrows into the soil and becomes inactive for a 2-week summer hibernation period. The beetles re-emerge in August and continue feeding until killed by early frosts. If insect population levels and damage have been determined to be too high through IPM practices, then the application of an insecticide may be warranted. Insecticide sprays help control heavy infestations when applied at the first outbreak (larval or maggot stage). Cultural practices such as weed control (tansy mustard, *Descurainia sophioides* Fisch., is an alternate host) and volunteer control are also recommended to reduce red turnip beetle populations. Always remember to read the pesticide label to be sure the crop is specified and follow the directions on mixing, application, and disposal. Contact your local Cooperative Extension Service for more information on pest control (see Appendix 1 for addresses and contact information). Because of the higher glucosinolate levels in the seed, crop damage from songbirds or migratory waterfowl is likely to be minimal.

Mustards, like canola, ripen from the bottom of the plant to the top. When 40% to 50% of the seeds near the bottom have turned yellow or brown, harvest can begin. There will still be green seeds in the pods near the tips of the side branches and at the top of the plant. Average seed moisture content at this stage is about 35% to 45%. Use seed color change and not pod color change as an indicator of maturity, because some varieties can have ripe seeds in green pods. Mustard is usually swathed prior to combining, because seed continues to mature in the windrow and can change color by 5% per day with enough heat and low humidity. Swathing also helps dry both the mustard plants and any green weeds before harvest, making combining easier and reducing shatter loss. After a heavy precipitation event, standing mustard dries better than swathed mustard in windrows. Swathing too early reduces overall yields and oil content, while swathing too late increases shatter loss. Windrows can become very lightweight as the crop dries down. These light windrows can then be blown around by even a slight breeze, spreading the plants out and shattering seed pods, which results in a significant yield reduction.

Combining either the swathed or standing mustard can begin when the seed has around 12% to 15% moisture content. Pod shatter is greater for mustards than it is for canola. To reduce the loss of seed due to shatter, set the header reel height to just at the top of the crop or windrow and slow down the reel speed. Reduce cylinder speeds to one-half or two-thirds of that used for small grains. Concave clearance should be increased for mustards because of the greater volume of plant material to about 1.5 inches at the front and 1 inch at the back. These settings can be reduced later only if the plant tissue is dry enough to thresh out properly. This will reduce the chance of overthreshing and causing cracked seeds and excess plant material in the hopper. Reduce the fan speed to about three-quarters of that used for small grains to avoid blowing the seed out with the chaff. The cleaning action for mustard seed relies more on shaking action than on air flow. Top screens should be between one-quarter inch and one-third inch and the bottom screens between one-eighth inch and one-quarter inch depending on seed size. Care must be taken to seal up all small holes and cracks in the combine, augers, trucks, and bins, as mustard seed is small and round in shape and thus leaks out easily. Equip the combine with a straw chopper and spreader to evenly distribute the plant material in order to incorporate it for the allelochemical effect the following growing season.

Typical grain dryers have perforated floor openings that are too large for the small seeds. A 5-mesh nylon sheet over the floor prevents seed loss. Mustard seed should be recleaned, dried to about 8% to 9% moisture, and cooled to between 60°F and 40°F before storage. Any green or moist material can cause molds to form, reducing the quality of the oil as well as the germination ability of the seed. Aeration from the bottom up through the bin with supplemental heat to drive off excess moisture is the usual first step. Do not heat the seed above 120°F because this causes a reduction in germination ability. The seed should be cooled immediately after drying to between 60°F and 40°F. Temperatures and moisture content of the seed in the bin should be checked every day for a week after harvest, then every week after that. Repeat the aeration and drying if needed because seed can spoil quickly in storage. The limit for green seed in the mustard seed market is only 2% or less. Green seed and clean-outs can be used sparingly on farm as an animal feed for ruminants.

Recommended Variety Descriptions for Yellow, Brown, and Oriental Mustard

Note: See Appendix 1 for the addresses of seed suppliers.

'IdaGold' is a mid- to late-maturing, very tall, high-yielding, spring yellow mustard developed by the Canola, Rapeseed, and Mustard Program of the University of Idaho in 2000. It yields about the same as 'Reward' Polish canola and matures about 1 week earlier. Poor lodging resistance is due to the tall plant height. Green seed percentage is similar to Polish canola varieties and shatter resistance is fair. This variety is an acceptable condiment mustard. 'IdaGold" is highly resistant to flea beetles (*Phyllotreta cruciferae* Goeze). It produces a large amount of biomass with high concentrations of glucosinolates, making it a good cover crop for bio-fumigation control of some weeds. Direct inquiries about seed sources to the L.A. Hearne Company.

'Kodiak' is a mid- to late-maturing, very tall, high-yielding, spring brown mustard developed by the Canola, Rapeseed, and Mustard Program of the University of Idaho in 2005. It is slightly higher yielding than 'Reward' Polish canola and matures about 2 to 3 days earlier. Lodging resistance is poor because of the tall plant height. Green seed percentage is similar to Argentine canola varieties and shatter resistance is fair. This variety is an acceptable spice mustard suitable for dry powder mustards and spice mixes. It produces a large amount of biomass with high concentrations of glucosinolates, making it a good cover crop for bio-fumigation control of nematodes and soilborne diseases. Direct inquiries about seed sources to the L.A. Hearne Company.

'Pacific Gold' is a mid- to late-maturing, very tall, high-yielding, spring oriental mustard developed by the Canola, Rapeseed, and Mustard Program of the University of Idaho in 2001. It is slightly higher yielding than 'Reward' Polish canola and matures about the same time. Lodging resistance is poor because of the tall plant height. Green seed percentage is similar to Argentine canola varieties and shatter resistance is fair. This variety is an acceptable oriental spice mustard oil. 'Pacific Gold' is moderately resistant to flea beetles (*Phyllotreta cruciferae* Goeze). It produces a large amount of biomass with high concentrations of glucosinolates, making it a good cover crop for bio-fumigation control of nematodes and soilborne diseases. Direct inquiries about seed sources to the L.A. Hearne Company.

Like canola, mustard seed is considered a marginal crop for Alaska. In good years with adequate soil moisture and GDDs, the varieties listed previously will still have uneven ripening resulting in a high percentage of green seed at harvest. This is due to any immature seed that was killed by fall frost. Any seed killed by frost does not continue to ripen and remains green. Green seed is immature seed that contains chlorophyll, which imparts a green color to the condiment or oil and shortens the shelf life by turning rancid quickly. There is increasing interest in Alaska in producing an oilseed crop for both the edible oil and biofuel markets. Any seed grown for these markets should be grown on contract with a processing facility, because a high-quality seed lot is required. Unfortunately, there is currently no large-scale facility in Alaska to process oil from mustard seed for either the edible oil or biofuel oil markets. Also, there are no elevators in Alaska currently set up to take mustard seed. However, there are a few on-farm, small-scale oilseed presses set up to extract oil without the secondary chemical extraction.

All mustard varieties have higher biomass yields with correspondingly higher glucosinolate levels than the Polish canola varieties. As a result, all mustard varieties have a greater benefit when grown in rotation as a bio-fumigant cover crop for an organic control of weeds, insects, nematodes, and soilborne diseases. The primary purpose of testing these varieties in this study was for oilseed yield and not as a bio-fumigant, so there is no data on the effectiveness of the biomass for weed or insect control. However, in general observations of the plots in the following year, it did appear that there were fewer types of weeds than in untreated plots; most notably, hawksbeard (*Crepis tectorum* L.) and lambsquarter (*Chenopodium album* L.) seemed affected. Further studies into this allelochemical effect can measure the impact.

Yields by Location for Yellow, Brown, and Oriental Mustard

Mustards (yellow, brown, and oriental) are bought and sold by weight. Similar to canola, there is a standard test weight for mustard seed that is used as the legal unit for purchase or sale of the crop. This standard test weight for clean, dry, and undamaged mustard seed is 50 pounds per bushel. Along with test weights, additional samples should be taken on-farm to determine quality. Any seed lots not meeting high quality standards should be used as lower feed grades. It is important, then, for the producer to clean and size all seed lots before delivery to a niche market. Test weights are used here as a measure of seed quality to determine maturity. Yields are expressed here in pounds per acre and bushels per acre. Determine bushels per acre by dividing the yield of any specific cultivar by the standard test weight.

Tables 92 and 94 list yields and quality measurements for mustard seed varieties for 2 test locations, Fairbanks and Delta Junction. All sites in the Delta Junction area have been combined into the Delta dryland site (Table 94). There were no irrigation trials conducted on mustards. Each table also contains information on seed type (yellow, brown, or oriental) and the years it was tested at each location. Seed can be used as either a condiment and spice mustard or as a biofuel. The meal can be used sparingly in ruminant animal feeds. Maturity in this study was defined as when 50% of the seed for each plot turned a yellow or brown color. Growing degree days (GDD) for average maturity were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. The low temperature point for all mustards in this report is the freezing point of water, 32°F. The GDD calculations for each day were then added to the preceding GDD value to determine the date at which the specific variety had reached 50% maturity. All varieties were compared with 'Reward' Polish canola as the standard variety. Yield as a percent of the standard variety 'Reward' was determined by dividing the average yield of each variety by the average yield of 'Reward'. Maturity vs. Std. (Standard variety) is the number of days it took for each variety to reach 50% maturity either before or after the number of days that 'Reward' reached 50% maturity. Estimated oil yield data is based on extracting about half of the oil contained in the mustard seed, or about 20% by weight, through the primary pressing process and not the secondary chemical extraction process. Therefore, the seed yield in pounds per acre times 20% equals the oil yield in pounds per acre. The density of mustard oil is the same as for canola oil (7.81 pounds per gallon). This number is used to convert the oil yield in pounds per acre into gallons of oil per acre.

Seed quality data (percent oil, percent crude protein, percent green seed, and other nutrients) for Fairbanks (Table 93) and Delta dryland (Table 95) are presented without statistical differences and solely for the reader's benefit. More detailed information and explanation about the industry standards for food-grade mustard oil can be obtained from the Canadian Grain Commission (2010). Detailed explanation of the feed analysis that follows as well as laboratory procedures can be obtained from J. Schroeder (1994) and G.J. Michaelson and others (1987).

Percent green seed is a measure of the maturity of the crop. Seed coat color is not always a good indicator of plant maturity because it can start to turn yellow or brown while the inside is still green and immature. To determine if the inner seed color is still green, collect multiple random samples of 100 seeds after drying and cleaning. Place the seeds on a grid over white paper and crush them with a roller. The inner color of any immature seed will then show up as green or yellowish-green blots, which can then be counted. The percent green seed is then determined from the original 100 seed subsample. High percentages of green seed indicate that the crop is immature. Oil or condiments processed from a crop with a high percentage of green seed will go rancid quicker.

Percent oil (%Oil) is a measure of the amount of plant-based oils contained in the seed. These oils contribute some of the major essential fatty acids and energy needed in animal diets. High levels of plant-based oils can supply more energy but also dilute mineral nutrient concentrations.

Percent crude protein is calculated from the total percent nitrogen analysis of the seed multiplied by a constant of 6.25. Crude protein is made up of amino acids, which are 16% nitrogen, as well as other non-protein portions of the plant, and so percent crude protein is not a measure of true protein. Industry standards of crude protein for all mustards are set for a range between 22% and 37%. Higher values have greater nutritional food value, but too high a value (>37%) is an indicator of immature green seed at harvest, which makes a lower quality grade oil because it turns rancid quicker. In a standard feed analysis, other major nutrient mineral concentrations that are measured are percent phosphorus (%P) and potassium (%K).

Table 92. Average yields and quality measurements for all mustard varieties from test plots in the Fairbanks area.

Mustard Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Oil Yield (gal/acre)	Seed Test wt. (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Yellow edible condiment oilseed, spring											
IdaGold	Idaho	3	1068	21	99	27	46	47	3-Aug	-11	2107
Brown edible spice and condiment oilseed, spring											
Kodiak Brown	Idaho	3	1295	26	121	33	46	68	8-Aug	-6	2259
Oriental edible oil and spice oilseed, spring											
Pacific Gold	Idaho	3	1340	27	122	34	45	80	10-Aug	-4	2312

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. All varieties were compared with 'Reward' Polish canola as the standard variety.

Table 93. Average quality measurements for select mustard varieties from test plots in the Fairbanks area.

Mustard Variety Name	Source	Years Tested	Green Seed (%)	Oil Content (%)	Crude Protein (%)	Total P (%)	Total K (%)
Edible Oil Industry Standards			**<2%**	**33-45%**	**22-37%**	**0.5-0.8%**	**0.6-0.9%**
Yellow edible condiment oilseed, spring							
IdaGold	Idaho	3	8	24.90	30.60	0.69	0.70
Brown edible spice and condiment oilseed, spring							
Kodiak Brown	Idaho	3	14	29.90	27.50	0.65	0.72
Oriental edible oil and spice oilseed, spring							
Pacific Gold	Idaho	3	16	31.50	26.20	0.69	0.73

All varieties were compared with 'Reward' Polish canola as the standard variety.

Table 94. Average yields and quality measurements for all mustard varieties from test plots in the Delta Junction area, dryland site.

Mustard Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Oil Yield (gal/acre)	Seed Test wt. (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Yellow edible condiment oilseed, spring											
IdaGold	Idaho	3	1111	22	84	28	48	38	10-Aug	-4	2353
Brown edible spice and condiment oilseed, spring											
Kodiak Brown	Idaho	3	1133	23	87	29	49	43	13-Aug	-1	2449
Oriental edible oil and spice oilseed, spring											
Pacific Gold	Idaho	3	965	19	71	25	48	57	12-Aug	-2	2418

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. Differences between varieties in Average Maturity GDD in relation to the Average Maturity Date are due to differing years of testing. All varieties were compared with 'Reward' Polish canola as the standard variety.

Table 95. Average quality measurements for select mustard varieties from test plots in the Delta Junction area, dryland site.

Mustard Variety Name	Source	Years Tested	Green Seed (%)	Oil Content (%)	Crude Protein (%)	Total P (%)	Total K (%)
Edible Oil Industry Standards			**<2%**	**33-45%**	**22-37%**	**0.5-0.8%**	**0.6-0.9%**
Yellow edible condiment oilseed, spring							
IdaGold	Idaho	3	16	26.30	25.63	0.62	0.95
Brown edible spice and condiment oilseed, spring							
Kodiak Brown	Idaho	3	17	31.65	24.52	0.68	0.94
Oriental edible oil and spice oilseed, spring							
Pacific Gold	Idaho	3	17	34.40	26.94	0.69	0.94

All varieties were compared with 'Reward' Polish canola as the standard variety.

Camelina

Spring Edible Camelina Oilseed

Camelina (*Camelina sativa* (L.)), commonly known as false flax or gold-of-pleasure, is a mid-season, spring or winter annual, edible or industrial oilseed crop in the same cruciferous family as canola and mustards. It grows anywhere from 1 to 3 feet tall with multibranched stems that become woody when it reaches maturity. The leaves are arrow-shaped, pointed at the ends, and about 2 to 3 inches long. It produces a large mass of small, pale yellow to greenish-yellow mostly self-pollinated flowers. After pollination the plant will form 0.25- to 0.5-inch seed pods that closely resemble flax bolls and contain a number of very small (one-sixteenth inch) pale yellow, orange, or brown rough, oblong seeds. Camelina seed contains between 29% and 41% oil that is high in omega-3 fatty acids and low in saturated fats, making it a high-quality edible oil. High levels of omega-3 fatty acids (linolenic) have been shown to reduce LDL cholesterol levels in the blood and are good for heart and cardiovascular health. Camelina oil at about 12% saturated fat content is greater than flax (linseed) oil and canola oil. The oil in camelina is made up of major fatty acids, some of which are considered essential fatty acids as they can't be synthesized by the body but must come from the diet. According to D.T. Ehrensing and S.O. Guy (2008) and A.L. Pilgeram and others (2007), camelina seed contains the following ranges of mono- and polyunsaturated essential fatty acids: 6% to 8% palmitic acid, 2% to 3% stearic acid, 15% to 20% oleic (an omega-9 fatty acid), 20% to 25% linoleic (an omega-6 fatty acid), and 30% to 39% linolenic (an omega-3 fatty acid). It also contains gamma tocopherol (vitamin E), an antioxidant, which increases the stability and shelf life of the processed oil over that of canola or mustard oils. The oil also contains high levels of nonessential fatty acids such as eicosenoic acid (10% to 12%) and erucic acid (2% to 5%), more than the 2% maximum limit for canola-quality edible oil. However, there is very little to no concentration of glucosinolates in camelina seed.

Camelina oil has been used as an edible oil in salad dressings and cooking oil (but not deep-fat frying oil because the smoke point occurs at a fairly low temperature), and as an industrial oil for lighting, or as a biofuel. The ancient Romans used camelina oil as a massage oil (gold-of-pleasure) and it is currently used in cosmetics, soaps, and detergents. The seed have been fed without processing to caged birds, and the meal, at 45% to 47% crude protein and 10% to 11% fiber, to poultry and dairy animals to increase the omega-3 content in eggs and dairy products.

Camelina oil is obtained by a combination of expressing and extraction with a solvent. The best of the commercial oilseed presses is only capable of extracting about half of the oil contained in the seed, or about 15% to 20% by weight. Small-scale to kitchen-scale presses can only get about one-quarter of the oil in the seed, or about 8% to 10% by weight. The remaining half to three-quarters of the oil is extracted with a hexane solvent process. The solvent is then removed from the oil, which is blended in with the pressed oil, and everything is run through a filtration and cleaning process. The resulting meal is then used as a high-quality omega-3 content animal feed.

Fertilization practices for camelina are similar to those for canola and mustards, but it does better on marginal soils than either. Camelina requires more nitrogen than any other nutrient. Nitrogen should be used for increased

leaf production and increased yields if sufficient available soil moisture is present during the growing season. With adequate soil moisture conditions, a maximum of 10 pounds per acre of nitrogen can be banded with the seed. Because soil moisture conditions are rarely sufficient in Alaska unless irrigation is used, most if not all nitrogen carriers should be broadcast applied. In low soil-moisture conditions, germinating seeds and seedlings can be injured by nitrogen fertilizers. Avoid using more nitrogen fertilizer than recommended because it can induce lodging, delay maturity, and cause an increased risk of fungal attacks at harvest, especially if grown under irrigation.

Camelina requires moderate phosphorus and low potassium levels, which improve disease resistance and tolerance for frost and drought. Because Alaska soils are generally acidic, they tend to fix phosphorus, making it unavailable for plant uptake, so banding the phosphorus carrier with or next to the seed at planting would not help increase the level of available phosphorus. The small seed is planted shallowly, where soil moisture is usually less than optimum, which renders the phosphorus unavailable for plant use. Thus, phosphorus and potassium fertilizers should be broadcast with the nitrogen fertilizers.

Sulfur and boron are needed by camelina to promote flowering and seed set and to increase the oil content. Soils low in available sulfur should have sulfur broadcast applied as ammonium sulfate or as potassium sulfate. A ratio of 2:1:1:0.5 of N, P_2O_5, K_2O, and S have produced acceptable yields of camelina. With irrigated farming practices, the ratio should be reduced to about 1:0.5:0.5:0.25. An application rate of 0.5 pound per acre of actual boron is sufficient to correct most soil deficiencies. Actual percentages of all nutrients and the application rates vary according to the specific soil test results. All fertilizer must be broadcast prior to spring tillage.

Choice of the field for camelina production is important. It should not have been cropped to canola or mustards in the previous 3 to 5 years. Camelina production should follow a year of summer fallow to help reduce the likelihood of plant disease, broad-leaved weeds, and volunteers, or it should be planted in a rotation following a grain crop like barley. This also increases available soil moisture and reduces the amount of fertilizer required. To conserve soil moisture, minimum tillage is recommended for incorporating fertilizer and plant residue and preparing the seedbed. Pulling a packer behind the tillage implement and using a seed drill equipped with press wheels ensures that the seed is in contact with moist soil during germination. If the crop is to be grown under irrigation, the soil should be irrigated sufficiently to bring the soil moisture levels close to the maximum water-holding capacity before tillage. It is very important not to irrigate above the maximum water-holding capacity before tilling and planting as this could cause a crust to form on the surface of the soil that would impede seedling emergence, reduce plant density, and lower seed yields. Seeding depth is shallow, 0.25 to 0.5 inch, or to moisture. Seeding deeper than 1 inch may result in delayed germination and emergence. Seeding rate is 3 to 8 pounds per acre of pure live seed. Higher seeding rates produce thicker stands that ripen more uniformly and reduce the possibility of green seeds at harvest. Camelina is very frost tolerant and will germinate in soil temperatures as low as 38°F. Planting as early as possible to avoid loss of important soil moisture and utilize as much of the short growing season as possible is recommended. Use of certified seed is strongly recommended. Certified seed has strict limits on maximum content of weed seeds and diseased seed, and must meet a minimum percent germination. This helps to ensure good germination and emergence and reduces weed and disease infestations.

Like canola, irrigation should begin again after the crop has reached about 50% emergence to avoid any problems resulting from too hard of a crust on the surface. Thereafter, a good range of irrigation plus precipitation is around 0.5 to 1.0 inch per week. Irrigation should continue until the crop has reached the 50% pod set growth stage.

Using IPM techniques, assess each field for all pests (weeds, diseases, and insects) and plan control measures accordingly. Weed control in camelina is easier than for canola or mustards as it is naturally weed resistant. Even though there are very low levels of glucosinolates in camelina it does have a natural allelopathic effect during the year in which it is grown. This is usually very short-lived and will stop at maturity when leaf drop occurs. However, perennial weeds such as the common grassy weeds like bluejoint reed grass (*Calamogrostis canadensis* (Michx.) Beauv.), foxtail barley (*Hordeum jubatum* L.), and quackgrass (*Agropyron repens* (L.) Beauv.) are much more difficult to control. The best weed control is a combination of mechanical and chemical summer fallow to reduce the number and species of weeds for the following season. In the spring, wait for weeds to germinate, then perform seedbed tillage using proper fertilization and seeding rates. There are no herbicides registered for use on camelina in Alaska. To eliminate both grassy and broad-leaved weeds, a broad-spectrum, nonselective post-emergence herbicide such as glyphosate (Roundup) can be used in the chemical fallow rotation.

The same fungal diseases that attack canola and mustard seed and seedlings, causing damping-off, downy mildew (*Peronospora camelinae*), and root rot, also attack camelina. They cause seed decay and seedling blight with delayed emergence and eventual uneven stands. Cool, wet soil conditions in the spring favor development of seed-borne fungal attacks. Sclerotinia, or white mold fungus (*Sclerotinia sclerotiorum*), infects the base of the plant, causing wilt. This fast-acting disease often takes only 4 to 7 days from the first appearance to complete wilting. Cool, wet soil conditions in the spring and infected plant residue from the previous year favor development of this fungal disease. It can spread from plant contact and through airborne spores. Control is through crop rotation and certified seed as there are no registered fungicides for camelina in Alaska. Sunflowers, mustards, and canola are also susceptible to this disease and should not be used in the crop rotation. Camelina is resistant to blackleg (*Leptosphaeria maculans*) so it can be planted in place of canola to reduce the incidence of this disease in crop rotations. Camelina is not as susceptible to insect pests, song birds, or migratory waterfowl as canola and mustards. Contact your local Cooperative Extension Service for more information on pest control (see Appendix 1 for addresses and contact information).

Camelina, like canola, ripens from the bottom of the plant to the top. When two-thirds of the seed pods have turned yellow or brown, harvest can begin. There will still be green seeds in the pods near the tips of the side branches and at the top of the plant. Average seed moisture content at this stage is about 25%. Camelina is usually swathed prior to combining because seed continues to mature in the windrow and can change color by 5% per day with enough heat and low humidity. Swathing also helps dry both the plants and any green weeds before harvest, making combining easier. After a heavy precipitation event, standing camelina dries better than swathed in windrows. Unlike canola or mustards, camelina pods hold on to the seed tightly, so seed shatter is not a serious problem. Windrows can become very light weight as the crop dries down. These light windrows can then be blown around by even a slight breeze, spreading the plants out and making harvest difficult, resulting in a significant yield reduction.

Combining either the swathed or standing camelina can begin when the seed is around 10% moisture content. To reduce the loss of seed out of the back of the combine, set the header reel height to just at the top of the crop or windrow and slow down the reel speed. Header height should be set as high as possible, to just below the first set of seed pods. This will help to reduce the amount of woody stem plant material that goes through the cylinder. Reduce cylinder speeds to one-half or two-thirds of that used for small grains. Concave clearance should be similar for that of canola to about 0.5 inch at the front and 1.5 inches at the back. This will reduce the chance of overthreshing and causing cracked seeds and excess plant material in the hopper. Reduce the fan speed to about three-quarters of that used for small grains to avoid blowing the seed out with the chaff. The cleaning action for camelina relies more on shaking action than on air flow. Top screens should be between 0.25 and one-third inch and the bottom screens between one-eighth and 0.25 inch to accommodate the small seed size. Care must be taken to seal up all small holes and cracks in the combine, augers, trucks, and bins as camelina seed is small in size, and thus leaks out easily. Equip the combine with a straw chopper and spreader to evenly distribute the plant material.

Typical grain dryers have perforated floor openings that are too large for the small seeds. A 5-mesh nylon sheet over the floor prevents seed loss. Camelina seed should be recleaned, dried to about 8% to 9% moisture, and cooled to between 60°F and 40°F before storage. Any green or moist material can cause molds to form, reducing the quality of the oil as well as the germination ability of the seed. Aeration from the bottom up through the bin with supplemental heat to drive off excess moisture is the usual first step. Do not heat the seed above 110°F because this causes a reduction in germination ability. The seed should be cooled immediately after drying to between 60°F and 40°F. Temperatures and moisture content of the seed in the bin should be checked every day for a week after harvest, then every week after that. Repeat the aeration and drying if needed because seed can spoil quickly in storage. Clean-outs can be used on-farm as a high quality animal feed.

Winter Edible Camelina Oilseed

Most camelina is planted as a spring annual to be harvested after the first frost. However, camelina seed is very small, which often results in a fair amount of seed loss during harvest. There is no seed dormancy requirement for camelina and it will germinate within 2 weeks after harvest. Seed buried in the soil over the winter survives, which results in a fairly high amount of volunteer camelina the following season. If sufficient stubble and surface plant residues remain after fall tillage, trapped snow results in increased spring soil moisture, reduced erosion, and minimal soil crusting. This provides a better environment for volunteer camelina germination in the spring. Spring camelina varieties can be planted in late fall just prior to freezeup with the hope that they will not germinate until next spring. If they do germinate, they are very frost hardy, often surviving in temperatures as low as 20°F. If the plants don't die during the winter because of freezing injury or desiccation, then new growth will begin as soon as soil temperatures reach around 38°F. These plants will then grow like spring-planted camelina. Tests show that spring camelina varieties planted in late fall in Alaska are only moderately successful. Soil temperature and moisture conditions in early spring are cold and wet, so uniform germination or regrowth doesn't always occur, leading to uneven ripening and lower seed yields. There is also the added probability of a warm period after fall planting that could cause the seed to germinate and grow too large before entering fall dormancy. This would lead to winterkill from desiccation under the snowpack. Also, with the snowpack in place, humidity under it is high and white snowmold fungi (*Sclerotinia borealis*) can attack and kill the plants. These snowmold fungi are present on the plant tissue before winter and only grow and spread in the spring when temperature and moisture conditions are right. At present, there are no fungicides registered for use on camelina in Alaska, so control is difficult. The best control of snowmold fungi is through crop rotations, which should include a fallow year to reduce the amount of infected plant matter in the soil.

Fertilization rates, tillage practices, seeding depths, irrigation practices, weed and insect control, harvesting, cleaning, and storage are the same as for spring camelina. The main advantage of fall-planted camelina is the frost-hardiness of the germinating seedlings. Germination and emergence occur in late April to early May, which gives fall-planted camelina a 1- to 2-week head start over spring-planted camelina. Fall-seeded camelina is marginally recommended for Alaska in areas of sufficient snow cover. To compensate for the reduced and uneven germination the following spring, seeding rates should be increased to the higher levels.

Recommended Variety Descriptions for Camelina

Note: See Appendix 1 for the addresses of seed suppliers.

'Blaine Creek' is a short-season, spring or winter, high-yielding, high omega-3 content, edible oilseed camelina line released by the breeding program at Montana State University's Northwest Foundation and Seed Program in 2007. It is a single plant selection from an early maturing, high-yield variety from Sweden. 'Blaine Creek' matures about 2 weeks earlier, with higher seed yields, than 'Reward' Polish canola. It has about the same lodging resistance as 'Reward'. It performs better when soil moisture and fertility conditions are not limiting. Direct inquiries about seed sources to Ernst Conservation Seeds.

'Suneson' is a mid-season, spring or winter, average-yielding, high omega-3 content, edible oilseed camelina line released by the breeding program at Montana State University's Northwest Foundation and Seed Program in 2007. It is a single plant selection from an early maturing, high-yield variety from Germany. 'Suneson' matures about 2 weeks earlier, with similar seed yields, than 'Reward' Polish canola. It has about the same lodging resistance as 'Reward' with marginal pod shatter resistance. It performs better in marginal soil moisture and fertility conditions. Direct inquiries about seed sources to Ernst Conservation Seeds.

Like canola and mustard seed, camelina is still considered a marginal crop for Alaska. In good years with adequate soil moisture and GDD, the varieties listed previously will still have uneven ripening resulting in a high percentage of green seed at harvest. Seed killed by frost does not continue to ripen and remains green. Green seeds are immature seed that contain chlorophyll, which imparts a green color to the oil and shortens the shelf life by turning rancid quickly. There is an increasing interest in Alaska in producing an oilseed crop for both the edible oil and biofuel markets. Any seed grown for these markets should be grown on contract with a processing facility because a high-quality seed lot is required. Unfortunately, there is currently no large-scale facility in Alaska to process oil from camelina for either the edible oil or biofuel oil markets. Also, there are no elevators in Alaska currently set up to take camelina seed. However, there are a few on-farm, small-scale oilseed presses set up to extract oil without the secondary chemical extraction.

Yields by Location for Camelina

Camelina seed (spring and winter) is bought and sold by weight. As for canola and mustards, there is a standard test weight for camelina seed that is used as the legal unit for purchase or sale of the crop. This standard test weight for clean, dry, and undamaged camelina seed is 50 pounds per bushel. Along with test weights, additional samples should be taken on farm to determine quality. Any seed lots not meeting high quality standards should be used as lower feed grades. It is important then for the producer to clean and size all seed lots before delivery to a niche market. Test weights are used here as a measure of seed quality to determine maturity. Yields are expressed here in pounds per acre and bushels per acre. Determine bushels per acre by dividing the yield of any specific cultivar by the standard test weight.

Tables 96 and 98 list yields and quality measurements for camelina seed varieties for 2 test locations: Fairbanks and Delta Junction. All sites in the Delta Junction area have been combined into the Delta dryland site (Table 98). There were no irrigation trials. Each table also contains information on the years it was tested at each location. Seed can be used as either an edible oil or as a biofuel product. The meal can be used as a high omega-3 feed in poultry and dairy animal feeds. Maturity in this study was defined as when 50% of the seed for each plot were an orange or brown color. Growing degree days (GDD) for average maturity were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. The low temperature point for camelina in this report is the freezing point of water, 32°F. The GDD calculations for each day were then added to the preceding GDD value to determine the date at which the specific variety had reached 50% maturity.

All varieties were compared with ‘Reward’ Polish canola as the standard variety. Yield as a percent of the standard variety ‘Reward’ was determined by dividing the average yield of each variety by the average yield of ‘Reward’. Maturity vs. Std. (Standard variety) is the number of days each variety reached 50% maturity either before or after the number of days that ‘Reward’ reached 50% maturity. Estimated oil yield data is based on extracting about half of the oil contained in the camelina seed, or about 20% by weight, through the primary pressing process and not the secondary chemical extraction process. Therefore, the seed yield in pounds per acre times 20% equals the oil yield in pounds per acre. The density of camelina oil is the same as for canola and mustard oil (7.81 pounds per gallon). This number is used to convert the oil yield in pounds per acre into gallons of oil per acre.

Seed quality data (percent oil, percent crude protein, percent green seed, and other nutrients) for Fairbanks (Table 97) and Delta dryland (Table 99) are presented without statistical differences and solely for the reader's benefit. More detailed information and explanation about the industry standards for food-grade camelina oil that follow can be obtained from D.T. Ehrensing and S.O. Guy (2008) and A.L. Pilgeram and others (2007). Detailed explanation of the feed analysis that follows as well as laboratory procedures can be obtained from J. Schroeder (1994) and G.J. Michaelson and others (1987).

Percent green seed is a measure of the maturity of the crop. Seed coat color is not always a good indicator of plant maturity because it can start to turn yellow or brown while the inside is still green and immature. To determine if the inner seed color is still green, collect multiple random samples of 100 seeds after drying and cleaning. Place the seeds on a grid over white paper and crush with a roller. The inner color of any immature seed will show up as green or yellowish-green blots, which can then be counted. The percent green seed is then determined from the original 100-seed subsample. High percentages of green seed indicate that the crop is immature. Oil processed from a crop with a high percentage of green seed will go rancid quicker.

Percent oil (%Oil) is a measure of the plant-based oils contained in the seed. These oils contribute some of the major essential fatty acids and energy needed in animal diets. High levels of these oils can supply more energy, but they also dilute mineral nutrient concentrations.

Percent crude protein is calculated from the total percent nitrogen analysis of the seed multiplied by a constant of 6.25. Crude protein is made up of amino acids, which are 16% nitrogen, as well as other, non-protein portions of the plant, and so percent crude protein is not a measure of true protein. Industry standards of crude protein for camelina are set for a range between 35% and 45%. Higher values have greater nutritional food value, but too high a value (>45%) is an indicator of immature green seed at harvest which makes a lower-grade oil because it turns rancid quicker. In a standard feed analysis, other major nutrient mineral concentrations that are measured are percent phosphorus (%P) and potassium (%K).

The gross energy (GE) contained in the seed or meal is measured in British thermal units (BTUs) and expressed in units of calories per gram of dry matter (cal/g). One BTU is the amount of energy required to raise the temperature of 1 pound of water by 1 degree F. The higher the BTU values, the more energy that is contained in the plant.

Table 96. Average yields and quality measurements for all camelina varieties from test plots in the Fairbanks area.

Camelina Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Oil Yield (gal/acre)	Seed Test wt. (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Edible oilseed, spring											
Blaine Creek	Montana	3	1447	29	95	37	50	45	28-Jul	-17	2003
Calena	Austria	3	1080	22	71	28	50	51	19-Aug	5	2581
Camena	England	1	872	17	57	22	38	25	30-Jul	-15	2060
Celine	France	2	1188	24	78	30	51	61	31-Jul	-14	2087
Ligena	Germany	2	1614	32	106	41	51	72	30-Jul	-13	2060
Suneson	Montana	3	1229	25	81	31	47	58	29-Jul	-16	2032
Willow Creek	Montana	1	1049	21	69	27	48	48	27-Jul	-18	1975
Wolff Creek	Montana	1	888	18	58	23	49	48	27-Jul	-18	1975
Edible oilseed, winter											
Suneson	Montana	1	672	13	44	17	38	25	30-Jul	-13	2060

*Growing degree days (GDD) for average maturity are calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. All varieties were compared with ‘Reward’ Polish canola as the standard variety.

Table 97. Average quality measurements for select camelina varieties from test plots in the Fairbanks area.

Camelina Variety Name	Source	Years Tested	Green Seed (%)	Oil Content (%)	Crude Protein (%)	Total P (%)	Total K (%)	Oil GE (cal/g)	Meal GE (cal/g)
Edible Oil Industry Standards			<2%	30-40%	35-45%	0.5-0.8%	0.6-0.9%		
Edible oilseed, spring									
Blaine Creek	Montana	3	2	33.75	34.91	0.69	0.70	6165.33	6208.51
Calena	Austria	3	1	34.40	30.72	0.65	0.72	6095.46	6108.91
Camena	England	1	1	32.70	N/D	N/D	N/D	N/D	N/D
Celine	France	2	1	33.20	34.21	0.69	0.73	6115.82	6220.21
Ligena	Germany	2	2	33.80	32.70	0.65	0.70	6087.21	6176.91
Suneson	Montana	3	1	32.87	30.83	0.65	0.72	6198.56	6205.67
Willow Creek	Montana	1	2	32.70	N/D	N/D	N/D	N/D	N/D
Wolff Creek	Montana	1	3	33.20	N/D	N/D	N/D	N/D	N/D
Edible oilseed, winter									
Suneson	Montana	1	3	32.70	30.80	0.69	0.70	6081.42	6105.31

N/D = No Data. All varieties were compared with 'Reward' Polish canola as the standard variety.

Table 98. Average yields and quality measurements for all camelina varieties from test plots in the Delta Junction area, dryland site.

Camelina Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Oil Yield (gal/acre)	Seed Test wt. (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Edible oilseed, spring											
Blaine Creek	Montana	2	950	19	88	24	51	60	3-Aug	-11	2090
Calena	Austria	2	968	19	90	25	52	60	3-Aug	-11	2090
Celine	France	2	968	19	90	25	52	56	3-Aug	-11	2090
Ligena	Germany	2	1114	22	103	29	52	63	4-Aug	-10	2117
Suneson	Montana	2	1249	25	116	32	51	55	3-Aug	-11	2090

*Growing degree days (GDD) for average maturity are calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. All varieties were compared with 'Reward' Polish canola as the standard variety.

Table 99. Average quality measurements for select camelina varieties from test plots in the Delta Junction area, dryland site.

Camelina Variety Name	Source	Years Tested	Green Seed (%)	Oil Content (%)	Crude Protein (%)	Total P (%)	Total K (%)	Oil GE (cal/g)	Meal GE (cal/g)
Edible Oil Industry Standards			<2%	30-40%	35-45%	0.5-0.8%	0.6-0.9%		
Edible oilseed, spring									
Blaine Creek	Montana	2	3	34.40	34.65	0.67	0.70	6189.65	6205.67
Calena	Austria	2	1	33.67	31.22	0.65	0.73	6230.26	6885.77
Celine	France	2	2	32.40	33.44	0.68	0.73	6202.41	6104.34
Ligena	Germany	2	5	31.20	32.39	0.65	0.70	6119.54	6198.56
Suneson	Montana	2	1	31.80	31.38	0.64	0.72	6188.37	6202.84

N/D = No Data. All varieties were compared with 'Reward' Polish canola as the standard variety.

Flax

Industrial Flax Oilseed and Fiber Flax

Flax (*Linum usitatissimum* L.) is an annual broad-leaved oilseed and fiber plant that grows 12 to 48 inches tall. There may be 2 or more basal branches on the main stem that in turn have secondary and tertiary branches. Flax stems consist of the inner pith, middle wood, and outer bark. The bark contains the long bast, or flax fiber cells, that makes up the linen fibers. The blue or red flowers on the outer ends of the branches turn into seed bolls at maturity. These bolls contain 8 or fewer small, smooth, shiny seeds that are yellow, light brown, or black. The seed shape and appearance is similar to that of canarygrass. The seed bolls retain the seed at maturity, so seed shatter is minimal. Flax is an indeterminate plant and continues to flower until growth is stopped by a killing frost.

There are 2 main types of flax, one grown for oilseed content and one grown for fiber content. Oilseed flax is shorter, 15 to 30 inches tall, and has multiple branches. The seed is generally larger and higher in oil content, 32% to 44% oil, than that of fiber flax. Linseed oil has about 8% saturated fatty acids, greater than canola oil but less than camelina oil. This oil is made up of major fatty acids, some of which are considered essential fatty acids as they can't be synthesized by the body but must come from the diet. According to D.T. Ehrensing and S.O. Guy (2008) linseed oil contains the following ranges of mono- and polyunsaturated essential fatty acids: 5% to 8% palmitic acid; 2% to 4% stearic acid; 15% to 20% oleic, an omega-9 fatty acid; 10% to 17% linoleic, an omega-6 fatty acid; and 45% to 63% linolenic, an omega-3 fatty acid. High levels of omega-3 fatty acids (linolenic) have been shown to reduce LDL cholesterol levels in the blood and are good for heart and cardiovascular health. However, the very high levels found in flaxseed can have detrimental health effects that could potentially lead to increased risk of bleeding. The oil also contains very low levels of nonessential fatty acids such as erucic acid (1% to 2%), which is lower than the 2% maximum limit for canola-quality edible oil.

Linseed oil is obtained by a combination of expressing and extraction with a solvent and yields about 2.5 gallons for each bushel of clean flaxseed. The best of the commercial oilseed presses is only capable of extracting about half of the oil contained in the flaxseed, or about 12% to 20% by weight. Small-scale to kitchen-scale presses can only get about one-quarter of the oil in the seed, or about 6% to 10% by weight. The remaining half to three-quarters of the oil in the meal is extracted with a hexane solvent process. The solvent is then removed from the oil, which is blended with the pressed oil and everything is run through a filtration and cleaning process. The resulting oil is is a high-quality industrial drying oil used in the production of paints, varnishes, linoleum, oilcloth, inks, soaps, and other products. Flax oil does not make a good cooking oil; it goes rancid very quickly and heat will quickly degrade all essential fatty acids, which lessens the nutritional value of the oil. The short, harsh fiber of oilseed flax is used for producing upholstery and insulation materials and high-grade paper products. Fiber flax plants are taller, 37 to 48 inches, and usually single-stemmed, although single-stemmed growth can be obtained from oilseed flax by planting at a heavier rate. Fiber flax seed is smaller and slightly lower in oil content than oilseed flax.

Fiber flax is pulled or dug at harvest to retain as much of the long bast fibers as possible. It is dried and cured in the fields before the seed is threshed in a combing process to knock the seed bolls off without causing damage to the stems. The stems are then retted (partially rotted) in large tanks of continuously replenished and cleaned water that is kept at 80°F for 6 to 8 days. This retting process breaks down the binding gums and thin-walled tissues that surround the fibers. The breaking process first takes the retted fibers and dries them, and then runs them between fluted rollers to break and loosen the woody portions into

shives. The shives are then removed from the long fibers by a cylinder wheel in a process called scutching, which hacks and separates the fibers lengthwise by drawing them through multiple rows of sharp spikes to separate the short fibers (tow flax) from the longer fibers (line flax). The yield of the different types of fibers in this process is about half tow flax and half line flax. The short tow flax fibers, about 10 inches long, can be spun and woven into a coarse cloth. Good, long fibers, about 20 inches in length, are strong enough to resist breaking down during the breaking and scutching processes. Flax fiber is spun wet into smooth, shiny linen threads. The finishing process takes the spun threads through a soda and detergent washing process to remove any remaining gums. The threads are then woven into yards that are used for producing fine textiles and high-grade paper products.

Flax straw can be fed to livestock and has a feed value about equal to that of wheat or oat straw. The oilseed meal remaining after the oil extraction process contains about 1% to 6% oil and is about 20% to 35% crude protein. This linseed meal can also be fed to livestock as a high omega-3 feed supplement. Immature green seed or flax seed and meal that has been frozen can develop high levels of prussic acid, or hydrocyanic acid (HCN). This is caused by a breakdown of a glucoside called dhurrin. Immature green seed lacks the complete molecular bonds within the dhurrin glucoside that mature seed has, so it breaks down quickly. Freezing also causes the acid to be released quickly from the glucoside form. Any feed that has been frozen or that could contain high amounts of immature green seed after harvest should be tested for prussic acid before feeding. Any feed lot testing over 200 ppm is considered toxic. Sheep are less susceptible than cattle, while horses and swine are apparently not injured. Flax seed is considered primarily an industrial oil and thus is not part of the edible oil market. However, there are varieties that have been developed in Canada with less than 5% linolenic acid that produce food-quality edible oil for use in salad dressings or are sold as whole seed in health food markets. Varieties with this trait are marketed under the term Solin. None of these types of cultivars have been tested in this study.

Fertilization, tillage practices, and seeding depths are similar to those for canarygrass. However, flax is generally seeded on soils with lower levels of available nutrients. Soils with low to moderate levels of available nutrients should receive a complete fertilizer blend of nitrogen, phosphorus, potassium, sulfur, and boron. Sulfur and boron are needed by flax to promote flowering and seed set, and to increase the oil content. Soils low in available sulfur should have it broadcast as ammonium sulfate or as potassium sulfate. An application rate of 0.5 pound per acre of actual boron is sufficient to correct most soil deficiencies. For fiber production, a ratio of 1:4:2:0.5 of N, P_2O_5, K_2O, and S produces the best results. Oilseed production requires higher levels of nitrogen, or a ratio of about 1:2:1:0.25 of N, P_2O_5, K_2O, and S. The fertilizer can be broadcast before spring tillage or portions can be banded at planting. Higher levels of phosphorus increase the fiber percentage. Avoid excess nitrogen fertilizer because it can reduce the percentage of fiber, induce lodging, and delay maturity, especially if grown under irrigation. Actual percentages of all nutrients and the application rates vary according to the specific soil test results. All fertilizer must be broadcast prior to spring tillage.

To conserve soil moisture, minimum tillage is recommended for incorporating fertilizer material and plant residue and preparing the seedbed. Pulling a packer behind the tillage implement and using a seed drill equipped with press wheels ensures that the seed is in contact with moist soil during germination. If the crop is to be grown under irrigation, the soil should be irrigated sufficiently to bring the soil moisture levels close to the maximum water-holding capacity before tillage. It is very important not to irrigate above the maximum water-holding capacity before tilling and planting, as this could cause a crust to form on the surface of the soil that would impede seedling emergence, reduce plant density, and lower seed yields. Flax does best on well-drained silt loam soils but requires a fair amount of soil moisture to produce high yields. It is a shallow-rooting plant and obtains most of the soil moisture from the top 2 feet of soil. Seeding depth is shallow at 1 to 1.5 inches, or to moisture. The seeding rate is 28 to 42 pounds of pure live seed per acre for oilseed production and 75 to 85 pounds per acre for fiber production. The higher rate should be used to reduce branching in fiber flax varieties. Early planting dates are recommended to use as much of the short growing season as possible and get the straw as mature as possible before harvest. In the seedling stage and in the flowering to green boll stages, flax can be damaged or killed by light frosts. Otherwise, it requires moderate to cool temperatures during the growing season. Certified seed is strongly recommended. Certified seed has strict limits on maximum content of weed seeds and diseased seed, and must meet a minimum percent germination. This helps to ensure good germination and emergence and reduces weed and disease infestations.

Like canola, irrigation should begin again after the crop has reached about 50% emergence to avoid any problems resulting from too hard of a crust on the surface. Thereafter, a good range of irrigation plus precipitation is around 0.5 to 1.0 inch per week. Irrigation should continue until the crop has reached the 50% boll set growth stage.

Using IPM techniques, assess each field for all pests (weeds, diseases, and insects) and plan control measures accordingly.

Flax competes poorly with weeds, so weed control is important. J.H. Martin and others (1976) reported that heavy weed infestations can reduce yields by as much as 70%. The best weed control is a combination of mechanical and chemical summer fallow to reduce the number and species of weeds for the following season and an application of a post-emergence herbicide when needed as determined through IPM practices. If weed populations have been determined to be high enough to cause a potential loss in yield or quality of the crop, then the application of herbicides may be warranted. The best weed control is with the broadleaf-selective herbicide Bromoxynil and MCPA tank mixes (which are labeled for use on flax) applied when the flax is 2 to 8 inches tall, but before the bud stage. Pennsylvania smartweed (*Polygonum pensylvanicum* L.) and volunteer canarygrass both have seed similar in size, shape, and weight, making them difficult to clean out. Seed lots containing these weed seeds are rejected by purchasers. Planting in clean ground helps to control these weeds. To eliminate grassy weeds with chemical fallow, a broad-spectrum, nonselective post-emergence herbicide such as glyphosate (Roundup) can be used. Although no serious diseases have yet been found on flax in Alaska, in other locations a Fusarium wilt caused by the fungus *Fusarium lini* causes infected plants to wilt and die. This fungus has been found in Alaska, where it can infect small grains and survive in the soil for many years. Control by planting resistant varieties. The same insect pests that affect small grains also affect flax. The most serious pests are grasshoppers, including the lesser migratory grasshopper (*Melanoplus sanguinipes* Fabricias), the northern grasshopper (*Melanoplus borealis* Fieber), and the clear-winged grasshopper (*Camnula pellucida* Scudder). They chew off the pedicels below the base of the seed bolls, causing the bolls to fall to the ground. If insect population levels and damage have been determined to be too high through IPM practices, then the application of an insecticide may be warranted. Insecticide sprays or baits can help control heavy infestations if applied at the nymph growth stage. Always remember to read the pesticide label to be sure the crop is specified and follow the directions for mixing, application, and disposal. Contact your local Cooperative Extension Service for more information on pest control (see Appendix 1 for addresses and contact information). Flax is not particularly attractive to migratory waterfowl, especially if small grains are present nearby.

Flaxseed is harvested when a majority of the seed bolls have reached a dark brown color. Since flax is indeterminate, there are still green seed and green stems at this point. The crop can be direct combined only if stems are thoroughly dry and weed free. Otherwise, cut with a swather and allow to dry in windrows. Green or wet flax stems are quite tough and wiry and can wrap around cylinders inside combines, impeding the combining process. Use the same combine settings used to harvest canarygrass. For proper threshing, slow the feeding rate by reducing cylinder speeds. The small seed size requires reducing air flow settings similar to those for canarygrass. Control seed cracking by running augers at full capacity or slowing them down. Continual checking for cracked seeds and adjusting combining methods is important. Cracked seeds will start to degrade the essential fatty acids very quickly, reducing the quality of the seed lot and the value to the producer. Because of the small seed size, all cracks and holes in the combine, augers, trucks, and bins should be sealed to prevent seed loss during handling. Flax does not head shatter, so combine operations can wait for the seed to field dry to around 13% moisture. This also allows the straw to reach full maturity for easier harvesting. Flaxseed must be around 9% to 11% moisture for safe, long-term storage. Higher moisture content can cause the stored seed to germinate or mold, and lower moisture content can damage the embryo, reducing germination ability. Both situations reduce the quality of stored seed. The highest quality seed is achieved when swathing or combining at the lowest moisture content. On-farm drying may be necessary to get the seed to safe moisture levels for storage. Typical grain dryers have perforated floor openings that are too large for the small seeds. A 5-mesh nylon sheet over the floor prevents seed loss. Immature green seed must be removed during the cleaning process to reduce the potential breakdown of dhurrin into toxic levels of prussic acid in the seed lot. Levels of 200 ppm prussic acid or higher will result in rejection of the seed lot. On-farm cleaning and sizing of the seed to oilseed standards before drying results in easier drying and eventual higher prices paid to the producer. Clean-outs can be used on farm or sold as lower-grade seed.

Harvesting fiber flax is done when only one-third to one-half of the seed bolls are a dark brown color and the stems have turned yellow. The leaves should have fallen off the main stems about two-thirds of the way up the plant. Flax harvested too early has long, silky fibers that lack strength. Flax harvested too late has coarse and brittle fibers. The plants are pulled from the ground with special pulling machines or by hand and allowed to dry and cure in the field before processing. Yields of 3,500 pounds per acre are considered good for unprocessed fiber flax.

Recommended Variety Descriptions for Oilseed and Fiber Flax

Note: See Appendix 1 for the addresses of seed suppliers.

'NorLin' is an early- to mid-maturing, mid-tall, high-yielding oilseed flax developed at the Agri-Food Research Centre at Morden, Alberta in 1982. It is a cross between 'Rocket' x 'Raja' and 'Linott'. 'NorLin' has good lodging resistance, small seed size, medium oil content, and a moderate resistance to Fusarium wilt. It has a lower capability of producing secondary basal branches than most other varieties. This was the standard variety against which all other flax varieties were compared. Direct inquiries about seed sources to the SeCan Association.

'Viking' is a mid- to late-maturing, short, high-biomass-yielding, golden-seeded, dual-purpose industrial fiber flax developed at the North Dakota State University Agricultural Experiment Station at Fargo in 1932. It is a cross between 'B-Golden' and 'Burbank's Golden'. 'Viking' has good disease resistance, lodging resistance, and high biomass yields. Unlike other flax varieties that have pale blue flowers, 'Viking' has pale pink flowers. The short plant height (25-30 inches) produces shorter line fibers that are less suited for linen production. This is an older variety so seed may no longer be available. Direct inquiries to the North Dakota State Seed Department.

Flax is still considered a marginal crop for Alaska. In years with plenty of soil moisture and GDD, 'NorLin' produced acceptable seed yields. However, uneven ripening resulted in green seed at harvest, which was killed by fall frost. There is an increasing interest in Alaska in producing an oilseed crop for both the edible oil and industrial biofuel markets. Any seed grown for the edible oil or industrial and biofuel oil markets should be grown on contract with a processing facility because a high-quality seed lot is required. At present, there is no facility in Alaska to process oil from flaxseed for either the edible oil or industrial and biofuel oil markets. Also, there are no elevators presently set up to accept flaxseed in Alaska. All fiber flax varieties are later-maturing than the oilseed varieties. As a result, there are no varieties that have been tested in Alaska that consistently produce acceptable fiber yields. However, the most consistent variety tested at both the Fairbanks and Delta Junction locations has been 'Viking', a dual-purpose oilseed and fiber flax. A dual-purpose cultivar is one that has acceptable yields of both seed and fiber, although yields of either seed or fiber will usually be lower than single-purpose cultivars. 'Viking' was first released by North Dakota State University in the early 1930s, so seed for this variety will be more difficult to obtain. However, any of the newer dual-purpose cultivars should also produce acceptable yields of either oilseed or fiber biomass when grown in Alaska.

Yields and Test Weights by Location for Oilseed and Fiber Flax

Seed from both oilseed and fiber flax are bought and sold by weight. As for small grains, there is a standard test weight for all flaxseed that is used as the legal unit for purchase or sale of the crop. This standard test weight for clean, dry, and undamaged flaxseed is 56 pounds per bushel. Along with test weights, additional samples should be taken on-farm to determine quality. Any seed lots not meeting high oilseed quality standards should be used as lower-grade seed. It is important, then, for the producer to clean and size all seed lots before delivery to a niche market. Test weights are used here as a measure of seed quality to determine maturity. Yields are expressed here in pounds per acre and bushels per acre. Determine bushels per acre by dividing the yield of any specific cultivar by the standard test weight.

Tables 100, 102, and 104 list yields and quality measurements for oilseed and fiber flax varieties for 3 test locations: Fairbanks, Eielson, and Delta Junction. All sites in the Delta Junction area have been combined into Delta dryland site (Table 104). There were no irrigation trials done for either oilseed or fiber flax. Each table also contains information on seed type (oilseed or fiber), biomass yield, the source or the location of where it was bred, and the years it was tested at each location. Maturity in this study was defined as when 50% of the bolls for each plot were a dark brown in color and the stems were a yellow in color. Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. The low temperature point for both oilseed and fiber flax in this report is the freezing point of water, 32°F. The GDD calculations for each day were then added to the preceding GDD value to determine the date at which the specific variety had reached 50% maturity. All varieties were compared with 'NorLin' as the standard variety. Yield as a percent of the standard variety 'NorLin' was determined by dividing the average yield of each variety by the average yield of 'NorLin'. Maturity vs. Std. (Standard Variety) is the number of days it took for each variety to reach 50% maturity either before or after the number of days that 'NorLin' reached 50% maturity. Estimated oil yield data is based on extracting about half of the oil contained in the flaxseed, or about 20% by weight, through the primary pressing process and not the secondary chemical extraction process. Therefore, the seed yield in pounds per acre times 20% equals the oil yield in pounds per acre. The density of linseed oil is 7.88 pounds per gallon. This number is used to convert the oil yield in pounds per acre into gallons of oil per acre.

Seed and forage quality data on a dry-weight basis (percent oil, percent crude protein, percent green seed, and other nutrients, and the nutritive composition of the biomass from 'NorLin' presented for animal feed purposes) for Fairbanks (Table 101), Eielson (Table 103), and Delta dryland (Table 105) are presented without statistical differences and solely for the reader's benefit. More detailed information and explanation about the industry standards for food-grade flax oil that follow can be obtained from

D.T. Ehrensing and S.O. Guy (2008). Detailed explanation of the feed analysis that follows as well as laboratory procedures can be obtained from J. Schroeder (1994) and G.J. Michaelson and others (1987).

Percent oil (%Oil) is a measure of the amount of plant-based oils contained in the seed. These oils contribute some of the major essential fatty acids and energy needed in animal diets. High levels of plant-based oils can supply more energy but also dilute mineral nutrient concentrations.

Percent crude protein is calculated from the total percent nitrogen analysis of the seed multiplied by a constant of 6.25. Crude protein is made up of amino acids, which are 16% nitrogen, as well as other, non-protein portions of the plant, and so percent crude protein is not a measure of true protein. Industry standards of crude protein for linseed are set for a range between 20% and 35%. Higher values have greater nutritional food value, but too high a value (>35%) is an indicator of immature green seed at harvest which makes a lower-grade oil because it turns rancid quicker. In a standard feed analysis, other major nutrient mineral concentrations that are measured are percent phosphorus (%P) and potassium (%K).

Percent dry matter (%DM) is the amount of plant biomass left after the water has been driven off in an oven at 140°F. The actual time that it takes to dry to a constant weight at 140°F varies from a few days to a week or more, depending on the type of plant matter. The nutrient concentrations are always expressed on a dry weight basis as it allows for better comparisons between different plant types.

Table 100. Average yields and quality measurements for all flax varieties from test plots in the Fairbanks area.

Flax Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Oil Yield (gal/acre)	Seed Test wt. (lbs/bu)	Biomass Yield (lbs/acre)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Industrial oilseed, spring												
Dufferin	Manitoba	1	1188	21	110	30	49	N/D	0	5-Sep	2	2912
Linott	Ontario	1	512	9	48	13	47	N/D	0	4-Sep	1	2894
McGregor	Manitoba	1	400	7	37	10	50	N/D	0	5-Sep	2	2912
Noralta	Manitoba	2	1097	20	102	28	50	N/D	0	4-Sep	1	2894
NorLin	Manitoba	3	1077	19	100	27	51	2476	0	3-Sep	0	2878
Raja	Ontariio	1	504	9	47	13	49	N/D	0	5-Sep	2	2912
Industrial fiber, spring												
Ariane	France	2	806	14	75	20	46	3984	0	5-Sep	2	2912
Cascade	Oregon	1	737	13	68	19	45	N/D	25	4-Sep	1	2894
Viking	North Dakota	2	680	12	63	17	46	3150	0	4-Sep	1	2894

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. N/D = No Data. All varieties were compared with 'NorLin' oilseed flax as the standard variety.

Table 101. Average quality measurements for 'NorLin' oilseed flax from test plots in the Fairbanks area.

Flax Variety Name	Source	Years Tested	Oil Content (%)	Crude Protein (%)	Total P (%)	Total K (%)	Dry Matter (%)
Industry Standards			**30-45%**	**20-35%**	**0.5-0.8%**	**0.6-0.9%**	**> 93%**
Industrial oilseed, spring							
NorLin	Manitoba	3	37.58	26.50	0.65	0.70	98.10
Industrial fiber, spring (biomass)							
NorLin	Manitoba	3	39.76	26.10	0.58	0.73	99.10

Analysis done on whole plant biomass (seed and stems) at maturity

Table 102. Average yields and quality measurements for all flax varieties from test plots in the Eielson area.

Flax Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Oil Yield (gal/acre)	Seed Test wt. (lbs/bu)	Biomass Yield (lbs/acre)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Industrial oilseed, spring												
NorLin	Manitoba	2	484	9	100	12	45	2233	0	5-Sep	0	2830
Industrial fiber, spring												
Ariane	France	2	552	10	114	14	43	905	0	5-Sep	0	2830
Cascade	Oregon	1	585	10	121	15	42	N/D	20	5-Sep	0	2830
Viking	North Dakota	2	477	9	99	12	42	3124	0	5-Sep	0	2830

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. N/D = No Data. All varieties were compared with 'NorLin' oilseed flax as the standard variety.

Table 103. Average quality measurements for 'NorLin' oilseed flax from test plots in the Eielson area.

Flax Variety Name	Source	Years Tested	Oil Content (%)	Crude Protein (%)	Total P (%)	Total K (%)	Dry Matter (%)
Edible Oil Industry Standards			**30-45%**	**20-35%**	**0.5-0.8%**	**0.6-0.9%**	**> 93%**
Industrial oilseed, spring							
NorLin	Manitoba	2	39.65	23.29	3.78	1.25	97.88
Industrial fiber, spring (biomass)							
NorLin	Manitoba	2	N/D	11.25	0.30	1.80	N/D

Analysis done on whole plant biomass (seed and stems) at maturity. N/D = No Data.

Table 104. Average yields and quality measurements for all flax varieties from test plots in the Delta Junction area, dryland site.

Flax Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Oil Yield (gal/acre)	Seed Test wt. (lbs/bu)	Biomass Yield (lbs/acre)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Industrial oilseed, spring												
Linott	Ontario	1	771	14	290	20	51	N/D	0	4-Sep	0	2778
Noralta	Manitoba	1	486	9	183	12	50	N/D	0	4-Sep	0	2778
NorLin	Manitoba	2	266	5	100	7	53	473	0	4-Sep	0	2778
Raja	Ontario	1	879	16	330	22	49	N/D	0	5-Sep	1	2795
Industrial fiber, spring												
Ariane	France	2	0	0	0	0	0	4865	0	9-Sep	5	2859
Cascade	Oregon	1	0	0	0	0	0	N/D	10	7-Sep	3	2827
Viking	North Dakota	2	0	0	0	0	0	5074	0	11-Sep	7	2888

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. N/D = No Data. All varieties were compared with 'NorLin' oilseed flax as the standard variety.

Table 105. Average quality measurements for 'NorLin' oilseed flax from test plots in the Delta Junction area, dryland site.

Flax Variety Name	Source	Years Tested	Oil Content (%)	Crude Protein (%)	Total P (%)	Total K (%)	Dry Matter (%)
Edible Oil Industry Standards			**30-45%**	**20-35%**	**0.5-0.8%**	**0.6-0.9%**	**> 93%**
Industrial oilseed, spring							
NorLin	Manitoba	2	38.35	26.35	0.52	0.90	98.03
Industrial fiber, spring (biomass)							
NorLin	Manitoba	2	N/D	14.06	0.15	1.50	N/D

Sunflower

Common, Dwarf, and Sunwheat Sunflower Oilseed

Sunflower (*Helianthus annus* L.) is an annual broad-leaved edible oilseed plant that can grow 5 to 20 feet tall. They have stout, rough, hairy stems (1 to 3 inches diameter) topped by a seed head (3 to 24 inches diameter). The heads have many (1,000 to 2,000) small, cross-pollinated flowers surrounded by pointed scales and 40 to 80 yellow rays. Wild sunflowers or horticultural varieties may have multiple branched heads from a single stalk. Two types of sunflowers are grown as an agronomic crop: those that have black or dark brown seed grown for oil content (45% to 55% oil from hulled seed) and those with white stripes on the seed grown for the confectionary market. Both the heads and the leaves of sunflowers track the sun during the day and tilt upwards at midnight. This phototropic phenomenon is called nutation and continues every day until the end of the flowering stage. Sunflowers have no photoperiod response and are insensitive to day length. About half of the dried weight of sunflower heads is seed. The whole seed contains about 24% to 45% oil. Sunflower oil is obtained by a combination of expressing and extraction with a solvent. However, the best of the commercial oilseed presses is only capable of extracting about 20% to 35% oil from the whole seed. Small-scale to kitchen-scale presses can only get about one-quarter of the oil in the seed, or about 10% to 18% by weight. The remaining half to three-quarters of the oil in the meal is extracted with a hexane solvent process. The solvent is then removed from the oil, which is blended in with the pressed oil and everything is run through a filtration and cleaning process. The remaining meal, which contains about 35% protein, is used as a livestock feed. Sunflower oil is mostly polyunsaturated and is used in the edible oil market as a salad and cooking oil. This oil is made up of major fatty acids, some of which are considered essential fatty acids as they can't be synthesized by the body, but must come from the diet. According to D.T. Ehrensing and S.O. Guy (2008), sunflower oil contains the following ranges of mono- and polyunsaturated essential fatty acids: 5% to 8% palmitic acid, 3% to 5% stearic acid, 15% to 20% oleic acid (an omega-9 fatty acid), and 60% to 80% linoleic acid, an omega-6 fatty acid. Because of the high concentration of linoleic acid, it is used as a semidrying oil in the manufacture of soaps and paints as well as in the biofuel industry. Whole oilseed is used as a feed for poultry and caged and wild birds. Confectionary seeds are either eaten raw or roasted. Although sunflowers have been grown as a high-oil content silage for dairy and livestock, they are less palatable and nutritious than either grasses or legumes. In Alaska, sunflowers have been grown on limited acreages off and on for many years, primarily as livestock and dairy forage and secondarily as oil and confectionary seed for the local birdseed market, but with limited success.

Common sunflowers are either open-pollinated or hybrid varieties. Hybrid varieties have been specifically bred to have higher oil contents than open-pollinated varieties. They are long-season plants that are both drought- and heat-resistant. Because of the large amount of biomass they produce before flowering, few ever reach physiologic seed maturity in Alaska before the first killing frosts. Sunwheats, on the other hand, are a semi-dwarf hybrid sunflower similar in head size to the common sunflower but only growing 36 to 50 inches tall. They are earlier maturing (about the same as for wheat) and the seeds often reach physiologic maturity in Alaska. When grown in areas where both reach complete physiologic maturity, sunwheats are slightly lower-yielding with lower oil content compared to common sunflowers. However, when both are grown in areas with short growing seasons,

sunwheats outperform the common sunflower. Sunola is the term for the open-pollinated dwarf sunflower made from Canadian selections of the common sunflower. Sunola is shorter than sunwheat, 24 to 36 inches high, and has a correspondingly smaller head size (3 to 5 inches in diameter). It is lower-yielding than the common sunflower, but it has a higher oil content. No sunola varieties have been tested in this study.

Fertilization, tillage practices, and seeding depths are identical to those for small grains. Sunflowers require a well-drained soil with a near-neutral pH (6.5 to 7.5). Soils with moderate to low levels of available nutrients should receive a complete fertilizer blend of nitrogen, phosphorus, potassium, sulfur, and boron. A ratio of 2:1:1:0.5 of N, P_2O_5, K_2O, and S can produce acceptable yields. With irrigated farming practices, the ratio should be reduced to about 1:0.5:0.5:0.25. Sulfur and boron are needed by sunflowers to promote flowering and seed set and increase the oil content. Soils low in available sulfur should have a sulfate form of sulfur broadcast applied as ammonium sulfate or as potassium sulfate. A rate of 0.5 pound per acre of actual boron is sufficient to correct most soil deficiencies. Actual percentages of each nutrient and the application rate vary according to specific soil test results. The fertilizer can be broadcast before spring tillage, or portions can be banded at planting. Sunflower seed is quite sensitive to soluble salts from fertilizers applied with the seed. There is a greater yield response to increases in phosphorus applications but little response from any increase in potassium applications. Alaska soils are generally acidic, which tends to make phosphorus unavailable for plant uptake. Banding the phosphorus carrier with or next to the seed at planting increases the available phosphorus. No more than 15 to 20 pounds per acre of phosphorus should be applied with the seed. Broadcast the remaining phosphorus with the other fertilizer materials. Avoid excess nitrogen fertilizer, which can delay maturity and reduce oil content, especially if grown under irrigation.

To conserve soil moisture, minimum tillage is recommended for incorporating fertilizer material and plant residue and preparing the seedbed. Pulling a packer behind the tillage implement and using a seed drill equipped with press wheels ensures that the seed is in contact with moist soil during germination. If the crop is to be grown under irrigation, the soil should be irrigated sufficiently to bring the soil moisture levels to close to the maximum water-holding capacity before tillage. It is very important not to irrigate above the maximum water-holding capacity before tilling and planting, as this could cause a soil crust to form on the surface that would impede seedling emergence, reduce plant density, and lower seed yields. Seeding depth is the same as that for small grains, 1.5 to 2 inches, or to moisture. Seeding rate varies depending on seed size. Number 2 grade size contains 5,000 to 6,000 seeds per pound, number 3 grade contains 6,000 to 7,000, number 4 contains 7,000 to 8,000, and number 5 contains 9,000 to 10,000. Generally, a population density of 30,000 to 40,000 plants per acre is recommended for common sunflowers and semi-dwarf sunwheat. Sunola and dwarf sunflowers should have a population density of about 60,000 plants per acre. Common sunflowers should be seeded about 12 to 14 inches apart on 36-inch row spacing. Semi-dwarf sunwheat should be planted 12 to 14 inches apart on 12-inch row spacing. Sunola and dwarf sunflowers, because of the smaller head size, can be seeded 6 inches apart on 6-inch row spacing. Seeding heavier than recommended rates compensates for some establishment loss because of poor conditions. Grain drills can be used to plant sunflowers by blocking off the appropriate opening in the seed box. The seed box should be kept full to account for the effect of seed weight on the flow through the drill. Early planting dates are recommended to use as much of the short growing season as possible. Certified seed is strongly recommended. Certified seed has strict limits on maximum content of weed seeds and diseased seed, and must meet a minimum percent germination. This helps to ensure good germination and emergence and reduces weed and disease infestations. Hybrid seed must be purchased new every year to maintain variety purity. Seed from open-pollinated varieties can be used the following season, if no other sunflower varieties have been grown within a mile of any other variety. A mile is the distance insect pollinators such as honeybees would travel from their hive to a nectar and pollen source.

Uniform seedling germination requires a soil temperature of at least 50°F and good soil moisture. Cool soil or low soil moisture conditions delay germination and cause non-uniform stands. Young sunflower plants have a strong frost tolerance before the 6-leaf stage. Also, the ripening seeds have strong frost tolerance after physiologic maturity has been reached. Light frosts after flowering do not effect seed production. For maximum seed production, sunflowers require about an inch more soil moisture than small grains or canola. For maximum seed production, sunflowers should be irrigated. Irrigation should begin again after the crop has reached about 50% emergence to avoid any problems from too hard a crust on the surface. Thereafter, a good range of irrigation plus precipitation is greater than for most other crops and should be around 1 to 2.0 inches per week. Irrigation should continue until the crop has reached the 50% flowering growth stage. Sunflowers can deplete soil moisture for the following year.

Using IPM techniques, assess each field for all pests (weeds, diseases, and insects) and plan control measures accordingly. Weed control in sunflowers is extremely important. Like canola and mustards, sunflowers need warm soil temperatures to germinate and do not compete well with weeds until about 4 weeks after emergence.

The best weed control is a combination of mechanical and chemical summer fallow to reduce the number and species of weeds for the following season. In the spring, wait for weeds to germinate, then perform seedbed tillage and use proper fertilization and seeding rates. To eliminate all weeds with chemical fallow, a broad-spectrum, nonselective, post-emergence herbicide such as glyphosate (Roundup) can be used. There are no registered herbicides for sunflowers in Alaska.

There are several fungal diseases that attack sunflowers, but only a few are of economic importance. Downy mildew (*Peronspora parasitica*) and root rot cause seed decay and seedling blight with delayed emergence and eventual uneven stands. Sclerotinia, or white mold fungus (*Sclerotinia sclerotiorum*), can infect any part of the sunflower plant from the base to the head. The most important disease is wilt caused by this white mold infection at the base of the plant. This fast-acting disease often takes only 4 to 7 days from the appearance of the first symptoms to produce complete wilting. Wilted plants are noticeable just after the flowering growth stage. Cool, wet soil conditions in the spring favor development of these fungal diseases. They can also spread from root-to-root contact and heavy planting. Controls are crop rotation and certified seed. Canola, camelina, and mustards are also susceptible to these diseases and should not be used in the crop rotation.

Sunflower heads bend down towards the ground and then curl back when mature. This shape acts like a cup, catching any precipitation and holding it there. This extra moisture on the back of the head provides an environment for the development of a botrytis head rot (*Botrytis cinerea*). This gray mold works its way through the head, infecting the seed before it is dry enough to harvest. It is found mostly on late- and very late-maturing varieties that are still high in moisture after the first killing frost. If it is harvested with uninfected seed, the mold can spread during storage. The only control is planting early-maturing varieties.

Grasshoppers, including the lesser migratory grasshopper (*Melanoplus sanguinipes* Fabricias), the northern grasshopper (*Melanoplus borealis* Fieber), and the clear-winged grasshopper (*Camnula pellucida* Scudder) attack sunflowers later on in the year. They feed on the leaves but not on the heads and not severely enough to affect crop yields. No control is necessary at this time. The cutworm (*Hylemya brassicae* Bouche) also attacks sunflowers. It is the larval stage of a fly that infests the base and roots of sunflowers in the flowering to mature growth stages. Infestations of only one or more per square foot can cause a 25% to 30% stand reduction. Also, their feeding creates wounds that can later serve as entry sites for fungal diseases. If insect population levels and damage have been determined to be too high through IPM practices, then the application of an insecticide may be warranted. There is limited chemical control of cutworms but insecticide sprays can help control heavy infestations if applied at the larval (maggot) growth stage. Another control measure that works well is to increase the number of years between planting sunflowers, canola, or mustards in the same field. Always remember to read the pesticide label to be sure the crop is specified and follow the directions on mixing, application, and disposal. Contact your local Cooperative Extension Service for more information on pest control (see Appendix 1 for addresses and contact information).

Many bird species like sunflower seeds and sunflowers are grown specifically for use as feed for both caged and wild birds. Large flocks of both pigeons and migratory waterfowl can cause large yield losses while trying to get at the seed. Propane scare cannons, designed to swivel in different directions and go off at uneven time intervals, are recommended to keep birds away. Check with and inform the neighbors before setting up cannons.

Sunflowers are also used as a forage crop for livestock. Therefore, large ungulates like moose and bison can also cause serious damage to the crop. A single moose or a cow and calf pair usually don't cause much damage to large fields but can wipe out small-scale plots in the fall. They are attracted to mature plants, which have concentrated energy in the seeds and sugars contained in the stalks. In the Delta Junction area, bison congregate in large herds that don't usually cause serious damage until their fall migrations north of the Alaska Highway. This migration occurs during the time when the sunflowers are mature, ripe, and ready for harvest. The bison herd may not only eat large portions of the crop, but a large herd walking through or bedding down in the field can flatten the crop into the ground, making harvest impossible. It is illegal to harass wildlife in Alaska so the only control is to erect large (6 feet or higher), stout, highly visible fencing that can direct the animals around the fields. For more information on wildlife control in agricultural fields, contact the local office of the Alaska Department of Fish and Game.

Sunflower heads are mature when the backs of the heads have turned from green to yellow and the bracts have turned brown. The seed matures from the outside of the head to the inside, and continues to ripen as the stalks dry. Average seed moisture at this time is around 40%. Sunflowers can be harvested 2 to 3 weeks after physiologic maturity when the seed has reached 20% to 25% moisture levels. In Alaska, the harvest season is often wet. When moldy heads and wet stalks make direct combining of sunflowers extremely difficult, hand harvesting, drying, and threshing become the only option. If the weather cooperates and stalks are dry and brittle, then direct combining can be successful. Moisture content of the seed should be around 12% to 15% for best combining results. Conventional combines can be used with a sunflower pan attachment to the header to reduce shatter loss. Heads should be cut just below the attachment to the stalk to reduce the volume running through the combine. Forward speed depends on the moisture content of the seed. To reduce shattering losses, as moisture content decreases, speed should be decreased. Reduce cylinder speed as much as possible to minimize cracked and dehulled seed. Concave adjustments depend on seed moisture content. If less than 12%, open the front to 1 inch and set the back at 0.75 inch. At moisture levels higher than 12%, slightly reduce concave settings to increase threshing success. With moisture levels of 20% or greater, reduce the concave setting and increase the cylinder speed. Remember that closer concave settings result in more cracked and dehulled seed. Reduce air speed over the sieves to avoid blowing the lightweight seed out with the chaff. Properly set combines should pass through only slightly broken heads with unfilled seed remaining. The amount of cracked and dehulled seed is limited to 2% to 5%.

Sunflower seed is dry and safe for long-term storage at 8% to 10% moisture. It is often harvested before that to prevent losses because of shattering or bird damage. Supplemental drying is then required. Cleaning the seed lot to remove all green foreign material and cracked and dehulled seeds facilitates drying and produces a more acceptable seed lot after drying. Clean-outs can be used on farm or sold for animal feed. Supplemental heat in driers should not be above 120°F. Higher temperatures can damage seed. Also, the many fine hairs that are rubbed off the seeds during handling can easily ignite at high temperatures.

Recommended Variety Descriptions for Sunwheat and Dwarf Sunflower

Note: See Appendix 1 for the addresses of seed suppliers.

'Midnight Sun-flower' is an early-maturing, dwarf, open-pollinated, oilseed sunflower unofficially released in 2008 by the AFES agronomy research program in Fairbanks. Starting in 1993, seeds were collected from the earliest-maturing heads of the 'Sunwheat 103' variety in the Fairbanks area. These seeds were hand-threshed, cleaned, and planted in test plots the following season. This process has been repeated every year since then. Since 'Sunwheat 103' is a hybrid semi-dwarf sunwheat, there was considerable variation in the following year's crop. However, continued selection for early maturity and high seed yields has resulted in an increasingly uniform, open-pollinated dwarf sunflower that closely resembles the Canadian sunola varieties. To date, the plants are quite dwarf, averaging 20 to 24 inches tall with head diameters of close to 6 inches. It matures 2 to 3 weeks earlier than

"Midnight" Sun-flower

'Sunwheat 103' and 4 to 5 weeks earlier than common sunflowers. Because of its smaller size, planting is similar to sunola, with plant populations of 60,000 per acre. This results in yields equal to that of 'Sunwheat 103'. However, because this is still an open-pollinated crop there is some variability among plants. This was the standard variety against which all other sunflower and safflower varieties were compared. Direct inquiries about seed sources to the AFES Fairbanks Experiment Farm.

'Sunwheat 103' is an early-maturing, semi-dwarf, high-yielding, hybrid oilseed sunflower developed by SeedTec International and Agripro Seeds Inc. of Minnesota. It has an oil content of 38% to 42%, slightly less than conventional sunflowers, but equal to that of dwarf sunflowers. Maturity is 2 weeks earlier than common sunflowers but 2 to 4 weeks later than dwarf sunflowers. Seed yields are greater than 'Midnight Sun-flower' because of the larger seed heads, but a fair proportion of the seed will still be immature at harvest, lowering the total oil content. Direct inquiries about seed sources to Proven Seed - Agricore United of Winnipeg.

Sunflowers are considered a marginal crop for Alaska. In good years with plenty of soil moisture and GDD, the sunwheat and dwarf sunflower listed previously will produce acceptable yields. Even in good years, there is uneven ripening that results in immature seed at harvest. There is an increasing interest in Alaska in producing an oilseed crop for both the edible oil and industrial oil and biofuel markets. Any seed grown for both the edible oil and industrial and biofuel markets should be grown on contract with a processing facility because a high-quality seed lot is required. At the present time there is no facility in Alaska to process oil from sunflower seed and no elevator is set up to accept sunflower seed. However, there are a few on-farm, small-scale oilseed presses set up to extract oil without the secondary chemical extraction. All common sunflower varieties are later maturing than the sunwheat or dwarf sunflower varieties. As a result, no varieties that have been tested in Alaska have consistently produced a viable crop. Due to these cultural problems, no common sunflower varieties are generally recommended. However, just because there was a crop failure for this study does not mean that sunflowers might not be successfully grown somewhere within the state. Therefore, the reader is not discouraged from trying any of the common sunflower varieties not recommended, but the probability of success in attempting to produce these crops will likely be low.

Yields and Quality by Location for Common, Dwarf, and Sunwheat Sunflower

Common, semi-dwarf sunwheat, and dwarf sunflowers (oil and confectionary) are bought and sold by weight. Similar to small grains, a standard test weight for all sunflower seed is used as the legal unit for purchase or sale of the crop. This standard test weight for clean, dry, and undamaged sunflower seed is 25 pounds per bushel. Other than test weights, additional samples should be taken on-farm to determine quality. Because seed lots not meeting high-quality oilseed standards should be used as lower feed grades, it is important that the producer clean and size all seed lots before delivery to a niche market. Test weights are used here as a measure of seed quality to determine maturity. Yields are expressed here in pounds per acre and bushels per acre. Determine bushels per acre by dividing the yield of any specific cultivar by the standard test weight.

Tables 106, 108, 110, and 112 list yields and quality measurements for sunflower varieties grown at 3 test locations: Fairbanks, Eielson, and Delta Junction. All sites in the Delta Junction area have been combined into either the Delta dryland site (Table 110) or, if grown under irrigation, the Delta irrigated site (Table 112). Each table also contains information on seed type (common, dwarf, or sunwheat), the source or the location where it was bred, biomass yield, heights, and the years it was tested at each location. Maturity in this study was defined as when 50% of the backs of the heads for each plot were a yellow color. Average maturity GDD were calculated from the average daily temperature minus a standard low temperature at which there can be no continued growth of the crop. The low temperature point for all sunflowers in this report is the freezing point of water, 32°F. The GDD calculations for each day were then added to the preceding GDD value to determine the date at which the specific variety had reached 50% maturity. The many varieties that did not reach maturity because of seasonal frosts are represented by N/D (No Data) in each of the tables. All varieties were compared with 'Midnight Sun-flower' dwarf, open-pollinated oilseed sunflower as the standard variety. Yield as a percent of the standard variety 'Midnight Sun-flower' was determined by dividing the average yield of each variety by the average yield of 'Midnight Sun-flower'. Maturity vs. Std. (Standard variety) are the number of days it took each variety to reach 50% maturity either before or after the number of days that 'Midnight Sun-flower' reached 50% maturity. Estimated oil yield data is based on the assumption of extracting about half of the oil contained in the seed, or about 25% by weight, through the primary pressing process and not the secondary chemical extraction process. Therefore, the seed yield in pounds per acre times 25% equals the oil yield in pounds per acre. The density of sunflower oil is 7.81 pounds per gallon. This number is used to convert the oil yield in pounds per acre into gallons of oil per acre.

Seed and forage quality data on a dry-weight basis (percent oil, percent crude protein and other nutrients, and the nutritive composition from the biomass) for Fairbanks (Table 107), Eielson (Table 109), and Delta dryland (Table 111) are presented without statistical differences and solely for the reader's benefit. More detailed information and explanation about the industry standards for food-grade sunflower oil that follow can be obtained from D.T. Ehrensing and S.O. Guy (2008). Detailed explanation of the feed analysis that follows as well as laboratory procedures can be obtained from J. Schroeder (1994) and G.J. Michaelson and others (1987).

Percent crude protein is calculated from the total percent nitrogen analysis of the seed multiplied by a constant of 6.25. Crude protein is made up of amino acids, which are 16% nitrogen, as well as other, non-protein portions of the plant, and so percent crude protein is not a measure of true protein. Industry standards of crude protein for all sunflowers are set for a range between 15% and 36% for seed and 10% and 25% for forage. Higher values have greater nutritional food value, but too high a value (>36% for seed and >25% for forage) is an indicator of immature green seed at harvest, which makes a lower-grade oil because it turns rancid quicker. In a standard feed analysis, other major nutrient mineral concentrations that are measured are percent phosphorus (%P) and potassium (%K).

Percent oil (%Oil) is a measure of the amount of oils contained in the seed or forage. These plant-based oils contribute some of the major essential fatty acids and energy needed in animal diets. High levels of these oils can supply more energy but also dilute mineral nutrient concentrations.

Percent dry matter (%DM) is the amount of plant biomass left after the water has been driven off in an oven at 140°F. The actual time that it takes to dry to a constant weight at 140°F is variable, from a few days to a week or more, depending on the type of plant matter. The nutrient concentrations are always expressed on a dry weight basis as it allows for better comparisons between different plant types.

Percent neutral detergent fiber (%NDF) is a measure of the percentage of partially digestible plant material (lignin, hemicellulose, and cellulose) of the forage. Lower levels of NDF usually result in a higher animal intake of the forage. It is also used to calculate the dry matter intake (DMI), where DMI = 120 ÷ %NDF. This value is later used to determine the relative feed values.

Percent acid detergent fiber (%ADF) is a measure of the highly indigestible plant material (lignin and cellulose) of the forage. Higher levels of ADF usually indicate a low digestibility of the plant material. It is also used to calculate the digestible dry matter (DDM), where DDM = 88.9 - (0.779 x %ADF). This value is also later used to determine the relative feed values.

The relative feed value (RFV) is a unitless index that combines the nutritional factors of the dry matter intake and the digestible dry matter of the plant material: RFV = (DDM x DMI) ÷ 1.29. Plant material with an ADF of 41% and a NDF of 53% has a RFV of 100. All other plant material is compared to this value. Lower ADF and NDF values will cause the RFV to increase. The higher the RFV, the lower the overall quality of the feed.

Percent cellulose (%Cellulose) is a measure of partially digestible plant material. Percent lignin (%Lignin) is a measure of highly indigestible plant material. Both percentages are determined from %ADF and %NDF determinations. Higher %ADF and %NDF result in higher percentages of indigestible plant material (%Lignin), which usually lead to lower feed intake and animal performance.

Table 106. Average yields and quality measurements for all sunflower varieties from test plots in the Fairbanks area.

Sunflower Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Oil Yield (gal/acre)	Seed Test wt. (lbs/bu)	Biomass Yield (lbs/acre)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Dwarf edible oilseed, spring												
Midnight Sun-flower	Alaska	17	1373	55	100	45	24	N/D	0	28-Jul	0	2003
Sunwheat semi-dwarf, edible oilseed, spring												
Sunwheat 101	Minnesota	3	1938	78	141	63	26	26,955	0	4-Sep	38	2894
Sunwheat 103	Minnesota	3	2638	106	192	86	26	26,955	0	3-Sep	37	2878
Common edible oilseed, spring												
Black Russian	Russia	1	N/D	N/D	N/D	N/D	N/D	N/D	0	4-Sep	38	2894
CM 400	Manitoba	2	N/D	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D
DO 164	Manitoba	2	N/D	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D
HA 89	Australia	2	N/D	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D
HA 124	Australia	1	N/D	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D
HA 300	Australia	1	N/D	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D

HA 301	Australia	1	N/D	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D
HA 303	Australia	1	N/D	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D
Hysun - 30	North Dakota	2	N/D	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D
IS 241	North Dakota	1	2604	104	190	85	22	N/D	0	25-Sep	59	3180
IS 893	North Dakota	1	2195	88	160	72	23	N/D	0	25-Sep	59	3180
IS 891	North Dakota	2	N/D	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D
IS 894	North Dakota	2	2961	118	216	97	23	N/D	0	25-Sep	59	3180
IS 897	North Dakota	2	2732	109	199	89	21	N/D	0	25-Sep	59	3180
IS 903	North Dakota	2	2156	86	157	70	24	N/D	0	25-Sep	59	3180
IS 907	North Dakota	2	2556	102	186	83	24	N/D	0	25-Sep	59	3180
IS 1166	North Dakota	1	1296	52	94	42	22	N/D	0	25-Sep	59	3180
IS 1210	North Dakota	1	1057	42	77	34	21	N/D	0	25-Sep	59	3180
IS 1490	North Dakota	1	1199	48	87	39	21	N/D	0	25-Sep	59	3180
IS 1500	North Dakota	1	1148	46	84	37	21	N/D	0	25-Sep	59	3180
IS 1500 x 2100	North Dakota	2	3849	154	280	126	25	N/D	0	25-Sep	59	3180
IS 1500 x 2490	North Dakota	1	2704	108	197	88	25	N/D	0	25-Sep	59	3180
IS 3107	North Dakota	2	2281	91	166	74	24	N/D	0	25-Sep	59	3180
IS 3500	North Dakota	1	827	33	60	27	22	N/D	0	25-Sep	59	3180
IS 3600	North Dakota	1	291	12	21	9	19	N/D	0	25-Sep	59	3180
IS 3800	North Dakota	1	553	22	40	18	19	N/D	0	25-Sep	59	3180
IS 7775	North Dakota	2	3062	122	223	100	25	N/D	0	25-Sep	59	3180
IS 7785	North Dakota	1	2137	85	156	70	24	N/D	0	25-Sep	59	3180
IS 8907	North Dakota	2	3615	145	263	118	26	N/D	0	25-Sep	59	3180
IS 8943	North Dakota	1	2235	89	163	73	24	N/D	0	25-Sep	59	3180
IS 8944	North Dakota	2	2802	112	204	91	23	N/D	0	25-Sep	59	3180
Peredovik	North Dakota	2	2506	100	182	82	22	N/D	0	25-Sep	59	3180
RHA 271	North Dakota	2	N/D	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D
RHA 274	North Dakota	2	N/D	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D
RHA 276	North Dakota	2	N/D	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D
RHA 290	North Dakota	1	N/D	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D
RHA 299	North Dakota	1	N/D	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D
S 894 A	Minnesota	2	N/D	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D
Sunfola 68-2	Hungary	2	N/D	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D
Confectionery, spring												
Sundak	North Dakota	2	2983	119	217	97	19	N/D	0	25-Sep	59	3180

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. N/D = No Data. All varieties were compared with 'Midnight Sun-flower' dwarf, open-pollinated oilseed sunflower as the standard variety.

Table 107. Average seed and forage quality measurements for select sunflower varieties from test plots in the Fairbanks area.

Sunflower Variety Name	Source	Years Tested	Oil Content (%)	Crude Protein (%)	Total P (%)	Total K (%)	Dry Matter (%)	NDF (%)	ADF (%)	Relative Feed Value	Cellulose (%)	Lignin (%)
Edible Oil Industry Standards			**24-45%**	**15-36%**	**0.5-1.1%**	**0.8-1.1%**	**> 93%**	**40-48%**	**30-48%**	**< 100**		
Dwarf edible oilseed, spring												
Midnight Sun-flower	Alaska	17	41.80	18.94	0.65	1.01	97.40	18.41	12.01	402	8.99	3.52
Sunwheat semi-dwarf, edible oilseed, spring												
Sunwheat 101	Minnesota	3	43.92	19.13	0.66	1.08	96.30	N/D	N/D	N/D	N/D	N/D
Sunwheat 103	Minnesota	3	51.60	18.38	0.62	0.87	98.70	18.83	11.95	391	8.04	3.91
Common edible oilseed, spring												
Black Russian	Russia	1	39.51	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
IS 241	North Dakota	1	42.40	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
IS 893	North Dakota	1	40.80	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
IS 894	North Dakota	2	41.90	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
IS 897	North Dakota	2	41.00	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
IS 903	North Dakota	2	41.40	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
IS 907	North Dakota	2	43.20	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
IS 1166	North Dakota	1	42.40	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
IS 1210	North Dakota	1	43.10	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
IS 1490	North Dakota	1	38.30	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
IS 1500	North Dakota	1	41.00	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
IS 1500 x 2100	North Dakota	2	42.40	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
IS 1500 x 2490	North Dakota	1	39.10	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
IS 3107	North Dakota	2	39.40	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
IS 3500	North Dakota	1	40.30	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
IS 3600	North Dakota	1	42.20	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
IS 3800	North Dakota	1	38.80	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
IS 7775	North Dakota	2	41.50	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
IS 7785	North Dakota	1	40.20	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
IS 8907	North Dakota	2	39.60	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
IS 8943	North Dakota	1	40.80	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
IS 8944	North Dakota	2	41.50	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Peredovik	North Dakota	2	37.30	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Confectionery, spring												
Sundak	North Dakota	2	27.70	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Forage Industry Standards			**10-40%**	**10-28%**	**0.5-1.1%**	**0.8-1.1%**	**>93%**					
Sunwheat, semi-dwarf, edible oilseed, spring												
Sunwheat 101	Minnesota	3	27.01	22.57	0.50	1.10	97.63	N/D	N/D	N/D	N/D	N/D
Sunwheat 103	Minnesota	3	39.51	22.29	0.59	0.99	97.87	N/D	N/D	N/D	N/D	N/D

Oil analysis done on whole seed (with hulls) at maturity. Forage analysis done on whole plant biomass (seed and stems) at maturity. N/D = No Data. All varieties were compared with 'Midnight Sun-flower' dwarf, open-pollinated oilseed sunflower as the standard variety.

Table 108. Average yields and quality measurements for all sunflower varieties from test plots in the Eielson area.

Sunflower Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Oil Yield (gal/acre)	Seed Test wt. (lbs/bu)	Biomass Yield (lbs/acre)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Dwarf edible oilseed, spring												
Midnight Sun-flower	Alaska	1	484	19	100	16	24	N/D	0	29-Jul	0	1960
Sunwheat semi-dwarf, edible oilseed, spring												
Sunwheat 101	Minnesota	3	978	39	202	32	20	23,746	0	7-Sep	40	2867
Sunwheat 103	Minnesota	3	1134	45	234	37	23	12,091	0	7-Sep	40	2867
Common edible oilseed, spring												
Black Russian	Russia	1	N/D	N/D	N/D	N/D	N/D	N/D	0	17-Sep	50	3019

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. N/D = No Data. All varieties were compared with 'Midnight Sun-flower' dwarf, open-pollinated oilseed sunflower as the standard variety.

Table 109. Average seed and forage quality measurements for select sunflower varieties from test plots in the Eielson area.

Sunflower Variety Name	Source	Years Tested	Oil Content (%)	Crude Protein (%)	Total P (%)	Total K (%)	Dry Matter (%)
Edible Oil Industry Standards			**24-45%**	**15-36%**	**0.5-1.1%**	**0.8-1.1%**	**>93%**
Dwarf, edible oilseed, spring							
Midnight Sun-flower	Alaska	1	41.80	15.00	0.61	1.28	99.14
Sunwheat, semi-dwarf, edible oilseed, spring							
Sunwheat 101	Minnesota	3	43.48	16.22	0.51	1.18	98.71
Sunwheat 103	Minnesota	3	48.35	16.22	0.56	1.12	96.49
Common, edible oilseed, spring							
Black Russian	Russia	1	39.51	N/D	N/D	N/D	N/D
Forage Industry Standards			**10-40%**	**10-25%**	**0.5-1.1%**	**0.8-1.1%**	**> 93%**
Sunwheat semi-dwarf, edible oilseed, spring							
Sunwheat 101	Minnesota	3	N/D	23.38	0.76	2.27	N/D
Sunwheat 103	Minnesota	3	N/D	18.94	0.69	1.50	N/D

Oil Analysis done on whole ripe seed (with hulls). Forage analysis done on whole plant biomass (seed and stems) at maturity. N/D = No Data. All varieties were compared with 'Midnight Sun-flow

Table 110. Average yields and quality measurements for all sunflower varieties from test plots in the Delta Junction area, dryland site.

Sunflower Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Oil Yield (gal/acre)	Seed Test wt. (lbs/bu)	Biomass Yield (lbs/acre)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Dwarf edible oilseed, spring												
Midnight Sun-flower	Alaska	4	408	16	100	13	24	N/D	0	5-Aug	0	2143
Sunwheat semi-dwarf, edible oilseed, spring												
Sunwheat 101	Minnesota	3	146	6	36	5	23	N/D	0	12-Sep	38	2902
Sunwheat 103	Minnesota	3	150	6	37	5	24	N/D	0	10-Sep	36	2874
Common edible oilseed, spring												
Black Russian	Russia	1	N/D	N/D	N/D	N/D	N/D	N/D	0	12-Sep	38	2902
IS 241	North Dakota	1	N/D	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D
IS 893	North Dakota	1	N/D	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D
IS 894	North Dakota	2	30	1	7	1	18	N/D	0	20-Sep	46	3003
IS 897	North Dakota	2	35	1	9	1	17	N/D	0	20-Sep	46	3003
IS 903	North Dakota	2	39	2	10	1	18	N/D	0	20-Sep	46	3003
IS 907	North Dakota	2	284	11	70	9	21	N/D	0	20-Sep	46	3003
IS 1166	North Dakota	1	52	2	13	2	17	N/D	0	20-Sep	46	3003
IS 1210	North Dakota	1	120	5	29	4	19	N/D	0	20-Sep	46	3003
IS 1490	North Dakota	1	N/D	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D
IS 1500	North Dakota	1	N/D	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D
IS 1500 x 2100	North Dakota	2	107	4	26	3	17	N/D	0	20-Sep	46	3003
IS 1500 x 2490	North Dakota	1	34	1	8	1	16	N/D	0	20-Sep	46	3003
IS 3107	North Dakota	2	N/D	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D
IS 3500	North Dakota	1	N/D	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D
IS 3600	North Dakota	1	N/D	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D
IS 3800	North Dakota	1	N/D	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D
IS 7775	North Dakota	2	48	2	12	2	16	N/D	0	20-Sep	46	3003
IS 7785	North Dakota	1	12	0	3	0	15	N/D	0	20-Sep	46	3003
IS 8907	North Dakota	2	121	5	30	4	18	N/D	0	20-Sep	46	3003
IS 8943	North Dakota	1	45	2	11	1	16	N/D	0	20-Sep	46	3003
IS 8944	North Dakota	2	208	8	51	7	21	N/D	0	20-Sep	46	3003
Peredovik	North Dakota	2	25	1	6	1	13	N/D	0	20-Sep	46	3003
Confectionery, spring												
Sundak	North Dakota	2	37	1	9	1	19	N/D	0	20-Sep	46	3003

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. N/D = No Data. All varieties were compared with 'Midnight Sun-flower' dwarf, open-pollinated oilseed sunflower as the standard variety.

Table 111. Average seed quality measurements for select sunflower varieties from test plots in the Delta Junction area, dryland site.

Sunflower Variety Name	Source	Years Tested	Oil Content (%)	Crude Protein (%)	Total P (%)	Total K (%)	Dry Matter (%)
Edible Oil Industry Standards			**24-45%**	**15-36%**	**0.5-1.1%**	**0.8-1.1%**	**>93%**
Dwarf edible oilseed, spring							
Midnight Sun-flower	Alaska	4	39.51	15.00	0.50	1.21	99.12
Sunwheat semi-dwarf, edible oilseed, spring							
Sunwheat 101	Minnesota	3	33.92	15.69	0.39	1.20	98.14
Sunwheat 103	Minnesota	3	41.48	15.81	0.42	1.10	96.20
Common, edible oilseed, spring							
IS 907	North Dakota	2	22.60	N/D	N/D	N/D	N/D
IS 1210	North Dakota	1	29.00	N/D	N/D	N/D	N/D
IS 8944	North Dakota	2	14.20	N/D	N/D	N/D	N/D

Oil analysis done on whole ripe seed (with hulls). N/D = No Data. All varieties were compared with 'Midnight Sun-flower' dwarf, open-pollinated oilseed sunflower as the standard variety.

Table 112. Average yields and quality measurements for all sunflower varieties from test plots in the Delta Junction area, irrigated site.

Sunflower Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Oil Yield (gal/acre)	Seed Test wt. (lbs/bu)	Biomass Yield (lbs/acre)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Dwarf edible oilseed, spring												
Midnight Sun-flower	Alaska	1	468	19	100	15	25	N/D	0	6-Aug	0	2170
Sunwheat semi-dwarf, edible oilseed, spring												
Sunwheat 103	Minnesota	1	N/D	N/D	N/D	N/D	N/D	N/D	0	9-Sep	34	2859

Crambe

Industrial Crambe Oilseed

Crambe (*Crambe abyssinica*), or Abyssinian mustard, is an annual, mid- to late-season, broad-leaved oilseed crop in the same cruciferous family as canola and mustards, so the leaves look very similar. It can grow between 24 and 50 inches tall, depending on plant density and environmental growing conditions. Unlike mustards, crambe is an indeterminate plant and continues to flower until growth is stopped by a killing frost. The plant is covered by many small, white flowers that form seed pods containing 1 small (one-eighth inch) seed each at maturity. Crambe is well adapted to fertile, well-drained soils of a pH between 6.0 and 7.5. It is drought-tolerant and will reach physiological maturity in about the same period as canola and barley.

According to A.L. Grombacher and others (1993) and K.D. Carlson and others (1996), crambe seed contains between 30% and 35% oil with 40% to 60% erucic acid and 45-70 micromoles per gram of glucosinolates. These levels are even higher than the high-erucic-acid, high-gulcosinolate industrial rapeseed cultivars. High erucic acid content in oil contributes to stability at high temperatures and helps keep it liquid at low temperatures. This characteristic makes crambe oil a good industrial lubricating and slip agent transfer oil (useful for keeping individual plastic sheets from sticking together).

Crambe oil is obtained by a combination of expressing and extraction with a solvent. The best of the commercial oilseed presses is only capable of extracting about half of the oil contained in the seed, or about 15% to 17% by weight. Small-scale to kitchen-scale presses can only get about 25% of the oil in the seed, or about 7% to 9% by weight. The remaining 50% to 75% of the oil in the meal is extracted with a hexane solvent process. The solvent is then removed from the oil, which is blended in with the pressed oil and run through a filtration and cleaning process. Since crambe seed is contained in single-seeded pods, the pods often remain intact with seed at harvest. The proportion of seed pods to seed after harvest and cleaning can vary significantly, so the composition of the meal will also vary. The crude protein levels will vary from a low of about 25% in seed plus pods to a high of 50% in seed alone. The meal does contain high levels of erucic acid that can cause heart lesions and high levels of glucosinolates that can cause goiters when fed to animals, so it can only be fed sparingly in ruminant diets and only for meat production.

All crambe varieties produce higher biomass yields than the Polish canola varieties, with higher glucosinolate levels. As a result, crambe, like mustards, might benefit when grown in rotation as a bio-fumigant cover crop for an organic control of weeds, insects, nematodes, and soilborne diseases. The primary purpose of testing crambe in this study was for oilseed yield and not as a bio-fumigant, so there is no data on the effectiveness of the biomass for weed or insect control.

Fertilization practices for crambe are similar to those for mustards. Like mustards, crambe requires more nitrogen than any other nutrient, which is essential for increased leaf production and increased yields if sufficient available soil moisture is present during the growing season. With adequate soil moisture conditions, a maximum of 10 pounds per acre of nitrogen can be banded with the seed. Because soil moisture conditions are rarely sufficient in Alaska unless irrigation is used, most, if not all, nitrogen carriers should be broadcast applied. In low soil moisture conditions, germinating seeds and seedlings can be injured by the nitrogen fertilizers. Avoid excess nitrogen fertilizer because it can induce lodging, delay maturity, and cause an increased risk of fungal attacks at harvest, especially if grown under irrigation.

Crambe requires relatively moderate phosphorus levels and low potassium levels, which improve disease resistance and tolerance for frost and drought. Because Alaska soils are generally acidic, they tend to fix phosphorus, making it unavailable for plant uptake, so banding the phosphorus carrier with or next to the seed at planting would not help increase the level of available phosphorus. The small seed is planted shallowly, where soil moisture is usually less than optimum, which renders the phosphorus unavailable for plant use. Thus, phosphorus and potassium fertilizers should be broadcast with the nitrogen fertilizers.

Sulfur and boron are needed by crambe to promote flowering and seed set. Soils low in available sulfur should have ammonium sulfate or potassium sulfate broadcast applied. A ratio of 3:2:1:0.5 of N, P_2O_5, K_2O, and S have produced acceptable yields of crambe. With irrigated farming practices, the ratio should be reduced to about 1.5:1:0.5:0.25. A rate of 0.5 pound per acre of actual boron is sufficient to correct most soil deficiencies. Actual percentages of all nutrients and the application rates vary according to the specific soil test results. All fertilizer must be broadcast prior to spring tillage.

Choice of the field for crambe production is important. It should not have been cropped to canola or other *Brassica* species in the previous 3 to 5 years. Crambe production should follow a year of summer fallow to help reduce the likelihood of plant disease, broad-leaved weeds, and volunteers, or it should be planted in a rotation following a grain crop like barley. This also increases available soil moisture and reduces the amount of fertilizer required. To conserve soil moisture, minimum tillage is recommended for incorporating fertilizer and plant residue and preparing the seedbed. Pulling a packer behind the tillage implement and using a seed drill equipped with press wheels ensure that the seed is in contact with moist soil during germination. If the crop is to be grown under irrigation, the soil should be irrigated sufficiently to bring the soil moisture levels close to the maximum water-holding capacity before tillage. It is very important not to irrigate above the maximum water-holding capacity before tilling and planting as this could cause a soil crust to form on the surface that would impede seedling emergence, reduce plant density, and lower seed yields. Seeding depth is shallow, 0.75 to 1.5 inches, or to moisture. Seeding deeper than 2 inches may result in delayed germination and emergence. Seeding rates of 15 to 20 pounds per acre of pure live seed are recommended for seed and oil production. Heavier seeding rates produce thicker stands that ripen more uniformly and reduce the possibility of green seeds at harvest. Planting as early as possible to avoid loss of important soil moisture and using as much of the short growing season as possible is recommended. Use of certified seed is strongly recommended. Certified seed has strict limits on maximum content of weed seeds and diseased seed and must meet a minimum percent germination. This helps to ensure good germination and emergence and reduces weed and disease infestations.

Like mustards, irrigation should begin again after the crop has reached about 50% emergence to avoid any problems resulting from too hard of a crust on the surface. Thereafter, a good range of irrigation plus precipitation is around 0.5 to 1.0 inch per week. Irrigation should continue until the crop has reached the 50% pod set growth stage.

Using IPM techniques, assess each field for all pests (weeds, diseases, and insects) and plan control measures accordingly. Weed control in crambe is extremely important. Crambe needs warm soil to germinate and doesn't compete well with weeds. The same weeds that are a problem for canola and mustards also compete with crambe. The most difficult to control are wild mustard (*Sinapsis arvensis*), shepherd's purse (*Capsella bursa-pastoris* (L.) Medic.), tansy mustard (*Descurainia sophioides* Fisch.), and volunteer canola or mustard. The best weed control is a combination of mechanical and chemical summer fallow to reduce the number and species of weeds for the following season. In the spring, wait for weeds to germinate, then perform seedbed tillage using proper fertilization and seeding rates. There are no herbicides registered for use on crambe in Alaska. To eliminate both grassy and broad-leaved weeds, a broad-spectrum, nonselective post-emergence herbicide such as glyphosate (Roundup) can be used in a chemical fallow rotation.

The same fungal diseases that attack canola and mustard seed and seedlings, causing damping-off, downy mildew (*Peronspora parasitica*), and root rot also attack crambe. They cause seed decay and seedling blight with delayed emergence and eventual uneven stands. Cool, wet soil conditions in the spring favor development of seed-borne fungal attacks. Sclerotinia, or white mold fungus (*Sclerotinia sclerotiorum*), infects the base of the plant, causing wilt. This fast-acting disease often takes only 4 to 7 days from the first appearance to complete wilting. Cool, wet soil conditions in the spring and infected plant residue from the previous year favor development of this fungal disease. It can spread from plant contact and through airborne spores. Alternaria black spot (*Alternaria brassicae)* is a serious fungal disease that can infect crambe. It has been found on canola in Alaska. Small, dark lesions that occur on leaves and seed pods throughout the growing season cause a reduced photosynthetic ability of the leaves, premature pod drying, and seed shatter. Control is through crop rotation and certified seed, as there are no registered fungicides for use on crambe in Alaska. Sunflowers, canola, camelina, and mustards are also susceptible to this disease and should not be used in the crop rotation.

Similar to canola and mustards, crambe is susceptible to many different kinds of insect pests, many of which can cause serious yield losses and require control measures. Flea beetles (*Phyllotreta cruciferae* Goeze) are small, shiny, black insects that jump when disturbed. They can seriously damage the newly emerging crop by eating small holes in the leaves. The cabbage root maggot or cutworm (*Hylemya brassicae* Bouche) is the larval stage of a fly. It infests the base and roots in the seedling to mature growth stages. Infestations of only 3 or more per plant before or during the seedling growth stage can eventually girdle the plant. Also, their feeding creates wounds that can later serve as entry sites for fungal diseases. The red turnip beetle (*Entomoscelis americana* Brown) has recently become a pest in Alaska. The adult beetle is bright red with 3 black stripes down the back and a black patch behind the head. The larva feed on the leaves in late May to early June and the adults feed on the leaves in late June to early July, often causing total defoliation in heavy infestation years. After feeding for several weeks, the beetle burrows into the soil and becomes inactive for a 2-week summer hibernation period. The beetles re-emerge in August and continue feeding until killed by early frosts. A control measure that works well is to increase the number of years between growing any mustard crop in the same fields. Other cultural practices such as weed control (tansy mustard, *Descurainia sophioides* Fisch., is an alternate host) and volunteer control are also recommended to reduce red turnip beetle populations. There are no registered insecticides for crambe in Alaska. Contact your local Cooperative Extension Service for more information on pest control (see Appendix 1 for addresses and contact information).

Crambe, like canola and mustards, ripens from the bottom of the plant to the top. After physiological maturity, the lower leaves turn yellow and drop off the plant. The seed pods and upper branches turn a light brown or straw-colored. When the seed pods near the bottom have turned the same color, harvest can begin. There are still green seeds in the pods near the tips of the side branches and at the top of the plant. Average seed moisture content at this stage is about 15% to 20%. Crambe is usually swathed prior to combining because seed continues to mature in the windrow and can change color by 5% per day with enough heat and low humidity. Swathing should be done at about 12-18 inches from the ground to just below the lowest seed pods; this high height will leave stubble that can help hold drying windrows and prevent losses because of breezes. It also helps dry both the plants and any green weeds before harvest, making combining easier and reducing shatter loss. After a heavy precipitation event, standing crambe dries better than swathed crambe in windrows. Swathing too early reduces overall yields and oil content, while swathing too late increases shatter loss. Windrows can become very lightweight as the crop dries down. These light windrows can then be blown around by even a slight breeze, spreading the plants out and shattering seed pods, resulting in a significant yield reduction.

Combining either the swathed or standing crambe can begin when the seed has around 10% moisture content. Pod shatter is less for crambe than it is for canola. To reduce the loss of seed because of shatter, set the header reel height to just at the top of the crop or windrow and slow down the reel speed. The header should be set high if combining standing crambe to just below the lowest seed pods. Reduce cylinder speeds to one-half or two-thirds of that used for small grains. Concave clearance should be increased slightly for that of canola because of the greater volume of plant material to about 1.5 inches at the front and 1 inch at the back. These settings can be reduced later only if the plant tissue is dry enough to thresh out properly. This will reduce the chance of over-threshing and causing cracked seeds and excess plant material in the hopper. The seed has extremely low bushel weights. To avoid blowing the seed out with the chaff, reduce the fan speed to about half of that used for canola. The cleaning action for crambe seed relies more on shaking action than on air flow. Top screens should be between one-fourth and one-third inch and the bottom screens between on-eighth and one-fourth inch. Care must be taken to seal up all small holes and cracks in the combine, augers, trucks, and bins as crambe seed is small and round in shape, and so leaks out easily. Equip the combine with a straw chopper and spreader to evenly distribute the plant material in order to incorporate it for a potential allelochemical effect the following growing season.

Typical grain dryers have perforated floor openings that are too large for the small seeds. A 5-mesh nylon sheet over the floor prevents seed loss. Crambe seed should be recleaned, dried to about 8% moisture and cooled to between 60°F and 40°F before storage. Any green or moist material can cause molds to form, reducing the quality of the oil as well as the germination ability of the seed. Aeration from the bottom up through the bin with supplemental heat to drive off excess moisture is the usual first step. Do not heat the seed above 110°F because this causes a reduction in germination ability. The seed should be cooled immediately after drying to between 60°F and 40°F. Temperatures and moisture content of the seed in the bin should be checked every day for a week after harvest, then every week after that. Repeat the aeration and drying if needed, because seed can spoil quickly in storage. Green seed and clean-outs can be used sparingly on farm as an animal feed for ruminants.

Like mustards, crambe is considered a marginal crop for Alaska. In good years with adequate soil moisture and GDD, crambe will still have uneven ripening resulting in a high percentage of green seed at harvest. This is due to any immature seed that was killed by fall frost. Seed killed by frost does not continue to ripen and remains green. Green seeds are immature seeds that contain chlorophyll, which imparts a green color to the oil and shortens the shelf life by turning rancid quickly. There is an increasing interest in Alaska in producing an oilseed crop for the industrial and biofuel markets. Any seed grown for these markets should be grown on contract with a processing facility, because a high-quality seed lot is required. Unfortunately, there is currently no large-scale facility in Alaska to process oil from crambe seed for either the industrial oil or biofuel oil markets. Also, there are no elevators in Alaska currently set up to take crambe seed. However, there are a few on-farm, small-scale oilseed presses set up to extract oil without the secondary chemical extraction.

All crambe varieties are later-maturing than the Polish canola, camelina, or mustard varieties. As a result, there are no varieties that have been tested in Alaska that produce consistent yields. For this reason, no crambe varieties are generally recommended. However, just because there was a crop failure for this study does not mean that it might not be successfully grown somewhere within the state.

Therefore, the reader is not discouraged from trying any of the crambe varieties not recommended, but the probability of success in attempting to produce these crops will likely be low.

Yields by Location for Crambe

Crambe seed is bought and sold by weight. Similar to canola and mustards, there is a standard test weight for crambe seed that is used as the legal unit for purchase or sale of the crop. This standard test weight for clean, dry, and undamaged crambe seed is 25 pounds per bushel. Besides test weights, additional samples should be taken on farm to determine quality. Any seed lots not meeting high-quality standards should be used as lower feed grades. It is important, then, for the producer to clean and size all seed lots before delivery to a niche market. Test weights are used here as a measure of seed quality to determine maturity. Yields are expressed here in pounds per acre and bushels per acre. Determine bushels per acre by dividing the yield of any specific cultivar by the standard test weight.

Table 113 lists yield and quality measurements for the crambe seed variety tested for the Fairbanks location. There were no irrigation trials done on crambe. The table also contains information on the year it was tested. Maturity in this study was defined as when 50% of the seed for each plot was a light brown color. Growing degree days (GDD) for average maturity were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. The low temperature point for crambe in this report is the freezing point of water, 32°F. The GDD calculations for each day were then added to the preceding GDD value to determine the date at which the specific variety had reached 50% maturity. Differences between varieties in the average GDD at maturity in relation to the average maturity date are due to differing years of testing. All varieties were compared with 'Reward' Polish canola as the standard variety. Yield as a percent of the standard variety 'Reward' was determined by dividing the average yield of each variety by the average yield of 'Reward'. Maturity vs. Std. (Standard variety) are the number of days it took each variety to reach 50% maturity either before or after the number of days that 'Reward' reached 50% maturity. Estimated oil yield data is based on the assumption of extracting about half of the oil contained in the crambe seed, or about 15% by weight, through the primary pressing process and not the secondary chemical extraction process. Therefore, the seed yield in pounds per acre times 15% equals the oil yield in pounds per acre. The density of crambe oil is 7.96 pounds per gallon. This number is used to convert the oil yield in pounds per acre into gallons of oil per acre. There was no animal feed nutritional analysis done on crambe seed.

Table 113. Average yields and quality measurements for all crambe varieties from test plots in the Fairbanks area.

Crambe Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Oil Yield (gal/acre)	Seed Test wt. (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Industrial oilseed, spring											
Glactica	England	1	444	18	29	8	20	0	28-Sep	45	3199

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. This variety was compared with 'Reward' Polish canola as the standard variety.

Safflower

Edible and Industrial Safflower Oilseed

Safflower (*Carthamus tinctorius* L.) is an annual broad-leaved edible and industrial oilseed plant that grows 12 to 48 inches tall. It has multiple branches on smooth white or yellowish stems. Globular flower heads (0.5 to 1.5 inch diameter) occur at the top of each branch. The leaves and floral bracts bear short spines similar to those on thistles. The flowers may be white, yellow, orange, or red and produce smooth, white seed similar in shape to sunflower seed but smaller. Whole safflower seed contains 32% to 40% oil; dehulled seed contains 50% to 55% oil. Safflower oil is both an edible oil and an industrial drying oil. It contains 75% linoleic acid, an unsaturated omega-6 fatty acid. It contains no linolenic glycerides, which make it a superior drying oil for producing interior white paints; unlike linseed oil, it does not yellow when exposed to sunlight. It is also used in varnishes, enamels, and soap. The oil is obtained by a combination of expressing and extraction with a solvent similar to that used for linseed and sunflower oils. The best of the commercial oilseed presses is only capable of extracting about half of the oil contained in safflower seed, or about 15% to 20% by weight. Small-scale to kitchen-scale presses can only get about one-quarter of the oil in the seed, or about 6% to 10% by weight. The remaining half to three-quarters of the oil that remains in the meal is extracted with a hexane solvent process. The solvent is then removed from the oil, which is blended in with the pressed oil and run through a filtration and cleaning process. The resulting meal contains 20% to 50% protein, depending on the amount of hulls left on during processing. This meal can be used as a livestock feed. The flowers contain a commercial dye called carthamin that is yellow, orange, or red.

Fertilization, tillage practices, and seeding depths are identical to those for small grain production. Safflower requires well-drained soils and long growing seasons. Yields are increased when moderate levels of nitrogen and phosphorus are available, especially when plenty of soil moisture is also available. Safflowers are usually seeded into soils with lower available nutrients, but irrigation is recommended for complete nutrient use. Without irrigation, soils with low to moderate levels of available nutrients should receive a complete fertilizer blend of nitrogen, phosphorus, potassium, sulfur, and boron. A ratio of 2:1:1:0.5 of N, P_2O_5, K_2O, and S can produce acceptable yields. With irrigated farming practices, the ratio should be reduced to about 1:0.5:0.5:0.25. Sulfur and boron are needed by safflower to promote flowering, seed set, and to increase the oil content. Soils low in available sulfur should have a sulfate form broadcast as ammonium sulfate or as potassium sulfate. An application rate of 0.5 pound per acre of actual boron is sufficient to correct most soil deficiencies. Actual percentages of each nutrient and application rates vary according to specific soil test results. The fertilizer can be broadcast before spring tillage, or portions can be banded at planting. Avoid excess nitrogen because it can delay maturity, especially if grown under irrigation.

To conserve soil moisture, minimum tillage is recommended for incorporating fertilizer material and plant residue and preparing the seedbed. Pulling a packer behind the tillage implement and using a seed drill equipped with press wheels ensure that the seed is in contact with moist soil during germination. If the crop is to be grown under irrigation, the soil should be irrigated sufficiently to bring the soil moisture levels to close to the maximum water-holding capacity before tillage. It is very important not to irrigate above the maximum water-holding capacity before tilling and planting as this could cause a soil crust to form on the surface that would impede seedling emergence, reduce plant density, and lower seed yields. Seeding depth is the same as that for small grains, 1.5 to 2 inches, or to moisture. Seeding rates are between 15 and 30 pounds of pure live seed per acre, depending on row width and soil moisture. The lower rates should be used on wide row spacing or under dryland conditions. Safflowers should be seeded in rows that are 18 to 30 inches apart. Wider row spacings are required if mechanical cultivation weed control methods are to be used. Heavier seeding allows for some establishment loss due to poor conditions. Grain drills can be used to plant safflowers by blocking off the appropriate opening in the seed box. The seed box should be kept full to account for the effect of seed weight on the flow through the drill. Early planting dates are recommended to use as much of the short growing season as possible. Use of certified seed is strongly recommended. Certified seed has strict limits on maximum content of weed seeds and diseased seed, and must meet a minimum percent germination. This helps to ensure good germination and emergence, and reduces weed and disease infestations.

As with small grains, irrigation should begin again after the crop has reached about 50% emergence to avoid any problems resulting from too hard a crust on the surface. Thereafter, a good range of irrigation plus precipitation is around 0.5 to 1.0 inch per week. Irrigation should continue until the crop has reached the 50% flowering growth stage.

Using IPM techniques, assess each field for all pests (weeds, diseases, and insects) and plan control measures accordingly. Weed control in safflowers is extremely important. Like all the other oilseed crops, safflowers need warm soils to germinate and do not compete well with weeds until about 4 weeks after emergence. The best weed control is a combination of mechanical and chemical summer fallow to reduce the number and species of weeds for the following season. In the spring, wait for weeds to germinate, then perform seedbed tillage and use proper fertilization and seeding rates. To eliminate all weeds with chemical fallow, a broad-spectrum, nonselective, post-emergence herbicide such as glyphosate (Roundup) can be used. Safflower planted in wide rows can be mechanically cultivated to control weeds. There are no registered herbicides for safflowers in Alaska. Safflower is relatively free of disease in the dry climates of Interior Alaska. In areas of high fall moisture it suffers attack from botrytis head rot (*Botrytis cinerea*), which is found mostly on late- and very late-maturing varieties that are still high in moisture after the first killing frost. If harvested with uninfected seed, the mold can spread during storage. The only control is planting early-maturing varieties. Aphids (family Aphididae) are the most serious insect pests for safflowers, but they rarely become serious enough to warrant treatment. Contact your local Cooperative Extension Service for more information on pest control (see Appendix 1 for addresses and contact information). Despite the spines that are on the leaves and flower bracts, the seed is easily removed by songbirds when the plant reaches maturity. Since safflower is very late-maturing this often occurs when the birds are beginning to flock together before their fall migration. Small flocks can cause serious seed loss in small plots but rarely in large fields.

Safflower is ready to harvest when the bracts on the seed heads are brown and the leaves have lost most of their green color. When mature, the seeds thresh freely from the heads. This usually is 35 to 40 days after flowering. Safflower is resistant to lodging and shatter loss and can be direct combined when the stalks are dry and brittle. For best combining results, moisture content of the seed should be around 12% to 13% at this stage. Combine settings are similar to those used for sunflowers. Reduce cylinder speed to as slow as possible to reduce the amount of cracked and dehulled seed. Concave adjustments depends on the moisture content of the seed. If it is less than 12%, open the front 1 inch and set the back at three-quarter inch. At moisture levels higher than 12%, slightly reduce concave settings to increase threshing success. Remember that closer concave settings results in more cracked and dehulled seed. Reduce air speed over the sieves to avoid blowing the lightweight seed out with the chaff. The allowable percentage of cracked and dehulled seed is 2% to 5%.

Safflower seed is dry and safe for long-term storage at 8% to 10% moisture. In Alaska, the late maturity of most varieties requires harvest before this, so supplemental drying is required. Cleaning the seed lot to remove all green foreign material and cracked and dehulled seeds facilitates drying and produces a more acceptable seed lot after drying. Clean-outs can be used on farm or sold for animal feed. Supplemental heat in driers should not be above 120°F because higher temperatures can damage seed.

Safflowers are a marginal crop for Alaska. Even in the best years there are not enough GDD to mature seed completely before a killing frost. There is an increasing interest in Alaska in producing an oilseed crop for both the edible oil and industrial biofuel markets. Seed grown for the industrial oil markets should be grown on contract with a processing facility because a high-quality seed lot is required. Currently, there is no facility in Alaska to process oil from safflower seed and no elevators are set up to accept safflower seed. No varieties that have been tested in Alaska consistently produce a viable crop. Due to the cultural problems, there are no safflower varieties that are generally recommended. However, just because there was a crop failure for this study does not mean that it might not be successfully grown somewhere within the state. Therefore, the reader is not discouraged from trying any of the safflower varieties not recommended, but the probability of success in attempting to produce these crops will likely be low.

Yields and Quality by Location for Safflower

Safflower seed is bought and sold by weight. Similar to small grains, there is a standard test weight for safflower that is used as the legal unit for purchase or sale of the crop. This standard test weight for clean, dry, and undamaged safflower seed is 45 pounds per bushel. Other than test weights, additional samples should be taken on farm to determine quality. Any seed lots not meeting high oilseed quality standards should be used as lower-grade seed. It is important then for the producer to clean and size all seed lots before delivery to a niche market. Test weights are used here as a measure of seed quality to determine maturity. Yields are expressed here in pounds per acre and bushels per acre. Determine bushels per acre by dividing the yield of any specific cultivar by the standard test weight.

Tables 114 and 115 list yields and quality measurements for safflower varieties for 2 test locations: Fairbanks and Delta Junction. All sites in the Delta Junction area have been combined into Delta dryland site (Table 115). No irrigation trials were done for safflower. Each table also contains information on the source or the location where it was bred and the years it was tested at each location. Maturity in this study was defined as when 50% of the flower bracts for each plot were brown. Growing degree days (GDD) for average maturity were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. The low temperature point for safflowers in this report is the freezing point of water, 32°F. The GDD calculations for each day were then added to the preceding GDD value to determine the date at which the specific variety had reached 50% maturity. All varieties were compared with 'Midnight Sun-flower', a dwarf, open-pollinated oilseed sunflower, as the standard variety. Yield as a percent of the standard variety 'Midnight Sun-flower' was determined by dividing the average yield of each variety by the average yield of 'Midnight Sun-flower'. Maturity vs. Std. (Standard variety) are the number of days each variety took to reach 50% maturity either before or after the number of days that 'Midnight Sun-flower' reached 50% maturity. Estimated oil yield data is based on the assumption of extracting about half of the oil contained in safflower seed, or about 20% by weight, through the primary pressing process and not the secondary chemical extraction process. Therefore, the seed yield in pounds per acre times 20% equals the oil yield in pounds per acre. The density of safflower oil is 7.81 pounds per gallon. This number is used to convert the oil yield in pounds per acre into gallons of oil per acre. The many varieties that did not reach maturity due to seasonal frosts are represented by N/D (No Data) in each of the tables. There was no nutritional analysis of the seed done for animal feed.

Table 114. Average yields and quality measurements for all safflower varieties from test plots in the Fairbanks area.

Safflower Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Oil Yield (gal/acre)	Seed Test wt. (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Edible and industrial oilseed, spring											
Oker	Montana	1	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D
S-208	Montana	1	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D
Saffire	Alberta	1	132	3	10	3	12	0	25-Sep	59	3180
Sidwell	Montana	1	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. N/D = No Data. All varieties were compared with 'Midnight Sun-flower' dwarf, open-pollinated oilseed sunflower as the standard variety.

Table 115. Average yields and quality measurements for all safflower varieties from test plots in the Delta Junction area, dryland site.

Safflower Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Oil Yield (gal/acre)	Seed Test wt. (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Edible and industrial oilseed, spring											
S-208	Montana	1	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D
Sidwell	Montana	1	N/D	N/D	N/D	N/D	N/D	0	N/D	N/D	N/D

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. N/D = No Data. All varieties were compared with 'Midnight Sun-flower' dwarf, open-pollinated oilseed sunflower as the standard variety.

Borage

Edible and Industrial Borage Oilseed

Echium (*Echium plantagineum* (L)), commonly known as purple viperbugloss, is a member of the borage family. It is a spring annual, short (1 to 3 feet tall), broad-leaved, edible oilseed plant. Each plant has several long stems covered with long white hairs and several 4- to 5-inch-long pointed leaves. It has an indeterminate growth habit and will continue to flower until the first killing frost. The open-pollinated flowers are borne on separate spikes and are fairly large (0.75 inch), trumpet-shaped, and purple, pink, blue, or white. There will be 1 to 4 eighth-inch, triangular-shaped brown or grey seeds or nutlets formed in the calyx of each flower that tend to shatter as the plant matures. Echium seed contains between 20% and 25% oil that is high in multiple omega-3 and omega-6 fatty acids and low in saturated fats, making it a high-quality edible oil. High levels of omega-3 fatty acids (linolenic) have been shown to reduce LDL-cholesterol levels in the blood and are good for heart and cardiovascular health. The oil is made up of major fatty acids, some of which are considered essential fatty acids as they can't be synthesized by the body but must come from the diet. According to Technology Crops International (2011b), echium seed contains the following ranges of mono- and polyunsaturated essential fatty acids: 6% to 8% palmitic acid; 2% to 3% stearic acid; 10% to 15% oleic, an omega-9 fatty acid; 10-15% linoleic, an omega-6 fatty acid; and 30% to 35% alpha linolenic acid plus 10% to 15% gamma linolenic acid, omega-3 fatty acids. Because of the high levels of omega-3 essential fatty acids in echium oil, it is used as a dietary supplement for cardiovascular health, therapeutic skin care treatment of eczema, and in the cosmetics industry.

Echium plant tissue and pollen contain high levels of pyrrolizidine alkaloids, which are poisonous. If the plants are fed to animals it can cause weight loss and possibly death, if fed in large enough amounts. Monogastrics like horses and swine are particularly sensitive, but small ruminants like sheep and goats are less sensitive. Also, the long, white hairs on the stems of echium can cause irritation on the skin of humans, which can become a serious issue during harvest of the crop. C.C.J. Culvenor and others (1981) have determined that these alkaloids are also found in the pollen of echium. Since this crop is open pollinated, it requires insects like honeybees for complete pollination and seed set. Beekeepers should be aware of any large fields of echium within a 1-mile range (the distance insect pollinators such as honeybees would travel from their hive to a nectar and pollen source) of their hives to avoid potential contamination of the honey. If contamination is suspected, then blending with uncontaminated honey can potentially reduce the levels to acceptable minimum levels. The seed (and thus the oil) is the only portion of the plant that contains very low, nontoxic levels of these alkaloids.

Echium is native to western and southern Europe and northern Africa. Since its introduction to North America as a potential oilseed crop, it has escaped domestic cultivation and become an invasive weed in much of the southern United States. It grows best in temperate zones so the potential for it to become an invasive weed in Alaska is most likely limited to the Interior. This could cause echium to be included in the list of invasive and noxious plants for Alaska. For more information on invasive weeds in Alaska contact your local Integrated Pest Management (IPM) agent of the Cooperative Extension Service or visit the Committee for Noxious and Invasive Plants Management for Alaska (CNIPM) website at www.uaf.edu/ces/cnipm. For the abovementioned reasons, no varieties of echium are currently recommended for Alaska.

Corn Gromwell

Corn gromwell (*Buglossoides arvensis* or *Lithospermum arvense*) is also a member of the borage family. It is a spring annual, short (1 to 2 feet tall), broad-leaved, edible or industrial oilseed plant. It has hairy stems with narrow 1.5-inch long leaves. It has an indeterminate growth habit and will continue to flower until the first killing frost. The small (quarter-inch), white, open-pollinated flowers will produce 4 seeds or nutlets that are tightly held through maturity. Each seed is about one-eighth inch in diameter, tetrahedral in shape with a grey, rough and wrinkled seed coat. Similar to echium, corn gromwell seed contains between 20% and 25% oil that is high in multiple omega-3 and omega-6 fatty acids and low in saturated fats. The oil is made up of major fatty acids, some of which are considered essential fatty acids as they can't be synthesized by the body, but must come from the diet. According to Technology Crops International (2011a), Corn gromwell seed contains the following ranges of mono- and polyunsaturated essential fatty acids: 4% to 6% palmitic acid, 1% to 2% stearic acid; 5% to 8% oleic, an omega-9 fatty acid; 10% to 15% linoleic, an omega-6 fatty acid; and 35% to 40% alpha linolenic acid plus 5% to 7% gamma linolenic acid, omega-3 fatty acids. Because of the high levels of omega-3 essential fatty acids in corn gromwell oil, it could potentially be used as a dietary supplement for cardiovascular health, therapeutic skin care treatment, and in the cosmetics industry. Unlike echium, corn gromwell does not contain poisonous pyrrolizidine alkaloids.

All borage oil is obtained by a combination of expressing and extraction with a solvent. The best of the commercial oilseed presses is only capable of extracting about half of the oil contained in the seed, or about 10% to 12% by weight. Small-scale to kitchen-scale presses can only get about one-quarter of the oil in the seed, or about 5% to 6% by weight. The half to three-quarters of the oil that remains in the meal is extracted with a hexane solvent process. The solvent is then removed from the oil, which is blended in with the pressed oil and everything is run through a filtration and cleaning process.

All borage species require less fertilizer than other small-seeded oilseeds. Borage requires well-drained soils with available soil moisture levels similar to small grains and a pH of between 6.0 to 7.5. All borage types require relatively low nitrogen levels as high rates do not increase yields. Because soil moisture conditions are rarely sufficient in Alaska unless irrigation is used, most if not all nitrogen carriers should be broadcast applied. In low soil-moisture conditions, germinating seeds and seedlings can be injured by the nitrogen fertilizers. Avoid excess nitrogen fertilizer because it can induce lodging, delay maturity, and cause an increased risk of fungal attacks at harvest, especially if grown under irrigation.

Borage requires relatively low phosphorus and potassium levels as well. Because Alaska soils are generally acidic, they tend to fix phosphorus, making it unavailable for plant uptake, so banding the phosphorus carrier with or next to the seed at planting would not help increase the level of available phosphorus. The small seed is planted shallowly, where soil moisture is usually less than optimum, and which renders the phosphorus unavailable for plant use. Thus, phosphorus and potassium fertilizers should be broadcast with the nitrogen fertilizers.

Sulfur and boron are needed by all borage to promote flowering and seed set. Soils low in available sulfur should have sulfur broadcast as ammonium sulfate or as potassium sulfate. An application rate of 0.5 pound per acre of actual boron is sufficient to correct most soil deficiencies. A ratio of 1:1:1:0.5 of N, P_2O_5, K_2O, and S have produced acceptable yields of borage. With irrigated farming practices, the ratio should be reduced to about 0.5:0.5:0.5:0.25. Actual percentages of all nutrients and the application rates vary according to the specific soil test results. All fertilizer must be broadcast prior to spring tillage.

Choice of the field for borage production is important. Borage production should follow a year of summer fallow to help reduce the likelihood of plant disease, broad-leaved weeds, and other oilseed volunteers or planted in a rotation following a grain crop like barley. This also increases available soil moisture and reduces the amount of fertilizer required. To conserve soil moisture, minimum tillage is recommended for incorporating fertilizer and plant residue and preparing the seedbed. Pulling a packer behind the tillage implement and using a seed drill equipped with press wheels ensure that the seed is in contact with moist soil during germination. If the crop is to be grown under irrigation, the soil should be irrigated sufficiently to bring the soil moisture levels to close to the maximum water-holding capacity before tillage. It is very important not to irrigate above the maximum water-holding capacity before tilling and planting, as this could cause a soil crust to form on the surface that would impede seedling emergence, reduce plant density, and lower seed yields. Seeding depth is shallow, 0.5 to 1 inch, or to moisture. Seeding deeper than 1.5 inches may result in delayed germination and emergence. A seeding rate of 15 pounds per acre of pure live seed is recommended for seed and oil production. Heavier seeding rates produce thicker stands that ripen more uniformly and reduce the possibility of green seeds at harvest. Planting as early as possible to avoid loss of important soil moisture and use as much of the short growing season as possible is recommended. Use of certified seed is strongly recommended. Certified seed has strict limits on maximum content of weed seeds and diseased seed, and must meet a minimum percent germination. This helps to ensure good germination and emergence, and reduces weed and disease infestations.

Similar to all small-seeded oilseeds, irrigation should begin again after the crop has reached about 50% emergence to avoid any problems with emergence from too hard a crust on the surface. Thereafter, a good range of irrigation plus precipitation is around 0.5 to 1.0 inch per week. Irrigation should continue until the crop has reached the 50% flowering growth stage.

Using IPM techniques, assess each field for all pests (weeds, diseases, and insects) and plan control measures accordingly. Weed control in borage is extremely important. All borage species need warm soil (50°F) to germinate and don't compete well with weeds. The same weeds that are a problem for all oilseeds also compete with borage. The best weed control is a combination of mechanical and chemical summer fallow to reduce the number and species of weeds for the following season. In the spring, wait for weeds to germinate, then perform seedbed tillage using appropriate fertilization and seeding rates. There are no herbicides registered for use on borage in Alaska. To eliminate both grassy and broad-leaved weeds, a broad-spectrum, nonselective, post-emergence herbicide such as glyphosate (Roundup) can be used in a chemical fallow rotation.

The same fungal diseases that attack canola and mustard seed and seedlings, causing damping-off, downy mildew (*Peronspora parasitica*), and root rot also attack borage. They cause seed decay and seedling blight, resulting in delayed emergence and eventual uneven stands. Cool, wet soil conditions in the spring favor development of seedborne fungal attacks. Sclerotinia, or white mold fungus (*Sclerotinia sclerotiorum*), infects the base of the plant, causing wilt. This fast-acting disease often takes only 4 to 7 days from the first appearance to complete wilting. Cool, wet soil conditions in the spring and infected plant residue from the previous year can promote development of this fungal disease. It can spread from plant contact and through airborne spores. Control is through crop rotation and certified seed as there are no registered fungicides for use on borage in Alaska. Sunflowers, canola, and mustards are also susceptible to this disease and should not be used in the crop rotation.

Like mustards, borage is susceptible to many different kinds of insect pests, many of which can cause serious yield losses and thus require control measures. The red turnip beetle (*Entomoscelis americana* Brown) has recently become a pest in Alaska. The adult beetle is bright red with 3 black stripes down the back and a black patch behind the head. The larva feed on the leaves in late May to early June and the adults feed on the leaves in late June to early July, often causing total defoliation in heavy infestation years. After feeding for several weeks, the beetle burrows into the soil and becomes inactive for a 2-week summer hibernation period. The beetles re-emerge in August and continue feeding until killed by early frosts. A control measure that works well is to increase the number of years between growing any other oilseed crop in the same fields. Other cultural practices such as weed control and volunteer oilseed control are also recommended to reduce red turnip beetle populations. There are no registered insecticides for borage in Alaska. Contact your local Cooperative Extension Service for more information on pest control (see Appendix 1 for addresses and contact information). No borage types are the preferred oilseed by songbirds or migratory waterfowl.

Borage, like canola and mustards, ripens from the bottom of the plant to the top. After physiological maturity the lower leaves turn yellow. Since all borage is indeterminate it will flower until the first hard frost. Total maturity is usually when 80% to 90% of the flowers have dropped off the plant. When two-thirds of the seeds, held in the calyx after the flowers drop off, have turned grey, harvest can begin. There are still green seeds in the remaining flowers near the tips of the side branches and at the top of the plant. Average seed moisture content at this stage is about 15% to 20%. Borage is usually swathed prior to combining to dry down the plant material and make combining easier and reducing shatter loss. After a heavy precipitation event, standing borage dries better than swathed borage in windrows. Swathing too early reduces overall yields and oil content, while swathing too late increases shatter loss. Windrows can become very lightweight as the crop dries down. These light windrows can then be blown around by even a slight breeze, spreading the plants out and shattering seed pods, resulting in a significant yield reduction.

Combining either the swathed or standing borage can begin when the seed has around 10% to 15% moisture content. Seed shatter is variable for borage depending on the particular species, high for echium and low for corn gromwell. To reduce the loss of seed due to shatter, set the header reel height to just at the top of the crop or windrow and slow down the reel speed. The header should be set high if combining standing borage to just below the lowest flower branch. Reduce cylinder speed to that used for canola and mustards. Depending on the type of borage, concave clearances should be the same as used for canola for plants with small amounts of plant material like corn gromwell. However, they should be increased slightly because of the greater volume of plant material of echium to about 1.5 inches at the front and 1 inch at the back. These settings can be reduced later only if the plant tissue is dry enough to thresh out properly. This will reduce the chance of over-threshing and causing cracked seeds and excess plant material in the hopper. To avoid blowing the seed out with the chaff, reduce the fan speed to about half of that used for canola. The cleaning action for borage seed relies more on shaking action than on air flow. Top screens should be between a one-fourth and one-third inch and the bottom screens between one-eighth and one-fourth inch. Care must be taken to seal up all small holes and cracks in the combine, augers, trucks, and bins as the seed is small and so it leaks out easily. Equip the combine with a straw chopper and spreader to evenly distribute the plant material.

Typical grain dryers have perforated floor openings that are too large for the small seeds. A 5-mesh nylon sheet over the floor prevents seed loss. Borage seed should be recleaned, dried to about 9% moisture and cooled to between 60°F and 40°F before storage. Any green or moist material can cause molds to form, reducing the quality of the oil as well as the germination ability of the seed. Aeration from the bottom up through the bin with supplemental heat to drive off excess moisture is the usual first step. Do not heat the seed above 110°F because this causes a reduction in germination ability. The seed should be cooled immediately after drying to between 60°F and 40°F. Temperatures and moisture content of the seed in the bin should be checked every day for a week after harvest, then every week after that. Repeat the aeration and drying if needed, because seed can spoil quickly in storage.

Like mustards, borage is considered a marginal crop for Alaska. In good years with adequate soil moisture and GDD, all borage will still have uneven ripening resulting in a high percentage of green seed at harvest. This is due to any immature seed that was killed by fall frost. Any seed killed by frost does not continue to ripen and remains green. Green seed are immature seed that contain chlorophyll, which imparts a green color to the oil and shortens the shelf life by turning rancid quickly. There is an increasing interest in Alaska in producing an oilseed crop for both the edible oil and industrial and biofuel markets. Any seed grown for these markets should be grown on contract with a processing facility, because a high-quality seed lot is required. Unfortunately, there is currently no large-scale facility in Alaska to process oil from borage seed for either the edible oil or industrial and biofuel oil markets. Also, there are no elevators in Alaska currently set up to take borage seed. However, there are a few on-farm, small-scale oilseed presses set up to extract oil without the secondary chemical extraction.

All borage varieties are later-maturing than the Polish canola or mustard varieties. As a result, there are no varieties that have been tested in Alaska that produce consistent yields. For this reason, no borage varieties are generally recommended. However, just because there was a crop failure for this study does not mean that it might not be successfully grown somewhere within the state. Therefore, the reader is not discouraged from trying any of the borage varieties not recommended, but the probability of success in attempting to produce these crops will likely be low.

Yields by Location for Borage

All borage seed is bought and sold by weight. Similar to other oilseeds, there is a standard test weight for borage seed that is used as the legal unit for purchase or sale of the crop. This standard test weight for clean, dry, and undamaged borage seed is 43 pounds per bushel. Other than test weights, additional samples should be taken on farm to determine quality. Any seed lots not meeting high quality standards should be used as lower seed grades. It is important then for the producer to clean and size all seed lots before delivery to a niche market. Test weights are used here as a measure of seed quality to determine maturity. Yields are expressed here in pounds per acre and bushels per acre. Determine bushels per acre by dividing the yield of any specific cultivar by the standard test weight.

Table 116 lists yields and quality measurements for borage seed varieties for the Fairbanks test location. There were no irrigation trials done on borage. The table also contains information on the years it was tested. Maturity in this study was defined as when 50% of the seed for each plot were a grey color. Growing degree days (GDD) for average maturity were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. The low temperature point for borage in this report is the freezing point of water, 32°F. The GDD calculations for each day were then added to the preceding GDD value to determine the date at which the specific variety had reached 50% maturity. Differences between varieties in the average GDD at maturity in relation to the average maturity date are due to differing years of testing. All varieties were compared with 'Reward' Polish canola as the standard variety. Yield as a percent of the standard variety 'Reward' were determined by dividing the average yield of each variety by the average yield of 'Reward'. Maturity vs. Std. (Standard variety) are the number of days each variety took to reach 50% maturity either before or after the number of days that 'Reward' reached 50% maturity. Estimated oil yield data is based on the assumption of extracting about half of the oil contained in the borage seed, or about 12% by weight, through the primary pressing process and not the secondary chemical extraction process. Therefore, the seed yield in pounds per acre times 12% equals the oil yield in pounds per acre. The density of all borage oil is 7.66 pounds per gallon. This number is used to convert the oil yield in pounds per acre into gallons of oil per acre. There was no animal feed nutritional analysis done on borage seed.

Table 116. Average yields and quality measurements for all borage varieties from test plots in the Fairbanks area.

Borage Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Oil Yield (gal/acre)	Seed Test wt. (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Edible and industrial oilseed, spring											
Corn Gromwell	England	1	198	5	13	3	23	95	15-Aug	1	2485
Purple Viper Bugloss	North Carolina	1	558	13	37	9	23	95	15-Aug	1	2485

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. All varieties were compared with 'Reward' Polish canola as the standard variety.

Meadowfoam

Industrial Meadowfoam Oilseed

Meadowfoam (*Limnanthes alba* Hartw.) is a small broad-leaved annual oilseed plant that only grows 4 to 12 inches tall. It has very weak stems and so does not stand without lodging. The leaves grow in a rosette form and are long and segmented into pairs of leaflets along the midrib. Leaflets are light green and covered with a shiny wax layer. The flowers are borne on separate stems that grow up through the middle of the rosette. They are numerous, small, and white. The back of the buds are covered with many fine hairs. Meadowfoam is open-pollinated and requires insects for successful pollination and seed formation. At maturity, there are 3 seeds or nutlets per flower bud. Seeds are small (one-eighth inch diameter), round, elongated, and mottled brown. They can be smooth to wrinkled and rough with broad ridges. The seed contains 25% to 30% oil and about 20% protein. The oil is obtained through a combination of expressing and extraction with a solvent similar to that used for linseed and sunflower oils. The best of the commercial oilseed presses is only capable of extracting about half of the oil contained in the seed, or about 12% to 15% by weight. Small-scale to kitchen-scale presses can only get about one-quarter of the oil in the seed, or about 6% to 7% by weight. The half to three-quarters of the oil that remains in the meal is extracted with a hexane solvent process. The solvent is then removed from the oil, which is blended in with the pressed oil, and everything is run through a filtration and cleaning process. According to M. Walsh (2007), this unique oil is 90% to 95% long-chain (20 to 22 carbon atoms) unsaturated fatty acids, so it can be used on metal surfaces that are exposed to high variations in pressure and temperature without breaking down. The liquid wax esters are used in plastics production and as base oils in cosmetics and pharmaceuticals. The remaining meal from the extraction process contains high levels of glucosinolates and phytoecdysteroids and can only be used sparingly as a ruminant livestock feed. Like canola and mustard residues, the glucosinolates in meadowfoam have an allelochemical effect, inhibiting growth of some species of subsequent crops, weeds, nematodes, insects, and soilborne plant diseases. Research is ongoing in the Pacific Northwest to determine the effectiveness of meadowfoam meal residues as an organic pest control for the horticultural industry.

As a winter annual, meadowfoam grows naturally along gravelly stream banks in the Sierra Nevada foothills of California. It requires well-drained soils with available soil moisture levels similar to small grains and a pH of 5.6 to 6.0. Meadowfoam germinates well at 40°F and requires cool growing season temperatures of between 50°F and 65°F. High growing season temperatures and drought conditions severely reduce yields.

Fertilization and tillage practices are similar to those for other small-seeded oilseed crops. Meadowfoam is lower-yielding than other oilseed crops like canola, but it grows better under dryer soil conditions. It requires lower levels of available nitrogen to produce an acceptable crop but competes better against weeds if sufficient nutrients are present. Soils with low-to-moderate levels of available nutrients should receive a complete fertilizer blend of nitrogen, phosphorus, potassium, and sulfur at a ratio of 1:1:0.5:0.5 N, P_2O_5, K_2O, and S. With irrigated farming practices, the ratio should be reduced to about 0.5:0.5:0.25:0.25. Boron helps to induce flowering and should be applied at 0.5 pound per acre. Actual percentages of each nutrient and the application rate varies according to specific soil test results. The fertilizer can be broadcast before spring tillage. Meadowfoam does not usually respond to high levels of available nutrients, especially under dryland conditions. Following summer fallow, fertilization may not be required. Avoid excess nitrogen fertilizer, greater than 45 pounds of available N per acre, because it can delay maturity, especially if grown under irrigation.

To conserve soil moisture, minimum tillage is recommended for incorporating fertilizer material and plant residue and preparing the seedbed. Seedbed preparation is extremely important as a firm seedbed is needed to ensure seed contact with moist soil. Pulling a packer behind the tillage implement and using a seed drill equipped with press wheels ensure that the seed is in contact with moist soil during germination. If the crop is to be grown under irrigation, the soil should be irrigated sufficiently to bring the soil moisture levels close to the maximum water-holding capacity before tillage. It is very important not to irrigate above the maximum water-holding capacity before tilling and planting, as this could cause a soil crust to form on the surface that would impede seedling emergence, reduce plant density, and lower seed yields. Regular grain drills must have the drill speed reduced with a reducer sprocket due to the small seed size. Other options would be to use a grass seed attachment or horticultural vegetable seeder. Because of the small seed size, seeding depth is only 0.25 to 0.5 inch. The seeding rate for meadowfoam is 25 to 30 pounds of pure live seed per acre. Higher seeding rates help to reduce competition from weeds. Meadowfoam requires a long growing season in Alaska. An early planting date is therefore recommended to use as much of the growing season as possible. Certified seed is strongly recommended. Certified seed has strict limits on maximum content of weed seeds and diseased seed, and must meet a minimum percent germination. This helps to ensure good germination and emergence and reduces weed and disease infestations.

As with other oilseeds, irrigation should begin again after the crop has reached about 50% emergence to avoid any problems resulting from too hard a crust on the surface. Thereafter, a good range of irrigation plus precipitation is around 0.5 to 1.0 inch per week. Irrigation should continue until the crop has reached the 50% flowering growth stage.

Using IPM techniques, assess each field for all pests (weeds, diseases, and insects) and plan control measures accordingly. Weed control in meadowfoam is extremely important. Even though it germinates well in cool soil temperatures, when young it does not compete well with weeds. Best weed control is a combination of mechanical and chemical summer fallow to reduce the number and weed species for the following season and using proper fertilization and seeding rates. To eliminate all weeds with chemical fallow, a broad-spectrum, nonselective, post-emergence herbicide such as glyphosate (Roundup) can be used. There are no herbicides registered for use on meadowfoam in Alaska. There are no insect pests reported for meadowfoam in Alaska. However, it is susceptible to the botrytis head rot fungus, *Botrytis cinerea*. This gray mold works its way through the plant, infecting the seed before it is dry enough to harvest. Sunflowers are also susceptible to this fungus and should not be grown in rotation with meadowfoam. There are no registered fungicides for meadowfoam in Alaska. Contact your local Cooperative Extension Service for more information on pest control (see Appendix 1 for addresses and contact information). Meadowfoam is not preferred as an edible oilseed by songbirds or migratory waterfowl.

Meadowfoam is ripe and ready to harvest when the flower buds are completely brown and the seed has turned a mottled brown. At this stage the seed heads shatter easily. Direct combining or swathing into windrows can cause 16% to 54% seed loss due to shattering. Combine ground speed should be slower than that for other oilseed crops. The leaves do not dry quickly even at maturity and can wrap around the cylinder inside combines, impeding the combining process by causing delays to clean out the plant residues. Concave clearances must be opened to accommodate the thicker plant residues. Therefore, using grass seed stripper headers is recommended. Cylinder speeds and air flow should be reduced to avoid seed loss. Canola screens should be used for maximum seed separation from dirt and chaff. Even so, combined seed contains excess chaff and other plant residues. This material attracts moisture, molds, and insects and should be removed before grain drying. On-farm seed cleaning before shipment results in higher prices paid to the producer. Because of the small seed size, all cracks and holes in the combine, augers, trucks, and bins should be sealed to prevent seed loss during handling. Optimum moisture content for safe long-term storage of meadowfoam is 9%. Typical grain dryers have perforated floor openings that are too large for the small seed size of meadowfoam. A 5-mesh nylon sheet over the floor prevents seed loss.

Meadowfoam is considered to be a marginal crop for Alaska. Even in the best years there were not enough GDD to produce mature seed at harvest. There is an increasing interest in Alaska in producing an oilseed crop for the industrial oil and biofuel markets. Seed grown for the industrial oil markets should be grown on contract with a processing facility. Currently, there is no facility in Alaska to process oil from meadowfoam seed and no elevators are set up to accept meadowfoam seed. No varieties that have been tested in Alaska have consistently produced a viable crop. Due to these cultural problems, no meadowfoam varieties are generally recommended. However, just because there was a crop failure for this study does not mean that it might not be successfully grown somewhere within the state. Therefore, the reader is not discouraged from trying any of the meadowfoam varieties not recommended, but the probability of success in attempting to produce these crops will likely be low. The primary purpose of testing these varieties in this study was for oilseed yield and not as a bio-fumigant so there is no data on the effectiveness of the biomass for weed or insect control.

Yields by Location for Meadowfoam

There is no established standard test weight for meadowfoam. Higher prices are paid to the producer for the oilseed-grade niche crop but only if they meet the quality criteria established by the industry. Samples should be taken on farm to determine quality. Any seed lots not meeting high-quality oilseeed standards should be used as lower-grade seed. It is important, then, for the producer to clean and size all seed lots before delivery to a niche market. Yields are expressed here in pounds per acre. Typical yields for meadowfoam can range from 800 to 1,500 pounds per acre.

Tables 117 and 118 list yields and quality measurements for 1 meadowfoam variety for 2 test locations: Fairbanks and Delta Junction. All sites in the Delta Junction area have been combined into the Delta dryland site (Table 118). There were no irrigation trials done for meadowfoam. Each table also contains information on the source or the location where it was bred and the years it was tested at each location. Maturity in this study was defined as when 50% of the flower bracts for each plot were brown. Growing degree days (GDD) for average maturity were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. The low temperature point for meadowfoam in this report is the freezing point of water, 32°F. The GDD calculations for each day were then added to the preceding GDD value to determine the date at which the specific variety had reached 50% maturity. All varieties were compared with 'Reward' Polish canola as the standard variety. Yield as a percent of the standard variety 'Reward' were determined by dividing the average yield of each variety by the average yield of 'Reward'. Maturity vs. Std. (Standard variety) are the number of days it took each variety to reach 50% maturity either before or after the number of days that 'Reward' reached 50% maturity. Estimated oil yield data is based on the assumption of extracting about half of the oil contained in the seed, or about 15% by weight, through the primary pressing process and not the secondary chemical extraction process. Therefore, the seed yield in pounds per acre times 15% equals the oil yield in pounds per acre. The density of meadowfoam oil is 7.60 pounds per gallon. This number is used to convert the oil yield in pounds per acre into gallons of oil per acre. True maturity was not reached for any variety due to severe weed competition and seasonal frosts, so the recorded maturity date was the date of the first killing frost. There was no animal nutrition analysis done on meadowfoam seed.

Table 117. Average yields and quality measurements for all meadowfoam varieties from test plots in the Fairbanks area.

Meadowfoam Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Oil Yield (gal/acre)	Seed Test wt. (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Industrial oilseed, spring											
Foamore	Oregon	1	300	N/A	20	6	0	100	28-Sep	43	3199

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. N/A = Not Applicable. All varieties were compared with 'Reward' Polish canola as the standard variety.

Table 118. Average yields and quality measurements for all meadowfoam varieties from test plots in the Delta Junction area, dryland site.

Meadowfoam Variety Name	Source	Years Tested	Seed Yield (lbs/acre)	Seed Yield (bu/acre)	Seed Yield (% of Std.)	Oil Yield (gal/acre)	Seed Test wt. (lbs/bu)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Industrial oilseed, spring											
Foamore	Oregon	1	1340	N/A	88	26	0	100	30-Sep	47	3072

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. N/A = Not Applicable. All varieties were compared with 'Reward' Polish canola as the standard variety.

Jerusalem Artichoke

Tuber and Forage Sunchoke

The Jerusalem artichoke or sunchoke *(Helianthus tuberosus* L.) is a 6-foot-tall, broad-leaved plant more closely related to wild sunflowers than to the true artichoke. The artichoke name came from the taste of sunchoke tubers, which resemble the taste of the edible bracts of the true artichoke. Sunchokes are a long-season, short-day crop. Flowers and tubers do not form until the shorter days of late August. Since the tops are killed by a frost before harvest, this does not leave much time for tuber development. The tubers are small, oval, and irregular-shaped, weighing 1 to 5 ounces when mature. They can be white, yellow, or red-skinned and are thinner-skinned than potatoes. In the ground, tubers can survive Alaska winters quite well, and because it is difficult to retrieve all the tubers at harvest, the plant can establish itself as a perennial crop or as a weed.

The primary use of the tubers is human food. They are similar to potatoes in composition but contain no starch. The carbohydrates in sunchokes are mostly several polysaccharides that hydrolyze into a sugar called levulose. Levulose is sweeter than cane sugar and is often prescribed for diabetics. The tubers themselves turn watery when cooked and are low in digestibility. The tops, when harvested before flowering and tuber formation, are suitable forage for livestock. After tuber harvest they become woody and unpalatable. The entire plant can also be used in the fermentation and distillation of alcohol for fuel.

Fertilization and tillage practices are similar to those for potato production. Sunchokes require low levels of available nitrogen and high levels of available phosphorus and potassium to produce an acceptable tuber crop. Sufficient soil nutrients result in improved competition against weeds and higher yields. Soils with moderate levels of available nutrients should receive a complete fertilizer blend of nitrogen, phosphorus, potassium, sulfur, and boron. A ratio of 2:1:1:0.5 of N, P_2O_5, K_2O, and S can produce acceptable yields. With irrigated farming practices, the ratio should be reduced to about 1:0.5:0.5:0.25. Sulfur and boron are needed by sunchokes to promote flowering and tuber production. Soils low in available sulfur should have a sulfate broadcast as ammonium sulfate or as potassium sulfate. An application rate of 0.5 pound per acre of actual boron is sufficient to correct most soil deficiencies. Actual percentages of each nutrient and the application rate vary according to specific soil test results. The fertilizer can be broadcast before spring tillage, or portions can be banded at planting. Liming soil pH to around 6.5 increases tuber sugar content. Because sunchokes do better in areas of high available soil moisture, irrigation is recommended for complete nutrient utilization in both tuber and forage production. Avoid excess nitrogen fertilizer that can delay maturity, especially if grown under irrigation. There is a greater yield response to increases in phosphorus applications but little response from any increase in potassium applications. Alaska soils are generally acidic, which tends to make phosphorus unavailable for plant uptake. Banding the phosphorus carrier with or next to the seed at planting increases the available phosphorus.

To conserve soil moisture, minimum tillage is recommended for incorporating fertilizer material and plant residue and preparing the seedbed. Pulling a packer behind the tillage implement ensure that the seed tuber is in contact with moist soil during sprouting. If the crop is to be grown under irrigation, the soil should be irrigated sufficiently to bring the soil moisture levels close to the maximum water-holding capacity before tillage. It is very important not to irrigate above the maximum water-holding capacity before tilling and planting as this could cause a soil crust to form on the surface that would impede seedling emergence, reduce plant density, and lower yields. Seeding depth is 4 inches and the seeding rate for sunchokes is 300 to 1,300 seed tubers per acre in rows 3.5 to 5 feet apart. Seed tubers should be 2 to 3 ounces, either cut or whole. Large pieces of tubers produce more stems but not larger tubers. An early planting date is recommended so as to use as much of the growing season as possible. Certified seed tubers are strongly recommended. Certified seed tubers have strict limits on maximum content of weed seeds and diseased seed pieces and must meet a minimum sprouting percentage. This helps to ensure good stand development and reduces weed and disease infestations. Unlike potatoes, sunchokes do not need to be hilled during the growing season.

For maximum tuber production sunchokes should be irrigated. As with sunflowers, irrigation should begin again after the crop has reached about 50% emergence to avoid any problems with emergence from too hard of a crust on the surface. Thereafter, a good range of irrigation plus precipitation is around 1 to 2 inches per week. Irrigation should continue until the crop has reached the 50% flowering growth stage.

Using IPM techniques, assess each field for all pests (weeds, diseases, and insects) and plan control measures accordingly. The best weed control is a combination of mechanical and chemical summer fallow to reduce the number and species of weeds for the following season and cultivation between rows from spring through early fall. To eliminate all weeds with chemical fallow, a broad-spectrum, nonselective, post-emergence herbicide such as glyphosate (Roundup) can be used. There are no herbicides registered for sunchokes in Alaska. By midsummer, the plants are large enough to shade out weeds within the rows. Control of sunchokes as volunteer weeds involves mechanical summer fallow when the plants are about 1 foot high. This may take multiple seasons because the tubers can survive in the ground over several winters. Sunchokes suffer from the same diseases that attack sunflowers. The most prevalent is sclerotinia or white mold fungus (*Sclerotinia sclerotiorum*), a fungal stem rot that causes wilting, but it is not serious enough in Alaska to be of economic importance. Downy mildew (*Peronspora parasitica*) and root rot cause seed decay and seedling blight with delayed emergence and eventual uneven stands. Grasshoppers, including the lesser migratory grasshopper (*Melanoplus sanguinipes* Fabricias), the northern grasshopper (*Melanoplus borealis* Fieber), and the clear-winged grasshopper (*Camnula pellucida* Scudder), can attack the young vegetative portion of sunchokes, and voles often eat portions or whole tubers that are close to the soil surface; neither occur severely enough to affect crop yields. Contact your local Cooperative Extension Service for more information on pest control (see Appendix 1 for addresses and contact information).

Sunchoke stems and leaves are thick and high in moisture content, even late into the season. As the plant reaches maturity, lower leaves start to turn brown and curl, while the plant's upper portion remains green. It often takes a killing fall frost followed by sufficient good weather to dry. Digging for tubers is done with a potato digger modified to keep from losing the small tubers. Since the skins are thinner than those of potatoes, extra care should be taken in handling tubers. For safe, long-term storage, they are best kept in cold storage at 41° to 42°F and at 90% to 95% relative humidity.

Sunchokes are also used as a forage crop for livestock. Therefore, large ungulates like moose and bison can also cause serious damage to the crop. A single moose or a cow and calf pair usually don't cause much damage to large fields but can wipe out small-scale plots in the fall. They are attracted to mature plants, which have significant energy contained in the stalks. In the Delta Junction area, bison congregate in large herds that don't usually cause serious damage until their fall migrations north of the Alaska Highway. This migration occurs during the time when the sunchokes are mature and ready for harvest. The bison will not only eat large portions of the crop but a large herd walking through or bedding down in the field can flatten the crop into the ground making harvest impossible. It is illegal to harass wildlife in Alaska, so the only control is to erect large (6 feet or higher), stout, highly visible fencing that can direct the animals around the fields. For more information on wildlife control in agricultural fields, contact the local office of the Alaska Department of Fish and Game.

Producing sunchokes for tubers in Alaska is problematic. It is a long-season crop that needs short days with a dark period to set tubers. This often does not occur before the first killing frost. Harvest is difficult due to the thick plant material and small tuber size. Although there is a small health food niche market for sunchoke tubers that commands a high price paid to producers, no sunchoke processing facilities for either tuber or biomass for alcohol production presently exist in Alaska. Because of the high cost of production and the unlikelihood of consistently producing a high-quantity, high-value crop, it is not an economically viable crop for Alaska. Because of their cultural problems, no varieties of sunchokes are generally recommended. However, just because there was a crop failure for this study does not mean that it might not be successfully grown somewhere within the state. Therefore, the reader is not discouraged from trying any of the sunchoke varieties not recommended, but the probability of success in attempting to produce these crops will likely be low.

Yields by Location for Tuber and Forage Sunchoke

Table 119 lists yields and quality measurements for a sunchoke variety for the Fairbanks test location. The table also contains information on the source or the location of where it was bred, biomass yields, and the years it was tested. Maturity in this study was defined to be after the first killing frost. Growing degree days (GDD) for average maturity were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature. The low temperature point for sunchokes in this report is the freezing point of water, 32°F. The GDD calculations for each day were then added to the preceding GDD value to determine the date at which the specific variety had reached 50% maturity. True maturity was not reached for this variety due to the long growing season requirement. Tubers, however, are usually harvested after the top growth has been removed or killed by frost. Therefore, the recorded maturity date was the date of the first killing frost after which the tubers were harvested. The test was for 2 years. However, there were mature tubers produced each year because the plant came up as a volunteer weed for 3 years after the initial test. There are no standard varieties for sunchokes in Alaska, so there were no comparisons with other varieties. There was no animal nutrition analysis done on the sunchoke biomass.

Table 119. Average yields and quality measurements for all sunchoke varieties from test plots in the Fairbanks area.

Sunchoke Variety Name	Source	Years Tested	Tuber Yield (lbs/acre)	Biomass Yield (lbs/acre)	Lodging (%)	Average Maturity Date	Maturity vs. Std. (days)	Average Maturity (GDD)*
Tuber & forage								
Sunchoke	Illinois	2	997	52,005	0	25-Sep	0	3180

*Growing degree days for average maturity (GDD) were calculated by subtracting a standard low temperature at which the crop can no longer grow from the average daily temperature.

References and Additional Reading

Note: in the following references, the Alaska Agricultural and Forestry Experiment Station is abbreviated AFES, the Alaska Cooperative Extension Service (now known as the University of Alaska Fairbanks Cooperative Extension Service) is abbreviated ACES, and the University of Alaska Fairbanks is abbreviated UAF.

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Appendix 1: Addresses

Seed Suppliers

Agricore United – Winnipeg
P.O. Box 6600
2800 – 201 Portage Ave.
Winnipeg, Manitoba R3C 3A7 Canada
phone: (204) 944-5555
fax: (204) 944-5415
e-mail: infomaster@agricoreunited
website: www.agricoreunited.com (see also Viterra)

Alaska Farmers Co-Op
Elevator and Fertilizer
P.O. Box 447
Delta Junction, Alaska 99737
phone: (907) 895-4645
fax: (907) 895-4263

Alaska Plant Materials Center
Department of Natural Resources - Division of Agriculture
5310 South Bodenburg Loop Spur
Palmer, Alaska 99645
phone: (907) 745-4469
fax: (907) 746-1568
website: http://plants.alaska.gov/

Alaska Seed Growers Association
Box 895
Palmer, Alaska 99645
phone: (907) 745-4004
fax: (907) 745-4728

Bonis and Company, Ltd.
P.O. Box 217
Lindsay, Ontario K9V 5Z4 Canada
phone: (705) 324-0544
fax: (705) 324-2550
e-mail: sloffice@seed-link.ca
www.seed-link.ca

Brewers and Malting Barley Research Institute
612 – One Lombard Place
Winnipeg, Manitoba R3B 0X3
PO Box 1497 Station Main
Winnipeg, Manitoba R3C 2Z4 Canada
phone: (204) 927-1407
fax: (204) 927-5960
e-mail: info@bmbri.ca
website: www.bmbri.ca

Canadian Seed Growers Association
Stock Seed Distribution Committee
Box 8455
Ottawa, Ontario K16 3T1 Canada
phone: (613) 236-0497
fax: (613) 563-7855
website: www.seedgrowers.ca

Canterra Seeds
201 – 1475 Chevrier Boulevard
Winnipeg, Manitoba R3T 1Y7 Canada
phone: (204) 988-9750
fax: (204) 487-7682
info@canterra.com
website: www.canterra.com

Crop Diversification Centre South
Agriculture and Rural Development
301 Horticultural Station Road, East
Brooks, Alberta T1R 1E6 Canada
phone: (403) 362-3391
fax: (403) 362-2554
www.agriculture.alberta.ca

Crop Production Services (see also Proven Seed)
PO Box 5234 Station Main
High River, Alberta T1V 1M4 Canada
www.cpsaqu.ca

Ernst Conservation Seed
8884 Mercer Pike
Meadville, Pennsylvania 16335
phone: (814) 336-2404
toll-free: (800) 873-3321
fax: (814) 336-5191
e-mail: sales@ernstseed.com
website: www.ernstseed.com

Fenton Seed Farm, Ltd.
Box 777
Tisdale, Saskatchewan S03 1T0 Canada
phone: (306) 873-5438
fax: (306) 873-3021
e-mail: sales@fentonseeds.com
website: www.fentonseeds.com

L.A. Hearne Company
8525 Prunedale North Road
Salinas, California 93907-8890
phone: 1-800-253-7346
e-mail: seedsales@hearneco.com
www.hearneco.com, www.hearneco.com/beans/
www.hearneseed.com

Montana State University
Winter Wheat Breeding Program
324A Leon Johnson Hall
P.O. Box 173140
Bozeman, Montana 59717-3140
phone: (406) 994-5059

Morden Research Station
Cereal Research Centre
Agriculture and Agri-Food Canada
101 Route 100, Unit 100
Morden, Manitoba R6M 1Y5 Canada
phone: (204) 822-7556
fax: (204) 822-7507
www.agr.gc.ca

North Dakota State Seed Department
1313 18th Street North
P.O. Box 5257
Fargo, North Dakota 58105
phone: (701) 231-5400
website: www.nd.gov/seed/

Pennsylvania State University
College of Agricultural Sciences
201 Agriculture Administration Building
University Park, Pennsylvania 16802
phone: (814) 865-2541
website: http://agsci.psu.edu/

Progressive Seeds Ltd.
155 – 4752 50th Street
Red Deer, Alberta T4N 1X2 Canada
phone: (403) 347-4925

Proven Seed (see headquarters, a.k.a. Crop Production Services)
551 Henderson Drive
Regina, Saskatchewan S4N 5X1 Canada
phone: (306) 791-7176
fax: (306) 791-7180
www.provenseed.ca

Pulse USA
2002 Northern Plains Drive
Bismarck, North Dakota 58504
phone: (701) 530-0734
toll-free: (888) 530-0734
fax: (701) 530-1826
website: www.pulseusa.com

Saskatoon Research Centre
Agriculture and Agri-Food Canada
107 Science Place
Saskatoon, Saskatchewan S7N 0X2 Canada
phone: (306) 385-9301
fax: (306) 385-9482

SeCan Association
400 – 300 Terry Fox Drive
Kanata, Ontario K2K 0E3 Canada
phone: (613) 592-8600
toll-free: (800) 764-5487
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fax: (780) 492-4265
e-mail: afns-chair@ualberta.ca
website: www.afns.ualberta.ca/

University of Manitoba
Department of Plant Science
222 Agriculture Building
66 Dafoe Road
Winnipeg, Manitoba R3T 2N2 Canada
phone: (204) 474-8221
fax: (204) 474-7528
website: www.umanitoba.ca/afs/plant_science

University of Saskatchewan
Crop Development Centre
College of Agriculture and Bioresources
51 Campus Drive
Room 4D36 Agriculture Building
Saskatoon, Saskatchewan S7N 5A8 Canada
phone: (306) 966-5855
fax: (306) 966-5015
website: http://agbio.usask.ca/research/centres-facilities/

Viterra, Inc.
2625 Victoria Avenue
Regina, Saskatchewan S4T 7T9 Canada
phone: (306) 569-4411
fax: (306) 569-4708
website: www.viterra.com

Zeneca Seeds (now part of SynGenta)
74 Third Avenue N.
Yorkton, Saskatchewan S3N 1C3 Canada
phone: (306) 782-2180

Information and Services

University of Alaska Fairbanks

School of Natural Resources and Extension
Agricultural and Forestry Experiment Station
(Interior – Fairbanks Experiment Farm and Delta Junction Field Research Site)
303 O'Neill Resources Building
P.O. Box 757200
Fairbanks, Alaska 99775-7200
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website: www.uaf.edu/snre/afes/

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1509 South Georgeson Drive
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University of Alaska Fairbanks
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308 Tanana Loop, Room 101
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Anchorage District
1675 C Street
Anchorage, Alaska 99501
phone: (907) 786-6300
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Delta Junction District
Jarvis Building, 1402.5 Alaska Highway
P.O. Box 349
Delta Junction, Alaska 99737
phone: (907) 895-4215

Juneau District
Public Safety Building
450 Whittier Street, Suite 128
P.O. Box 21266
Juneau, Alaska 99802
phone: (907) 523-3280
fax: (907) 523-3220

Kenai Peninsula District
43961 Kalifornsky Beach Road, Suite A
Soldotna, Alaska 99669
phone: (907) 262-5824
fax: (907) 262-3939

Matanuska-Susitna/Copper River District
1509 South Georgeson Road
Palmer, Alaska 99645
phone: (907) 745-3360
fax: (907) 745-6268

Northwest District/Nome
Leonard Seppala Building
Moore Way
Pouch 400

Nome, Alaska 99762
phone: (907) 443-2320
fax: (907) 443-2150

Sitka District
1332 Seward Avenue
Sitka, Alaska 99835
phone: (907) 747-9440
fax: (907) 747-7790

Tanana District
724 - 27th Avenue
Fairbanks, Alaska 99701
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Yukon-Kuskokwim District/Bethel
201 Akiak Drive
P.O. Box 368
Bethel, Alaska 99559
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State of Alaska, Department of Natural Resources

Division of Agriculture

Main Office
1800 Glenn Highway, Suite 12
Palmer, Alaska 99645
phone: (907) 745-7200
fax: (907) 745-7112
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Mt. McKinley Meat & Sausage
385 Inner Springer Loop
Palmer, Alaska 99645
phone: (907) 745-5232
fax: (907) 746-0575

Northern Region Office
3700 Airport Way
Fairbanks, Alaska 99709
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fax: (907) 328-1951

Alaska Plant Materials Center
5310 South Bodenburg Loop Spur
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phone: (907) 373-7923
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e-mail: aacd@mtaonline.net (chief administrative officer)
website: www.alaskaconservationdistricts.org

Anchorage District
P.O. Box 110309
Anchorage Alaska 99511-0309
phone: (907) 677-7645
e-mail: aswcd@aswcd.org
website: www.aswcd.org

Fairbanks District
590 University Avenue, Suite 2
Fairbanks, Alaska 99709
phone: (907) 479-1213
fax: (907) 374-4922
e-mail: fairbanksswcd@gmail.com
website: www.fairbankssoilwater.org

Homer District
4014 Lake Street, Suite 201A
Homer, Alaska 99603
phone: (907) 235-8177 extension 5
fax: (907) 235-2364
e-mail: info@homerswcd.org
website: www.homerswcd.org

Kenai District
110 Trading Bay Drive, Suite 160
Kenai, Alaska 99611-7716
phone: (907) 283-8732 extension 108
fax: (907) 283-9667
e-mail: kenaiswcd@gmail.com
www.kenaisoilandwater.org

Kenny Lake District
phone: (907) 259-5999
e-mail: mgr.klswcd@gmail.com

Kodiak District
518 Marine Way, Suite 206
Kodiak, Alaska 99615
phone: (907) 486-5574
fax: (907) 486-5596
e-mail: district@kodiakswcd.com
website: www.kodiaksoilandwater.org

Mid-Yukon/Kuskokwim District
P.O. Box 88
Aniak, Alaska 99557
phone: (907) 676-0396
e-mail: ihermanwork2@gmail.com
website: www.midyukonkuskokwimswcd.com

Palmer District
North Fork Center
1700 East Bogard Road, 203A
Wasilla, Alaska 99654
phone: (907) 357-1440
e-mail: jeff.smeenk@gmail.com
website: www.palmersoilandwater.org

Salcha-Delta District
Jarvis Building, 1402.5 Alaska Highway
P.O. Box 547
Delta Junction, Alaska 99737
phone: (907) 895-6279
fax: (907) 895-6278
e-mail: info@salchadeltaswcd.org
website: www.salchadeltaswcd.org

Southeast District
P.O. Box 21788
Juneau, Alaska
cell: (907) 321-4149
phone: (907) 586-6878
fax: (907) 586-7383
e-mail: districtmanager@seswcd.org
website: www.seswcd.org

Upper Susitna District
HC 89 Box 8461
Talkeetna, Alaska 99676
phone: (907) 733-7923
e-mail: usswcd@mtaonline.net
website: www.usswcd.org

Wasilla District
1700 East Bogard Road
Building A, Suite 203
Wasilla, Alaska 99654
phone: (907) 357-4363 extension 103
fax: (907) 357-4564
e-mail: wswcd@wasillaswcd.org
website: www.wasillaswcd.org

State of Alaska, Department of Environmental Conservation

Division of Environmental Health

Food Safety and Sanitation
phone: 1-87-SAFE-FOOD
website: http://dec.alaska.gov/eh/fss/index.htm

Anchorage Office
555 Cordova Street, 5th Floor
Anchorage, Alaska 99501-2617
phone: (907) 269-7501
fax: (907) 269-7510

Dutch Harbor/Unalaska Office
Intersea Mall, Suite 206
179 Gilman Road
P.O. Box 465
Unalaska, Alaska 99685
phone: (907) 581-4632
fax: (907) 581-1795

Fairbanks/Interior Office
610 University Avenue
Fairbanks, Alaska 99706
phone: (907) 451-2120
fax: (907) 451-5120

Juneau Office
410 Willoughby, Suite 303
Juneau, Alaska 99801
phone: (907) 465-5163
fax: (907) 465-5362

Kenai/Soldotna Office
43335 Kalifornsky Beach Road, Suite 11
Soldotna, Alaska 99669
phone: (907) 262-5210
fax: (907) 262-2294

Ketchikan Office
540 Water Street, Suite 203
Ketchikan, Alaska 99901
phone: (907) 225-6200
fax: (907) 225-0620

Kodiak Office
316 Mission Road, Suite 106
P.O. Box 515
Kodiak, Alaska 99615-0515
phone: (907) 486-3350
fax: (907) 486-5032

Sitka Office
901 Halibut Point Road, Suite 3
Sitka, Alaska 99835-7106

phone: (907) 747-8614
fax: (907) 747-7419

Wasilla/Southcentral Office
1700 East Bogard Road, Suite 103
Wasilla, Alaska 99654
phone: (907) 376-1850
fax: (907) 376-2382

Pesticide Control
1700 East Bogard Road, Suite 202B
phone: (907) 376-1870
fax: (907) 376-2382
toll free in Alaska: 1-800-478-2577

United States Department of Agriculture

Natural Resources Conservation Service

Alaska State Office
800 West Evergreen Avenue, Suite 100
Palmer, Alaska 99645-6546
phone: (907) 761-7760
fax: (907) 761-7790
website: www.ak.nrcs.usda.gov

Bethel Field Office*
311 Willow Street, Building 3
P.O. Box 1869
Bethel, Alaska 99559
phone: (907) 543-7155
fax: (855) 833-8625
*office visit by appointment only

Delta Field Office
1402.5 Alaska Highway
Jarvis Office Center
P.O. Box 547
Delta Junction, Alaska 99737
phone: (907) 892-4241 extension 110
fax: (855) 705-9787

Fairbanks Service Center/Northern Hub Office
590 University Avenue
Fairbanks, Alaska 99709-3661
phone: (907) 479-3159
fax: (855) 833-8625

Homer Field Office
4014 Lake Street, Suite 201A
P.O. Box 400
Homer, Alaska 99603
phone: (907) 235-8177 extension 107
fax: (855) 711-9098

Juneau Field Office
709 West 9th Street, Suite 285C
PO Box 21788
Juneau, Alaska 99802-1788
phone: (907) 586-7220
fax: (855) 711-9099

Kenai Service Center/Southern Hub Office
110 Trading Bay Drive, Suite 160
Kenai, Alaska 99611-7787
phone: (907) 283-8732 extension 100
fax: (855) 711-9097

Kodiak Field Office
518 Marine Way, Suite 206
Kodiak, Alaska 99615
*office visit by appointment only
phone: (907) 486-5598
fax: (855) 711-9098

Wasilla Service Center/Central Hub Office
1700 East Bogard Road, Suite 206
Wasilla, Alaska 99654
phone: (907) 373-6492 extension 101
fax: (855) 705-9788

Appendix 2: Metrics

English and Metric Conversions, Units of Measure, and Calculations

In international markets, small grains and oilseed are bought and sold in metric units. In U.S. markets they're bought and sold in English units. The following conversion factors will assist readers in converting from English to metric units and metric to English units.

Length

1 mile = 5280 feet = 1760 yards = 1.6 kilometers
1 kilometer = 1000 meters = 0.6 miles
1 yard = 3 feet = 0.9 meters
1 meter = 100 centimeters = 3.3 feet = 1.1 yards
1 inch = 2.54 centimeters
1 centimeter = 0.4 inch

Area

1 acre = 43,560 feet^2 = 0.405 hectares
1 hectare = 10,000 meters^2 = 2.471 acres
1 yard^2 = 9 feet^2 = 0.8 meters^2
1 meter^2 = 10,000 centimeters^2 = 10.76 feet^2 = 1.2 yards^2
1 inch^2 = 6.5 centimeters^2
1 centimeter^2 = 0.16 inch^2

Volume

1 yard^3 = 27 feet^3 = 0.76 meters^3
1 meter^3 = 35.5 feet^3
1 bushel = 2150.42 inches^3 = 8 gallons = 30.4 liters = 0.30 hectoliters
1 hectoliter = 100 liters = 0.1 meters^3 = 3.53 feet^3 = 26.4 gallons
= 2.84 bushels
1 foot^3 = 1728 inches^3 = 0.03 meters^3
1 gallon = 128 fluid ounces = 16 cups = 8 pints = 4 quarts = 3.8 liters
1 liter = 1000 milliliters = 1000 centimeters^3 = 33.6 fluid ounces
= 1.06 quarts = 0.26 gallons = 0.028 bushel
1 fluid ounce = 28.4 milliliters
1 milliliter = 1 centimeter^3 = 0.034 fluid ounces

Weight

1 ton = 2000 pounds = 20 hundred weight = 0.9 metric tons
1 metric ton = 1000 kilograms = 2204 pounds
1 pound = 16 ounces = 454 grams = 0.454 kilograms
1 kilogram = 1000 grams = 2.2 pounds
1 ounce = 28 grams
1 gram = 0.035 ounces

Standard Test Weights

Amaranth = 63 pounds/bushel
Borage = 43 pounds/bushel
Buckwheat = 48 pounds/bushel
Camelina = 50 pounds/bushel
Canarygrass = 50 pounds/bushel
Canola and Rapeseed = 50 pounds/bushel
Chickpea = 60 pounds/bushel
Crambe = 25 pounds/bushel
Feed and Malting Barley = 48 pounds/bushel
Field Pea = 60 pounds/bushel
Flax = 56 pounds/bushel
Hulless Barley = 60 pounds/bushel
Hulless Oat = 44 pounds/bushel
Mustards = 50 pounds/bushel
Oat = 32 pounds/bushel
Quinoa = 50 lbs/bushel
Rye = 56 pounds/bushel
Safflower = 45 pounds/bushel
Sunflower = 25 pounds/bushel
Triticale = 56 pounds/bushel
Wheat = 60 pounds/bushel

Rates and Yields

1 pound/acre = 1.12 kilograms/hectare
1 kilogram/hectare = 0.9 pounds/acre
1 pound/bushel = 1.287 kilograms/hectoliter
1 kilogram/hectoliter = 0.8 pounds/bushel
bushels/acre = (pounds/acre) ÷ (standard test weight)
pounds/acre = (bushels/acre) x (standard test weight)
tons/acre = (pounds/acre) ÷ 2000

Appendix 3: Agronomic Varieties

Agronomic Varieties Tested 1971-2012

The following is a complete list of all agronomic varieties tested by the agronomy program at the University of Alaska Fairbanks AFES from 1971 through 2012, (Eielson 1993-2001, Palmer 1989-2012). It includes varieties that were previously published in the "Performance of Cereal Crops in the Tanana River Valley of Alaska" series, 1978-1986, by F.J. Wooding and others (denoted by an [*] after the name). It does not include any experimental breeding lines that were tested, unless those varieties were eventually released as an officially named cultivar.

Barley growing in Palmer, Alaska

Barley

Variety Name	Source	Fairbanks	Eielson	Delta Junction	Palmer
		Number of Years Tested at Each Location			
6-row feed, spring					
AC Albright	Alberta	13	0	12	13
AC Lacombe	Alberta	3	0	2	5
AC Stacey	Alberta	3	0	1	4
Agneta	Sweden	3	0	2	6
Akka	Sweden	0	0	0	1
Amy*	Colorado	1	0	1	0
Arra*	Finland	13	1	13	6
Arve	Finland	4	0	3	6
Azure	Idaho	2	0	2	1
Bamse	Sweden	3	0	1	4
Bedford*	Manitoba	1	0	1	0
Belli*	Idaho	1	0	1	0
Bere	Scotland	1	0	0	0
Bode*	Norway	4	0	2	4
Borckilli	Finland	0	0	0	1
Brier	Saskatchewan	3	0	1	4
Brock*	Ontario	2	0	0	0
Cathy*	Idaho	1	0	1	0
Conquest*	Manitoba	2	0	0	0
Cougbar	Washington	2	0	2	1
Datal*	Alaska	19	0	18	13

Barley, continued

Variety Name	Source	Fairbanks	Eielson	Delta Junction	Palmer
		Number of Years Tested at Each Location			
Diamond*	Alberta	1	0	1	0
Delores*	Canada	1	0	1	0
Early Hannchen*	Sweden	1	0	1	0
Edda*	Sweden	11	0	8	3
Empress*	Alberta	2	0	2	0
Etu*	Sweden	1	0	1	0
Finaska	Alaska	13	0	13	15
Finnaska (Experimental)*	Finland	6	0	5	0
Flynn	Minnesota	0	0	0	1
Frontier*	Manitoba	1	0	0	0
Galt*	Alberta	9	0	9	1
Gateway 63*	Alberta	5	0	5	1
Gunilla	Sweden	0	0	0	1
Hankkija 72802*	Finland	2	0	2	0
Hankkija 673*	Finland	1	0	2	2
Hannchen*	Sweden	1	0	1	0
Heartland*	Manitoba	2	0	2	1
Hiland*	Idaho	1	0	0	0
Hyproly*	Sweden	1	0	0	0
Hyproly Normal*	Sweden	1	0	0	0
Iuzhnii	Russia	0	0	0	1

Barley, continued

Variety Name	Source	Fairbanks	Eielson	Delta Junction	Palmer
		Number of Years Tested at Each Location			
Jackson*	Alberta	4	0	4	2
Johnston*	Manitoba	2	0	2	0
Jokioinen 1103*	Finland	4	0	4	0
Jokioinen 1161	Finland	0	0	0	2
Jokioinen 1164	Finland	0	0	0	2
Jokioinen 1178	Finland	0	0	0	2
Jokioinen 1218	Finland	0	0	0	2
Jokioinen 1262	Finland	0	0	0	2
Jokioinen 1315*	Finland	4	0	4	0
Jokioinen 1465	Finland	0	0	0	2
Jokioinen 1474	Finland	0	0	0	2
Jokioinen 1490	Finland	0	0	0	1
Jokioinen 1599	Finland	4	0	3	5
Jokioinen 1632	Finland	5	0	5	6
Jubilee*	Manitoba	4	0	0	4
Karin	Sweden	3	0	1	6
Klondike*	Manitoba	1	0	2	0
Leduc*	Saskatchewan	1	0	1	0
Lidal*	Alaska	19	0	16	10
Loviisa	Finland	4	0	2	4
Lyallpur	Pakistan	0	0	0	1
Massey*	Ontario	1	0	1	0
Melvin*	Saskatchewan	4	0	5	0
Mingo*	Ontario	1	0	1	0
Nobel	Alberta	2	0	2	1
Nord	Ontario	0	0	0	2
Nordlys	Norway	3	0	1	4
Nova*	Washington	1	0	1	0
Olli*	Finland	10	0	7	4
Olsok	Norway	3	0	1	3
Onda*	Washington	1	0	1	0
Otal*	Alaska	33	6	32	25
Otra*	Finland	15	0	17	2
P 693	Norway	0	0	0	2
Paavo*	Finland	7	0	8	1
Parkland*	Manitoba	2	0	0	0
Pirkka	Finland	0	0	0	1
Pohto	Finland	4	0	3	5
Pokko*	Finland	11	1	10	4
Polaris*	Alberta	4	0	4	0
Potra	Finland	0	0	0	3
Ripa	Sweden	3	0	2	6

Barley, continued

Variety Name	Source	Fairbanks	Eielson	Delta Junction	Palmer
		Number of Years Tested at Each Location			
Samson*	Alberta	3	0	3	0
Silja	Finland	0	0	0	2
Stanka*	Bulgaria	3	0	1	0
Steptoe*	Washington	7	0	6	2
Strom*	Alberta	1	0	1	0
Suvi	Finland	0	0	0	2
Svendal*	Alaska	8	3	8	1
Tammi*	Finland	2	0	0	1
Thule	Norway	3	0	1	3
Trebi*	Turky	1	0	0	0
Trophy*	North Dakota	1	0	0	0
Unitan*	Montana	1	0	0	0
Vale 70*	Oregon	1	0	1	0
Verner	Sweden	3	0	2	3
Windsor*	Alberta	2	0	3	0
Wooding	Alaska	12	0	10	9
	6-row feed, spring, semi-dwarf				
Aappo*	Finland	1	0	1	0
Advance*	Washington	1	0	1	1
CDC Earl	Saskatchewan	1	0	1	0
Duke	Saskatchewan	1	0	1	0
Eero 80*	Finland	20	4	19	8
Kasota	Alberta	4	0	3	4
Poco*	Idaho	1	0	1	0
Stetson	Alberta	1	3	3	0
Winchester	Alberta	2	0	2	1
	2-row feed, spring				
Abee*	Alberta	2	0	2	0
Andre*	Washington	2	0	2	0
Balder*	Sweden	3	0	2	0
Bonus*	Sweden	2	0	3	0
Bowman*	North Dakota	1	0	1	1
Carlsberg II*	Denmark	1	0	1	0
Centennial*	Alberta	1	0	2	0
CDC Dolly	Alberta	1	0	2	1
Duece	Saskatchewan	3	0	3	1
Early Carlsberg II*	Denmark	1	0	1	0
Early Freja*	Sweden	1	0	1	0
Elrose*	Saskatchewan	1	0	1	0
Fairfield*	Alberta	3	0	4	0
Freja*	Sweden	1	0	1	0
Gallatin	Montana	2	0	2	1

Barley, continued

Variety Name	Source	Fairbanks	Eielson	Delta Junction	Palmer
Herta*	Sweden	1	0	0	0
HV 52*	Afganistan	2	0	2	0
Lewis	Montana	2	0	2	1
Lud*	England	2	0	2	0
Mari*	Sweden	2	0	2	0
Norbet*	Saskatchewan	1	0	1	0
Otis*	Idaho	2	0	0	0
Palliser*	Alberta	4	0	2	0
Piroline*	Idaho	3	0	2	0
Valier*	Montana	1	0	1	1
2-row feed semi-dwarf, spring					
Icelandic	Iceland	2	0	1	0
6-row hooded forage, spring					
Weal*	Alaska	28	0	24	8
2-row hooded forage, spring					
Haybet	Montana	2	0	1	1
Hayes	Montana	2	0	1	1
Weal Selection*	Alaska	1	0	1	0
6-row hulless non-waxy, spring					
CDC Buck	Saskatchewan	3	3	4	0
CDC Silky	Saskatchewan	1	0	2	1
Peregrine	Alberta	4	0	4	4
Sunshine	Alaska	10	0	10	9
Thual*	Alaska	23	4	26	13
Tupper*	Saskatchewan	2	0	2	0
6-row hulless, hooded non-waxy, spring					
Trapmar*	Alaska	3	0	0	1
6-row hulless non-waxy, semi-dwarf, spring					
Falcon	Alberta	7	0	7	6
2-row hulless non-waxy, spring					
CDC Dawn	Alberta	4	0	4	4
CDC Freedom	Alberta	2	0	2	2
CDC Richard	Saskatchewan	4	3	5	1
HB 3352	Alberta	4	0	4	4
HB 3433	Alberta	6	0	6	6
Phoenix	Alberta	4	0	4	4
Scout*	Saskatchewan	2	0	2	0
Tibet*	Tibet	5	0	3	0
6-row malting, spring					
Argyle*	Manitoba	3	0	1	3
B 1602	Colorado	1	3	7	1
Beacon*	North Dakota	1	0	1	0

Number of Years Tested at Each Location (Fairbanks, Eielson, Delta Junction, Palmer)

Barley, continued

Variety Name	Source	Fairbanks	Eielson	Delta Junction	Palmer
Bonanza*	Manitoba	3	0	3	3
Cree*	North Dakota	1	0	1	0
Dickson*	North Dakota	1	0	0	0
Dual	Colorado	1	3	3	0
Karl*	Idaho	1	0	1	0
Larker*	North Dakota	1	0	1	0
Moravian III*	Czech Republic	1	0	1	0
Morex	Minnesota	3	0	2	1
Paragon*	Manitoba	2	0	0	0
Prilar*	South Dakota	1	0	0	0
Primus II*	South Dakota	2	0	1	0
Stander	Minnesota	1	3	3	0
2-row malting, spring					
B 1202	Colorado	1	0	1	0
B 1215	Colorado	2	3	4	1
Betzes*	Montana	6	0	5	1
Crest	Washington	1	0	1	0
Ellice	Manitoba	3	0	3	1
Erbet*	Montana	1	0	1	0
Ershabet*	Montana	2	0	2	0
Fergus*	Ontario	2	0	0	0
Firlbecks III*	Germany	2	0	1	0
Galena	Colorado	1	0	1	0
Harrington*	Saskatchewan	7	3	11	7
Hector	Alberta	0	0	0	1
Klages*	Idaho	4	0	4	1
M 14	Colorado	1	0	1	0
Shabet*	Montana	5	0	6	0
Stein	Saskatchewan	0	0	0	2
Summit*	Manitoba	2	0	3	0
Triumph*	Germany	3	0	3	0
6-row feed, winter					
Dicktoo*	Nebraska	1	0	0	0
Kearney*	Nebraska	1	0	0	0

Oats

Variety Name	Source	Fairbanks	Eielson	Delta Junction	Palmer
		Number of Years Tested at Each Location			
Astro*	New York	1	0	1	0
Athabasca*	Alberta	17	4	19	4
Calibre*	Saskatchewan	10	4	11	1
Cascade*	Alberta	15	4	18	3
Cavell*	Alberta	6	0	5	0
Cayuse*	New York	6	0	5	0
Ceal*	Alaska	12	0	11	9
Cherokee*	Kansas	1	0	0	0
Chief*	South Dakota	1	0	1	0
Clark*	Oregon	1	0	1	0
Cody II*	Wyoming	1	0	0	0
Derby	Alberta	1	0	1	0
Dumont*	Manitoba	2	0	2	0
Eagle*	Sweden	3	0	3	0
Fidler*	Saskatchewan	3	0	3	0
Foothill*	Alberta	2	0	2	0
Frazer*	Manitoba	5	0	5	0
Garry*	Manitoba	2	0	1	0
Gemini*	Alberta	0	0	1	0
Glen*	Quebec	5	0	4	0
Golden Rain*	Sweden	3	0	2	0
Grizzly*	Alberta	4	0	4	0
Harmon*	Ontario	6	0	5	0
Hinoat*	Saskatchewan	0	0	1	0
Hudson*	Manitoba	4	0	3	0
Jasper*	Alberta	4	0	4	1
Kelsey*	Ontario	4	0	3	0
Larry*	Illinois	1	0	1	0
Laurent*	Quebed	2	0	2	0
Markton*	Turkey	1	0	0	0
Ogle*	Illinois	1	0	1	0
Orbit*	New York	2	0	2	0
OT 238	Alberta	2	0	2	1
OT 736*	Alberta	2	0	2	0
OT 745*	Alberta	2	0	2	1
OT 755	Alberta	2	0	2	0
Pendek*	Netherlands	12	0	12	0
Pol*	Sweden	8	0	8	1
Proat	Minnesota	1	0	1	0
Puhti*	Sweden	1	0	1	0
Random*	Alberta	6	0	5	0
Rapida*	California	1	0	0	0
Riel	Manitoba	3	0	3	1

Oats, continued

Variety Name	Source	Fairbanks	Eielson	Delta Junction	Palmer
		Number of Years Tested at Each Location			
Rodney*	Manitoba	13	0	12	0
Russell*	Ontario	2	0	1	0
Sioux*	Manitoba	4	0	3	0
Spear*	South Dakota	1	0	1	0
Toral*	Alaska	34	4	31	12
Valko*	Finland	1	0	1	0
Vicland*	Wisconsin	1	0	0	0
Victory*	Sweden	5	0	5	0
Vouti*	Finland	1	0	1	0
Woodstock*	Ontario	2	0	2	0
Red feed, spring					
Bates 89	California	1	0	2	0
Kanota	Kansas	1	0	2	0
Montezuma	California	1	0	2	0
Pert	California	1	0	2	0
Sierra	California	1	0	2	0
Black feed. spring					
Nip*	Sweden	22	1	24	3
Orion*	Sweden	2	0	2	0
Hulless, spring					
AC Belmont	Manitoba	5	0	6	5
AC Gwen	Manitoba	4	0	4	4
Equavena	Quebec	3	0	2	2
Freedom	Maine	5	4	7	1
Pennuda	Pennsylvania	4	3	4	1
Terra*	Saskatchewan	1	0	2	0
Tibor	Alberta	2	0	2	1

Wheat

Variety Name	Source	Fairbanks	Eielson	Delta Junction	Palmer
		Number of Years Tested at Each Location			
Hard red, spring					
AC Intrepid	Saskatchewan	5	0	5	4
AC Splendor	Saskatchewan	3	0	3	3
Anza*	Mexico	1	0	0	0
Benito*	Manitoba	1	0	1	0
Butte*	North Dakota	1	0	1	0
Canthatch*	Manitoba	6	0	4	0
Canuck*	Manitoba	2	0	2	0
Capa*	Uruguay	1	0	0	0

Wheat, continued

Variety Name	Source	Fairbanks	Eielson	Delta Junction	Palmer
		Number of Years Tested at Each Location			
Carpo*	Germany	1	0	0	0
CDC Alsask	Saskatchewan	2	0	2	1
CDC Bounty	Saskatchewan	5	0	5	4
CDC Osler	Saskatchewan	2	0	2	1
Chena (Experimental)*	Finland	17	0	17	1
Colano*	Colorado	2	0	1	0
Columbus*	Manitoba	1	0	1	0
Conway	Saskatchewan	1	0	1	0
Crim*	Minnesota	2	0	0	0
ECM 316*	Afganistan	1	0	0	0
Fortuna*	Montana	2	0	1	0
Garnet*	Ontario	1	0	0	0
Ideal*	Australia	1	0	0	0
Katepwa*	Manitoba	2	0	2	0
Kenyon	Saskatchewan	2	0	2	1
Laura	Alberta	2	0	2	1
Leader*	Saskatchewan	1	0	1	0
Lemhi 66*	Idaho	1	0	0	0
Manitou*	Manitoba	4	0	2	0
MN 7083*	Minnesota	1	0	0	0
MN 70113*	Minnesota	1	0	0	0
Napayo*	Manitoba	0	0	1	0
Neepawa*	Alberta	4	0	5	0
Nogal*	Alaska	16	1	16	6
Norana*	Montana	1	0	1	0
Opal*	Germany	1	0	0	0
Park*	Alberta	19	0	19	1
Peak 72*	Idaho	0	0	1	0
Polk*	Minnesota	1	0	1	0
PT 425	Saskatchewan	3	0	3	3
PT 430	Saskatchewan	3	0	3	3
PT 437	Saskatchewan	3	0	3	3
Roblin	Manitoba	10	2	11	6
Ruso*	Finland	8	0	6	0
Saunders*	Ontario	7	0	6	0
Selkirk*	Manitoba	2	0	1	0
Sheridan*	Montana	2	0	0	0
Siberian Bearded*	Russia	3	0	2	0
Siberian Beardless*	Russia	3	0	2	0
Sinton*	Saskatchewan	2	0	2	0

Wheat, continued

Variety Name	Source	Fairbanks	Eielson	Delta Junction	Palmer
		Number of Years Tested at Each Location			
Sonora 64*	Mexico	1	0	0	0
Taava*	Finland	5	0	5	0
Tapio*	Finland	8	0	8	1
Thatcher*	Minnesota	7	0	6	0
Ulla*	Finland	6	0	6	0
Vidal*	Alaska	10	2	7	2
Hard red semi-dwarf, spring					
Ariabian*	Mexico	1	0	1	0
Cutler	Alberta	3	3	3	0
Explorer	Montana	3	0	3	3
Fletcher*	Minnesota	1	0	0	0
Hi-Line	Montana	3	0	3	3
HY 320	Saskatchewan	2	0	2	1
Ingal*	Alaska	35	3	29	11
Kitt*	Minnesota	1	0	0	0
McNeal	Montana	3	0	3	3
Mexipak*	Mexico	2	0	1	0
MT 0245	Montana	3	0	3	3
Oslo	Colorado	2	0	2	1
Pacific Triple Dwarf	California	1	0	0	0
Springfield*	Idaho	0	0	1	0
Soft red, spring					
Pitic 62*	Mexico	7	0	5	0
Hard red utility, spring					
Blue Sky	Alberta	2	0	2	1
CDC Walrus	Saskatchewan	2	0	2	1
Dundas*	Prince Edward Is	2	0	2	0
Gasser*	Alaska	19	0	19	1
Glenlea*	Manitoba	0	0	1	0
Lazer	Alberta	0	0	1	0
Vernon*	Prince Edward Is	2	0	2	0
Wildcat	Alberta	2	0	2	1
Durum, spring					
Macoun*	Saskatchewan	1	0	1	0
Wakooma*	Saskatchewan	1	0	1	0
Wascana*	Saskatchewan	1	0	1	0
Spelt, spring					
Speltz	South Dakota	1	0	2	0
Hard red, winter					
Bauermeister	Washington	3	0	3	0

Wheat, continued

Variety Name	Source	Fairbanks	Eielson	Delta Junction	Palmer
		Number of Years Tested at Each Location			
Blackhawk	Nebraska	1	0	0	0
Cheyenne	Nebraska	2	0	0	0
Decade	Montana	3	0	3	0
Finley	Washington	3	0	3	0
Froid	Montana	7	0	0	0
Jerry	North Dakota	3	0	3	0
Kharkov 22	Ukraine	2	0	0	0
Lancer	Colorado	2	0	0	0
NB 66403	Nebraska	2	0	0	0
Norstar	Alberta	2	0	0	0
Omaha	Nebraska	3	0	0	0
Rida	Norway	1	0	1	0
Roughrider	North Dakota	2	0	0	0
Sawmont	Montana	3	0	0	0
Scout 66	Nebraska	2	0	0	0
Shoshoni	Nebraska	3	0	0	0
Skjaldar	Norway	1	0	1	0
Sundance	Alberta	2	0	0	0
Trader	Nebraska	3	0	0	0
Trapper	Nebraska	3	0	0	0
Warrior	Nebraska	2	0	0	0
Winalta	Alberta	2	0	0	0
Yellowstone	Montana	3	0	3	0
Hard white, winter					
MDM	Washington	3	0	3	0
Soft white, winter					
Eltan	Washington	3	0	3	0
Xerpha	Washington	3	0	3	0

Wild Rice

Variety Name	Source	Fairbanks	Eielson	Delta Junction	Palmer
		Number of Years Tested at Each Location			
Food grade					
Canadian K	Saskatchewan	1	0	1	0
Franklin	Minnesota	2	0	1	0
K2	Minnesota	1	0	1	0
M1	Minnesota	1	0	1	0
Eco-region, food grade					
La Ronge	Saskatchewan	0	1	0	0

Rye

Variety Name	Source	Fairbanks	Eielson	Delta Junction	Palmer
		Number of Years Tested at Each Location			
Spring					
Gazelle*	Saskatchewan	3	0	3	0
Karlshulder	Germany	1	0	0	0
Norwegian	Norway	1	0	1	0
Petkusser	Germany	1	0	0	0
Prolific*	Saskatchewan	5	0	2	0
Winter					
Bebral	Alaska	4	0	3	0
Jussi	Finland	1	0	0	0
Saskatoon	Saskatchewan	5	0	0	0

Triticale

Variety Name	Source	Fairbanks	Eielson	Delta Junction	Palmer
		Number of Years Tested at Each Location			
Spring					
Carman	Manitoba	1	0	1	0
HN 470	Mexico	1	0	0	0
Rosner	Manitoba	1	0	0	0
6TA 208	California	1	0	0	0
6TA 419	California	1	0	0	0
6TA 518	California	1	0	0	0
Welsh*	Manitoba	2	0	2	0
Winter					
6TA 131	California	1	0	0	0

Canarygrass

Variety Name	Source	Fairbanks	Eielson	Delta Junction	Palmer
		Number of Years Tested at Each Location			
Birdseed, spring					
Elias	Minnesota	3	3	3	0

Millet

Variety Name	Source	Fairbanks	Eielson	Delta Junction	Palmer
		Number of Years Tested at Each Location			
		Proso birdseed, spring			
Abarr	Colorado	1	0	1	0
Big Red	Nebraska	1	0	1	0
Common White	Colorado	1	0	1	0
Dawn	Nebraska	1	0	1	0
Leonard	Colorado	1	0	1	0
Turgahi	Japan	1	0	1	0
		Foxtail birdseed, spring			
Golden German	Colorado	1	0	1	0
Manta	South Dakota	1	0	1	0
		Japanese birdseed, spring			
Japanese	Japan	1	0	1	0

Buckwheat

Variety Name	Source	Fairbanks	Eielson	Delta Junction	Palmer
		Number of Years Tested at Each Location			
		Small seed, spring			
CM-15	Manitoba	4	0	4	0
		Large seed, spring			
Botan Soba	Japan	1	0	1	0
Common	Minnesota	1	0	1	0
Common	New York	1	0	0	0
Hokkaido	Japan	1	0	1	0
Mancan	Manitoba	2	1	2	0
Manor	Manitoba	1	1	1	0
PA Composite	Pennsylvania	1	0	1	0
PA-158	Pennsylvania	1	0	1	0
Pennquad	Pennsylvania	4	0	4	0
Shumway Japanese	Illinois	1	0	1	0
Tempest	Ontario	1	0	1	0
Tokyo	Maryland	1	0	1	0
Winsor Royal	Minnesota	3	3	3	0

Quinoa

Variety Name	Source	Fairbanks	Eielson	Delta Junction	Palmer
		Number of Years Tested at Each Location			
		Yellow seed grain, spring			
CO407-78	Colorado	1	0	0	0
CO407-06	Colorado	1	0	0	0
CO407-260	Colorado	1	0	0	0

Amaranth

Variety Name	Source	Fairbanks	Eielson	Delta Junction	Palmer
		Number of Years Tested at Each Location			
		Grain & forage, spring			
1011	Nebraska	2	0	0	0
477914	Nebraska	2	0	0	0
K343	Pennsylvania	2	0	0	0
R158	Pennsylvania	2	0	0	0

Field Peas

Variety Name	Source	Fairbanks	Eielson	Delta Junction	Palmer
		Number of Years Tested at Each Location			
		Yellow seed tare-leaf, spring			
Express	Sweden	3	3	6	0
		Yellow seed normal-leaf, spring			
CPB Concorde	England	1	1	0	0
Discovery	England	1	1	0	0
Endeavor	England	1	1	0	0
Grande	Sweden	2	2	2	0
Korando	North Dakota	1	0	1	0
		Yellow seed semi-leafless, spring			
Anno	Wisconsin	2	2	2	0
Baroness	England	2	2	2	0
Carneval	Sweden	3	3	4	0
CDC Yorkton	Saskatchewan	1	1	0	0
Celeste	France	3	3	2	0
Century	Ontario	1	1	0	0
Choque	France	2	2	2	0
Fluo	France	2	2	2	0
Highlight	Sweden	3	3	2	0

Field Peas, continued

Variety Name	Source	Fairbanks	Eielson	Delta Junction	Palmer
		Number of Years Tested at Each Location			
Impala	Netherlands	2	2	2	0
LU-1-209	Canada	1	1	1	0
Miranda	Netherlands	1	1	1	0
Montana	Netherlands	2	2	2	0
Mustang	Denmark	1	1	0	0
Orb	England	2	2	2	0
Profi	Denmark	2	2	0	0
Ricardo	Netherlands	1	1	1	0
Scorpio	Netherlands	2	2	2	0
Spitfire	England	1	1	0	0
Spring D	Denmark	1	1	1	0
Stehgolt	Alberta	1	1	1	0
SV C 37133	Sweden	1	1	1	0
SV C 61414	Sweden	1	1	1	0
SV E 12226	Sweden	1	1	1	0
SV 0 32440	Sweden	1	1	1	0
SW Midas	Sweden	1	0	2	0
Trump	Ontario	1	1	1	0
Voyager	Sweden	1	1	0	0
Green seed normal-leaf, spring					
Clipper	Czech Republic	1	1	0	0
Patriot	Sweden	2	2	3	0
Green seed semi-leafless, spring					
Ascona	Alberta	2	2	3	0
CDC Sage	Saskatchewan	1	0	2	0
CPB Phantom	England	1	1	0	0
Danto	Denmark	2	2	1	0
Keoma	Alberta	2	2	2	0
Majoret	Sweden	3	3	2	0
Promar	Denmark	2	2	2	0
Radley	Alberta	1	1	1	0
SW Parade	Sweden	2	0	2	0
Totem	Sweden	1	1	0	0

Chickpeas

Variety Name	Source	Fairbanks	Eielson	Delta Junction	Palmer
		Number of Years Tested at Each Location			
Kabuli - Garbanzo, spring					
CDC Xena	Saskatchewan	1	0	0	0

Mustard

Variety Name	Source	Fairbanks	Eielson	Delta Junction	Palmer
		Number of Years Tested at Each Location			
Yellow edible condiment oilseed , spring					
IdaGold	Idaho	3	0	3	0
Brown edible spice and condiment oilseed, spring					
Kodiak Brown	Idaho	3	0	3	0
Oriental edible oil and spice oilseed, spring					
Pacific Gold	Idaho	3	0	3	0

Canola

Variety Name	Source	Fairbanks	Eielson	Delta Junction	Palmer
		Number of Years Tested at Each Location			
Polish edible oilseed, spring (Low E & High G)					
AC Sunbeam	Alberta	3	0	4	0
AC Sunshine	Alberta	4	4	8	0
Candle	Saskatchewan	6	0	6	0
Colt	Sweden	4	4	8	0
Deltana (Experimental)	Alaska	3	0	3	0
Eldorado	Alberta	4	4	5	0
Goldrush	Sweden	1	1	2	0
Horizon	Sweden	4	4	8	0
Hysyn 110	Manitoba	5	0	5	0
Maverick	Sweden	2	2	5	0
Reward	Manitoba	9	6	13	0
Tobin	Saskatchewan	10	4	10	0
Polish industrial oilseed, spring (Low E & High G)					
Span	Saskatchewan	1	0	1	0
Torch	Saskatchewan	3	0	3	0
Polish industrial oilseed, spring (Normal E & High G)					
Echo	Saskatchewan	1	0	1	0
Polish industrial oilseed, spring (High E & High G)					
R-500	Saskatchewan	2	0	2	0
Reston	Manitoba	1	0	1	0
Polish/Argentine hybrid edible oilseed, spring (Low E & Low G)					
43H57 (RR)	Saskatchewan	3	0	3	0
Argentine edible oilseed, spring (Low E & Low G)					
43A56 (RR)	Saskatchewan	3	0	3	0
44A89	Saskatchewan	0	0	1	0
AC Excel	Saskatchewan	0	0	1	0
Altex	Alberta	4	0	4	0

Canola, continued

Variety Name	Source	Number of Years Tested at Each Location: Fairbanks	Eielson	Delta Junction	Palmer
Alto	Alberta	3	3	3	0
Andor	Alberta	1	0	1	0
Delta	Sweden	3	3	3	0
Hyola 357 Magnum (RR)	North Dakota	1	0	1	0
Hyola 401	North Dakota	1	0	1	0
Legend	Sweden	3	3	3	0
OAC Trident (TTC)	Ontario	1	0	1	0
OAC Triton (TTC)	Ontario	1	0	1	0
Regent	Manitoba	3	0	4	0
Sprite	Canada	1	1	0	0
Tower	Manitoba	4	1	4	0
Westar	Saskatchewan	5	3	3	0
Argentine edible oilseed, winter (Low E & Low G)					
Bridger	Idaho	0	0	2	0
Cascade	Idaho	0	0	2	0
Argentine industrial oilseed, spring (Low E & High G)					
Midas	Saskatchewan	1	0	1	0
Oro	Saskatchewan	1	0	1	0
Zephyr	Saskatchewan	1	0	1	0
Argentine industrial oilseed, spring (Normal E & High G)					
Target	Manitoba	1	0	1	0
Turret	Manitoba	1	0	1	0
Argentine forage rape, spring					
Dwarf Essex	England	4	0	4	0

Camelina

Variety Name	Source	Number of Years Tested at Each Location: Fairbanks	Eielson	Delta Junction	Palmer
Edible oilseed, spring					
Blaine Creek	Montana	3	0	2	0
Calena	Austria	3	0	2	0
Camena	England	1	0	0	0
Celine	France	2	0	2	0
Ligena	Germany	2	0	2	0
Suneson	Montana	3	0	2	0
Willow Creek	Montana	1	0	0	0
Wolff Creek	Montana	1	0	0	0
Edible oilseed, winter					
Suneson	Montana	1	0	0	0

Flax

Variety Name	Source	Number of Years Tested at Each Location: Fairbanks	Eielson	Delta Junction	Palmer
Industrial oilseed, spring					
Dufferin	Manitoba	1	0	0	0
Linott	Ontario	1	0	1	0
McGregor	Manitoba	1	0	0	0
Noralta	Manitoba	2	0	1	0
NorLin	Manitoba	3	2	2	0
Raja	Ontario	1	0	1	0
Industrial fiber, spring					
Arianna	Oregon	2	2	2	0
Cascade	Oregon	1	1	1	0
Viking (Dual Purpose)	North Dakota	2	2	2	0

Crambe

Variety Name	Source	Number of Years Tested at Each Location: Fairbanks	Eielson	Delta Junction	Palmer
Industrial oilseed, spring					
Glactica	England	1	0	0	0

Safflower

Variety Name	Source	Number of Years Tested at Each Location: Fairbanks	Eielson	Delta Junction	Palmer
Edible and industrial oilseed, spring					
Oker	Montana	1	0	0	0
S-208	Montana	1	0	1	0
Saffire	Alberta	1	0	0	0
Sidwell	Montana	1	0	1	0

Borage

Variety Name	Source	Number of Years Tested at Each Location: Fairbanks	Eielson	Delta Junction	Palmer
Edible and industrial oilseed, spring					
Corn Gromwell	England	1	0	0	0
Purple Viper Bugloss	North Carolina	1	0	0	0

Meadowfoam

Variety Name	Source	Number of Years Tested at Each Location: Fairbanks	Eielson	Delta Junction	Palmer
Industrial oilseed, spring					
Foamore	Oregon	1	0	1	0

Jerusalem Artichoke

Variety Name	Source	Number of Years Tested at Each Location: Fairbanks	Eielson	Delta Junction	Palmer
Tuber & forage, spring					
Sunchoke	Illinois	2	0	0	0

Sunflower

Variety Name	Source	Number of Years Tested at Each Location: Fairbanks	Eielson	Delta Junction	Palmer
Dwarf edible oilseed, spring					
Midnight Sun-flower	Alaska	17	1	4	1
Sunwheat semi-dwarf, edible oilseed, spring					
Sunwheat 101	Minnesota	3	3	3	0
Sunwheat 103	Minnesota	3	3	3	0
Common edible oilseed, spring					
Black Russian	Russia	1	1	1	0
CM 400	Manitoba	2	0	0	0
DO 164	Manitoba	2	0	0	0
HA 89	Australia	2	0	0	0
HA 124	Australia	1	0	0	0
HA 300	Australia	1	0	0	0
HA 301	Australia	1	0	0	0
HA 303	Australia	1	0	0	0
Hysun - 30	North Dakota	2	0	0	0
IS 241	North Dakota	1	0	1	0
IS 891	North Dakota	2	0	0	0
IS 893	North Dakota	1	0	1	0
IS 894	North Dakota	2	0	2	0
IS 897	North Dakota	2	0	2	0
IS 903	North Dakota	2	0	2	0
IS 907	North Dakota	2	0	2	0
IS 1166	North Dakota	1	0	1	0

Sunflower, continued

Variety Name	Source	Number of Years Tested at Each Location: Fairbanks	Eielson	Delta Junction	Palmer
IS 1210	North Dakota	1	0	1	0
IS 1490	North Dakota	1	0	1	0
IS 1500	North Dakota	1	0	1	0
IS 1500 x 2100	North Dakota	2	0	2	0
IS 1500 x 2490	North Dakota	1	0	1	0
IS 3107	North Dakota	2	0	2	0
IS 3500	North Dakota	1	0	1	0
IS 3600	North Dakota	1	0	1	0
IS 3800	North Dakota	1	0	1	0
IS 7775	North Dakota	2	0	2	0
IS 7785	North Dakota	1	0	1	0
IS 8907	North Dakota	2	0	2	0
IS 8943	North Dakota	1	0	1	0
IS 8944	North Dakota	2	0	2	0
Peredovik	North Dakota	2	0	2	0
RHA 271	North Dakota	2	0	0	0
RHA 274	North Dakota	2	0	0	0
RHA 276	North Dakota	2	0	0	0
RHA 290	North Dakota	1	0	0	0
RHA 299	North Dakota	1	0	0	0
S 894 A	Minnesota	2	0	0	0
Sunfola 68-2	Hungary	2	0	0	0
Confectionery, spring					
Sundak	North Dakota	2	0	2	0

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About the Alaska Agricultural & Forestry Experiment Station

The federal Hatch Act of 1887 authorized establishment of agricultural experiment stations in the U.S. and its territories to provide science-based research information to farmers. There are agricultural experiment stations in each of the 50 states, Puerto Rico, and Guam. All but one are part of the land-grant college system. The Morrill Act established the land grant colleges in 1862. While the experiment stations perform agricultural research, the land-grant colleges provide education in the science and economics of agriculture.

The Alaska Agricultural Experiment Station was not originally part of the Alaska land grant college system. In 1898, the station was established in Sitka, also the site of Alaska's first experiment farm. Subsequent branches were opened at Kodiak, Kenai, Rampart, Copper Center, Fairbanks, and Matanuska. The latter two remain as the Fairbanks Experiment Farm and the Matanuska Experiment Farm. The USDA established the Fairbanks experiment station in 1906 on a site that in 1915 provided land for a college. The land transfer and money to establish the Alaska Agricultural College and School of Mines was approved by the U.S. Congress in 1915. Two years later the Alaska Territorial Legislature added funding, and in 1922, when the first building was constructed, the college opened its doors to students. The first student graduated in 1923. In 1931, the experiment station was transferred from federal ownership to the college, and in 1935 the college was renamed the University of Alaska. When campuses were opened at other locations, the Fairbanks campus became the University of Alaska Fairbanks.

Early experiment station researchers developed adapted cultivars of grains, grasses, potatoes, and berries, and introduced many vegetable cultivars appropriate to Alaska. Poultry and other animal management was also important. This work continues, as does research in soils and revegetation, forest ecology and management, and rural and economic development. As the state faces new challenges in agriculture and resources management, the Agricultural and Forestry Experiment Station continues to bring state-of-the-art research information to the people of Alaska.