OBSERVATIONS ON PLANT AND TUBER GROWTH OF POTATO IN ALASKA

By
Curtis H. Dearborn

Agricultural Experiment Station
School of Agriculture and Land Resources Management
University of Alaska

James V. Drew, Director

In cooperation with
Agricultural Research, Science and Education Administration
United States Department of Agriculture

Bulletin 57

April, 1981

UNIVERSITY OF ALASKA

BOARD OF REGENTS

The Agricultural Experiment Station at the University of Alaska provides station publications and equal educational and employment opportunities for all, regardless of race, color, religion, national origin, sex, age, disability, or status as a Vietnam era or disabled veteran.

In order to simplify terminology, trade names of products or equipment may have been used in this publication. No endorsement of products or firms mentioned is intended, nor is criticism implied of those not mentioned.

OBSERVATIONS ON PLANT AND TUBER GROWTH OF POTATO IN ALASKA

by

Curtis H. Dearborn, AR, SEA, USDA

Bulletin No. 57

April, 1981

ABSTRACT

Several phenotypic characteristics that otherwise would be difficult to observe under field conditions in temperate-zone latitudes are amplified in Alaska at 61° 34' and north. At this latitude, the growing season for potato is marked by cool temperatures at its beginning and end as well as long daylight periods. Characteristics that have been observed include: rosetting, skirts-up, leaf color change, cut leaf, perforated leaf, fasciation, inverted leaf, flowering, stolon plant production, double tuber, second growth, stolon extension, tuber constriction, eye depth, heat sprout, cracking, tuberization, frost resistance, fruit set, sprout tuber, and sprout necrosis.

Stolon plant production and tuberization have been noted for samples of 27 *Solanum* species. Numerous plant- and tuber-growth manifestations are shown. Seed tubers of potato varieties stored over winter under identical conditions manifest significant differences in their capacity to generate a top following field planting. Stolon growth, stolon plant development, and tuberization indicate that a delicate physiological balance exists in some clones relative to the Alaskan environment. Changes in tuber shape, eye depth, and second growth are manifestations of environmental changes of rather short duration. Possibly heat sprout results from damage to the potato by particular foreign bodies.

Iopride showed the least rosetting and this character is conspicuous in some of its progeny. Leaves of some clones closed in toward the stem during light conditions approximating twilight. A few clones exhibited inverted leaf as a growth response to low light intensity while two clones lost their green color at the apex. Perforated leaf of potato and fireweed in the Matanuska Valley has been traced to aphid-feeding injury. Plants grown from tubers of potatoes with perforated leaves did not exhibit the perforated-leaf condition.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES, continued

LIST OF TABLES

INTRODUCTION

Alaska's great land mass stretches from near 55^0 to 68^0 N. latitude. Her varied climates provide opportunities for observing potato growth under the growing conditions of the interior represented by the valley floors of the Copper, Kuskokwim, Yukon, Kobuk, and Noatak Rivers. In these subarctic and arctic regions, the potato, *Solanum tuberosum* L., is the only starch food crop that can be economically produced and stored in sufficient volume to meet Alaskan needs the year round. Research and commercial production have both demonstrated that yields of 25 tons per acre are possible in favorable subarctic locations. This report documents information gained on potatoes for the past 30 years in Alaska.

Although it has been possible for a quater century, production of potatoes in Alaska has never met, much less exceeded, the state's market requirements. This can be attributed to several factors. Growers have not succeeded in supplying the market with a pack of uniform quality and dependable delivery. This situation usually only results where all potatoes move through a central packing house. Alaska growers have made a practice of storing their potatoes a little cooler than potatoes grown in other regions, causing a sugar buildup and a sweeter potato than those shipped into Alaska. They do not use sprout inhibitors and must hold their crop, after removal from storage, until the high sugars have been respired away. They do, however, produce an excellent-quality potato before storage. Because of the relatively small market, Alaskan growers have not organized to promote their potato sales. In contrast, Alaskan merchants have well-established supply lines to west coast ports that can and do provide produce to Alaskan buyers. Such produce is generally packaged in a manner that Alaska's newcomers became accustomed to in the 48 conterminous states. This kind of product has not required promotional expenses on the part of Alaskan retailers. Furthermore, Alaskan importers, who may wish to buy Alaskan potatoes, are sometimes threatened with the unavailability of other products such as apples and bananas if they do not take potatoes as well. Since Alaskan growers and retailers have not organized to support and carry on an effective promotional program, the buying public has had little incentive to buy locally packaged potatoes.

CHAPTER I

CULTURE AND ENVIRONMENT

In the high latitudes, the long photoperiod provides 21 to 24 hours of possible sunshine. Here potatoes are cultured with methods similar to those used in other potato-growing regions except that some varieties set their tubers deep in the soil and need not be hilled. Cultivation is not necessary as herbicides give satisfactory weed control. No foliage sprays or dusts are necessary as foliage diseases are nonexistent, and only cutworms, wiresworms, a few aphids, and leaf hoppers are present.

However, plant-food elements in Alaskan soils are inadequate for good crop production. Fertilizers used in the early 1950s did not supply enough potassium to some soils to support potato-top development (See Figure 1).This deficiency was corrected after some experimentation (Laughlin and Dearborn, 1960). In the cold soils of Alaska, phosphorus available from the potato seed piece is insufficient for development of a strong root system; therefore, all of the phosphorus that is likely to be needed for crop growth is banded in the conventional manner at planting. A complete fertilizer supplying 65 to 70 pounds of N, 256 to 288 pounds of $P_2 0_5$, and 128 to 144 pounds of $K_2 0$ per acre is most commonly used.

The environment is quite favorable for potato growing, although soil moisture is short at some time during each growing season. Cool nights and long days, coupled with a relatively short growing season of 85 to 120 days, bring out interesting characteristics in some potatoes. Occasionally, small plantings are made the last week of April in favorable sites along the Tanana, Copper, and Matanuska Rivers of Central and Southcentral Alaska, but most are made in May. Above the Arctic Circle (66^0 30'), potatoes are planted in late May and early June. Rainfall borders on desert conditions in areas most desirable for cropping. At Matanuska (61^0 34'), the average rainfall for the months of May, June, July, and August for the 28-year period, 1951-1978 was 7.26 inches (18.1 cm). In most growing seasons, 3 inches of irrigation is adequate when used properly.

Figure 1. Potato plants dying in the field in late July due to insufficient potassium in the soil to support plant growth.

In the Matanuska Valley, the usual soil temperature at the seed-piece level at planting is about 43° F (6° C), rising to about 57° F (14° C) by the time tuberization is occurring in the field. On June 21, the sun at Matanuska is above the horizon 19 hours and 21 minutes, while above the Arctic Circle at the same time there is no sunset. Under these circumstances, day-neutral and long-day clones tuberize between June 25 and July 14th. So-called "short-day" potatoes do not tuberize.

CHAPTER II

PHYSIOLOGICAL CHANGES OF POTATO IN RELATION TO CLIMATE AND ENVIRONMENT OF ALASKA'S HIGH LATITUDES

The potato plant, in its growth cycle in the field, responds to long and short climatic and environmental changes. The plant manifests growth changes in the rosette stage of plant development, leaf color and position, stem development, floral growth, stolon growth, and tuber growth. Underground parts change in response to the environment and can be significant guides to proper management of the crop — providing samples are harvested frequently enough to associate the growth manifestation with the particular climatic influence. Growth of the potato while the seed piece is below ground is a matter of extension of a bud of one or more of the eyes of the seed piece. As the sprout extends, it grows upward (apogeotropic), emerges, and leaves of the growing point expand to form a plant. At the same time, roots develop at nodes on the underground stem, first at the node nearest the seed piece and later at other nodes underground. If, for reasons to be discussed later, the sprout grows horizontally, it is considered to be functioning as a stolon. When an axillary bud of the above-ground stem extends and produces an aerial tuber, this supporting structure is referred to as a stolon.

Leaf, Stem, and Flower Changes

Leaves on emerging potato sprouts in Alaska normally form a rosette or partial rosette as a consequence of temporary light inhibition of the developing internodes of the sprout. Alaska Frostless, with *S. acaule* in its lineage (Dearborn, 1969), is especially conspicuous in the rosette stage, whereas the stem of the variety Iopride extends uninterrupted until it reaches full plant growth. Clone 26-68-2-71 is the only other line that has exhibited this nonrosetting character as distinctively as Iopride.

Responses of clones to natural light conditions are numerous and some can be used to alter cultural practices. In trials with flat culture and no tillage, I noted numerous clones and varieties not adapted to flat culture that might better be hilled between 11 p.m. and 2 a.m. because their foliage assumes an erect position during this low light period. Not all clones exhibit this "skirts-up" characteristic (Figure 2).

Potato variety Teton is conspicuous because of its light yellow-green leaves at the apices following a low light period (less than 200 langleys per day for 2 days). Leaves of the apical whorl regain their normal green color by the end of the third day of good light conditions. Leaf color changes several times in a season in response to changing light conditions. Clone 47-47-1-50, which seems not to have a common parent with Teton, responds to low light conditions the same as Teton. These are the only clones known to exhibit this characteristic so vividly in Alaska.

Wet leaf if a growth condition on a few leaves of some clones in which the affected area reflects light as if from a wet surface (Figure 3). Microscopic examinations reveal an undulated glassy surface devoid of the normal cuticular layer and pubescence. Removing affected plants from a clone for over five years did not eliminate wet-leaf condition. This condition was also observed on broccoli.

Perforated leaf of potato and fireweed *Epilobium angustifolium* L. in the Matanuska Valley (Dearborn, 1964) has reduced yields of potatoes planted in close proximity to willow (*Salix* spp). I have observed a very large-bodied green aphid that moves quickly when disturbed, migrates from willow to fireweed and potato early in the growth of these plants. These aphids feed in the apices of some potatoes and, as the leaves expand, perforations from these punctures are common and entire plants are dwarfed. Tests have not been made to determine if the aphids are carrying some disease to potato and fireweed.

Fasciation on plant parts is quite common in Alaska. I have observed it in roots, stems, tubers, floral parts, and fruits of numerous genera. It is most prevalent in potato stems and less common in stolons than in tubers (Figure 4). Fasciation of the stem and flower are effects of the previous season's growth patterns whereas fasciation in the stolon and tuber are from current season's influences. Tubers from fasciated plants are more likely to produce fasciation in crops grown from them than are tubers from nonfasciated plants (Dearborn, 1963). Fasciation has been associated with rank vegetative growth in all genera observed.

Figure 2. Leaves of some potato clones straighten up about 10:30 p.m. and remain with their skirts up until about 2:30 p.m. In this condition they are ideal for hilling. A minimum of soil moisture is lost by hilling during this period.

Figure 3. Wet leaf is a growth abnormality of a few leaves of some clones. The cause of this peculiar growth is unknown.

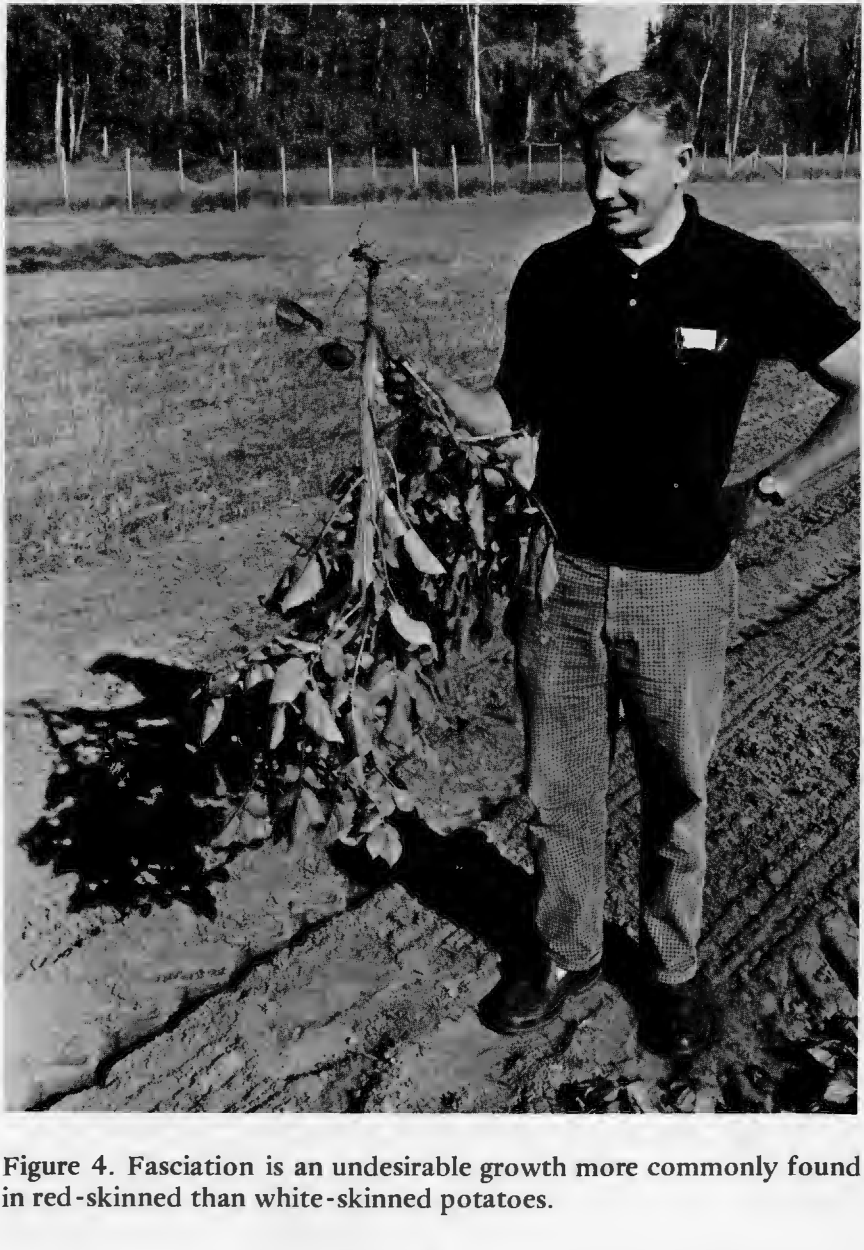

Figure 4. Fasciation is an undesirable growth more commonly found in red-skinned than white-skinned potatoes.

Inverted leaf is another conspicuous temporary physiological change which I cannot account for other than as a response to the environment. Following a night rainfall significant enough to provide the plant with an abundance of soil moisture, a mature leaf in the lower half of plants a foot tall rotates 180^0 so that it is bottom up (Figure 5). The same clones do not show inverted leaf in response to overhead irrigation.

Flowering of potato in this northern region is profuse in some clones and abortive in others. Alaska Red, Alaska Russet, Kennebec, and Russet Burbank seldom carry any flowers to maturity in the field. Although flowering is not associated directly with tuber production, I have noted that the earliest-flowering potato (Alaska Frostless) is not the earliest to set tubers. Stenospermocarpic fruit are not uncommon in controlled crosses.

Stolon Growth Change

The stolon, structurally a stem that emerges from a node either above or below ground, changes direction at either location in response to products within its structure. Although stolon development is only a means to a tuber, its growth pattern is extremely important.

Stolons from below-ground nodes start out at approximately right angles to the stem. As they extend they may become geotropic, they may remain in a horizontal plane finally emerging from the hill as stolon plants (Figure 6) or, as in most clones, tuberization stimuli terminate stolon extension after some geotropic growth has occurred. Thickening of the stolon behind the dormant tip ususally results in tuber growth.

Axillary buds of above-ground nodes generally remain dormant but they may develop into aerial stolons that form tubers in the leaf axils if the plant stem below them is girdled or partially girdled. Stolons that extend from above ground nodes undergo a sharp geotropic curvature near the stolon tip when the tuberization stimuli reach this region of the stolon. This tuberization results in a round aerial tuber. The change in polarity of the aerial stolon appears identical to that of the peduncle following pollen fertilization of flowers of some clones.

Figure 5. Inverted leaf is a characteristic expressed by some clones following a heavy rain. No specific weakness in the clones has been detected.

Figure 6. Stolon plants of potato appear along the row showing stage of mother plant development at the time these stolons emerge. Soil at lower right is cracked by a nontuberized stolon yet to appear. Stolon plants are more numerous on the west side of plants in rows running north and south.

Tuber Shape

Potato varieties and clones differ genetically in the shape of tubers they produce. The long types are conspicuous for their length during the first few days of tuber growth whereas ovals and oblongs may not show these shapes until the tubers are an inch (2.5 cm) or more in diameter. Double tuber is more common in red-skinned than in white-skinned or russet-skinned clones. A few instances of vertical instead of horizontal doubling have been noted. Doubling takes place early as shown in Figure 7 but in no case has doubling involved all stolons of a potato plant. Meristem splitting of the stolon tip produces numerous tuber configurations (Figure 8). Very early splitting results in the formation of two or more distinct growing points that develop into twin tubers or multiple tubers. Very late splitting in relation to tuberization produces a fasciated bud group whereas intermediate splitting produces distinct twinning of the new eye group but mature tuber shape is not affected significantly. Shape is also influenced by growing conditions that stimulate expansion of specific areas of the tuber. The variety Nampa may develop one or several tubers per hill that turn up at the apical end. A few clones have produced U-shaped tubers, which is a distinct change in polarity of the original stolon growing point. This apogeotropic growth is a response of the tuber to a change in the environment late in tuber development as the bud group (Figure 9) is carried up much the same as the stolon tip bends upward early in its production of a stolon plant.

Second Growth

Second growth at the eye, while the tuber is still attached to the stolon, is an undesirable change that occurs in some clones in response to environmental changes. Second growth of the underground parts of potato are of three distinct physiological types. The least common is the extension of growth from a bud of the newly formed tuber (Figure 10). This results from the potato top being exposed to environmental changes that temporarily break the dormancy of a bud or buds of the newly formed tuber. Some clones that are very sensitive to environmental change, like Alaska Frostless, tuberize, break dormancy of the apical bud, and then tuberize again sessile with the first tuber or on the extended stolon some distance from the first tuber (Figure 11). More commonly, there is accelerated growth of cortical and pith tissue subtending these dormant bud groups or eyes, and this type of growth produces turrets (Figure 12).

Figure 7. Double tuber is present on a stolon of both plants indicating a response to some environmental condition that persisted for a short time prior to or during first tuber formation. Doubling on all stolons has not been seen.

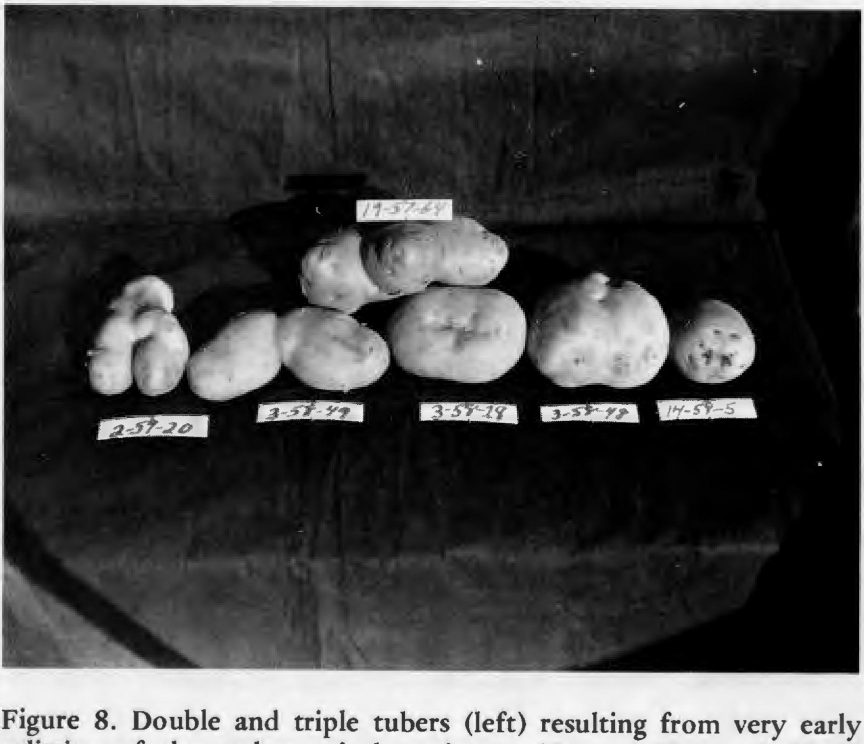

Figure 8. Double and triple tubers (left) resulting from very early splitting of the stolon apical meristem. (Center) Clone 19-57-64 developed three growing points. Fasciation illustrated by Clone 3-58-28 appears to be splitting while tuberization is occurring whereas the two tubers on the right are intermediate stages of splitting that do not significantly affect tuber shape.

Figure 9. Second growth affecting the entire apical region of the tuber but no loss of dormancy at any of the eyes. Proliferation to form the second growth began in the pith ray areas of the apical bud. Photo taken after tubers had been in storage for six months and dormancy had broken.

Figure 10. Stolon extension from the apical eye shows that dormancy of this bud was lost. In this case the sequence of events after the large tuber was formed were: loss of dormancy of apical bud or buds, extension of sprouts, return of dormancy, and initiation of tuberization.

Figure 11. Large sessile tuber on very small tuber (upper left) shows that in early tuberization the apical bud lost dormancy, extended a meristem and that new meristem soon became dormant and a second tuber developed. Two distinct cycles of tuberization are manifested.

Figure 12. Second growth of Russet Burbank in the form of little turrets at the lateral eyes was a response to environmental change in early July 1976. Incipient hollow heart is indicated in the brown pith tissue.

If growth at the eye area continues, the second growth becomes a distinct knob (Figure 13). Some knobs exceed the size of the tubers from which they grow. When the environmental change comes late in the season and tubers are large, second growth of most clones shows first on the basal end of the tuber at the second eye from the stolon attachment, and this bud is frequently on the lower side of the tuber (Figure 14). The basal bud's connection with the vascular system is structurally very poor in many clones, thus it is seldom affected by the stimulant that incites turret eye and is frequently ineffectual as a regenerative bud when it is the only bud on a seed piece. Growth at the second bud is due mainly to extension and enlargement of the pith region and is not an extension of a sprout. In this respect therefore the knob's formation on the lower side of the tuber is not in defiance of gravity.

Some clones manifest second growth by a constriction somewhere along the length of the tuber. When an unfavorable growing condition comes early in tuber growth, the constriction produces a dumbbell-shaped tuber (Figure 15). Varieties Green Mountain and Nooksack are especially susceptible to this growth form. The constriction that results in a dumbbell-shaped tuber in Clone 26-68-2-71 occurs very late in tuber growth (Figure 16). Eye development relative to tuber expansion in most varieties is not visibly detectable after the tuber weight reaches about one-fifth pound (90g). As new tubers grow, internal tissues that connect with the eye may or may not keep pace with the enlarging tubers. Failure of the tuber to extend connective tissue results in deep-eyed tubers. Likewise, early cessation of tuber extension results in radial instead of longitudinal tuber expansion. Clone 5-64-1-66 illustrates both deep eyes and radial growth (Figure 17).

A loss of dormancy in buds of the apical region of the tuber is seen as tubers mature in hot soils of lower latitudes and is seldom seen in Alaska; this condition is known as "heat sprout." Pungo is one of the very few named varieties on which I have observed heat sprout. A red-skinned clone among open-pollinated seedlings of Alaska Frostless exhibited a sprouting character at harvest in 1977 which I assumed to be typical of heat sprout (Figure 18). If this sprouting was the same as heat sprout in lower latitudes where soil temperatures run high late in the season, then is it really the heat of the soil that induces heat sprout? When Pungo showed heat sprout in 1955 the August mean air temperature was 62.6^0 F (17.3^0 C). No 3-

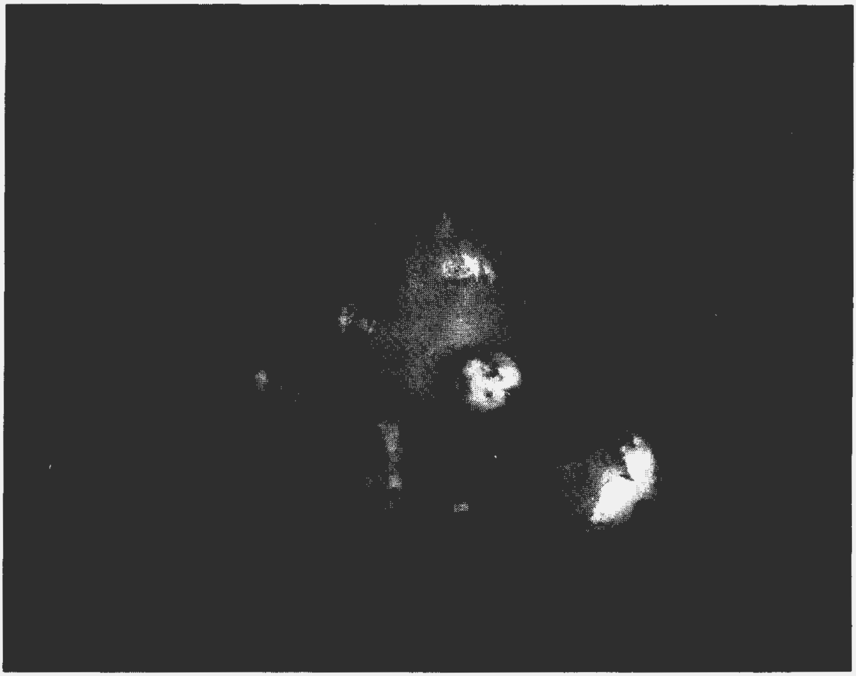

Figure 13. Second growth of potato where the second basal lateral bud area lost dormancy first, indicating that substances moving into the tuber through the stolon stimulated regeneration of cortical and pith tissues without breaking dormancy of buds.

Figure 14. Second growth on the ventral side of a tuber. Environmental conditions that brought about loss of dormancy affected only the second oldest bud of the tuber – the second bud from the stolon attachment.

Figure 15. Dumbbell shaped tubers are one expression of an environmental influence that caused a constriction in the central area of the tuber and prevented further expansion of that area. This response is to an early stimulus.

Figure 16. Tubers of a clone showing different stages of tuber development when their delicate balance with the environment shifted from normal tuber expansion to second growth of the entire apical region.

Figure 17. Eyes in this clone are very deep. The mechanism controlling expansion of parenchyma cells of the outer area of this clone is not altered by the environmental changes to which the plant is exposed at this high latitude. The diameter of these tubers is greater than their length.

Figure 18. Sprouting late in the season on many tubers in the soil still attached to their stolons is uncommon in Alaska. It resembles heat sprout in lower latitudes but soil temperatures in Alaska are not really high.

day runs of air temperature exceeded 64, 69 and 69° F. Soil temperatures at the 6-inch depth reached 62° F (17° C) once, but generally were below 58° F (14° C). September temperatures were much cooler.

The mean air temperature in August of 1977, when the Alaska Frostless seedling was seen, was 58.6° F (15° C), and the highest 3-day run of air temperatures was 70, 76, and 80° F for 19 through 21 August. The mean soil temperature for the first 20 days of September was 50° F (10° C). From the position of the sprouts, I concluded that they were at equilibrium with tropism forces and physiologically resembled stolons more than sprouts. Stolons produced by the potato tops of normal seed pieces usually respond apogeotropically before the sprout has extended to the length shown previously in Figure 18. If this were heat sprout, a short span of three days of high irradiation may be more influential to its development than temperature. This clone did not show heat sprout in 1978 when August mean air temperature was 56.8° F (14° C).

CHAPTER III

LIGHT QUALITY AND GROWTH

Light Values

Because light, particularly light quality, is the most variable growth factor to which the plant is exposed, a study of the light conditions accompanying growth changes was made. Energy expressed in Langleys, as recorded by a pyrheliometer at the experimental site, is presented in Table 1, together with other climatological information. In addition, light quality was measured in 12 narrow-wave bands of the natural spectrum, 800nm-310nm. For the entire growing season, two periods of irradiation are conspicuous; 6-10 July and 18-21 July. Irradiation during these periods was intense for this latitude and nearly continuous. Light-quality measurements showed energy in all wave bands in contrast to normal light periods in which quality is modified by clouds and showers. During periods of low Langley values, energy of wave bands 790, 750, 370, and 310nm were screened out by clouds. Since the two periods of high irradiation are an unusual condition, formative changes in potato would be expected to begin in response to these periods.

Growth Responses

Lateral buds of Russet Burbank developed little turrets in response to the period of high irradiation from 6 through 10 July 1976, with a second increase in the size of the turrets during the 18 through 21 July period. Scarcely any enlargement of these second-growth areas occurred throughout the remainder of the growing season. A study of the irradiation pattern for the season revealed no other periods of irradiation approximating these two in July. Furthermore, it appears that this turret-eye development became active when the crop was exposed to about 2000 Langleys over a 3-day

Table 1. Climatological Record of Period During Which Significant Physiological Changes Occurred in Potato in 1976 at the Matanuska Farm, Agricultural Research Center, Palmer.

July Day	Total Daily Langleys[a]	Temperature (°F) Max.	Min.	Avg.	Evaporation From Free Water Surface (inches)	Rainfall (inches)
1.	147.4	59	53	56.0	.106	.07
2.	420.8	67	45	56.0	.154	.07
3.	609.0	67	40	53.5	.068	—
4.	49.1	53	48	50.5	.198	—
5.	86.8	59	46	52.5	.278	.29
6.	700.4	74	40	57.0	.034	Tr.
7.	696.2	75	43	59.0	.200	—
8.	726.7	80	46	63.0	.252	—
9.	578.6	80	50	65.0	.241	—
10.	641.8	71	50	60.5	.257	—
11.	356.7	70	54	62.0	.232	—
12.	212.1	61	51	56.0	.042	.09
13.	371.3	67	51	59.0	.038	—
14.	580.0	71	46	58.5	.038	—
15.	375.3	66	47	56.5	.162	—
16.	338.6	69	52	60.5	.126	—
17.	289.7	65	48	56.5	.159	.70
18.	596.4	69	50	59.5	.061	—
19.	572.7	69	45	57.0	.169	—
20.	651.0	78	45	61.5	.141	—
21.	578.2	75	45	60.0	.198	—

[a] As recorded by a pyrheliometer at a Weather Observer location at the Matanuska Farm, Agricultural Research Center, Palmer.

period. This turret-eye growth is equivalent to a second cycle of tuberization as it is an enlargement process behind a dormant bud group.

Alaska Frostless tubers reacted differently to these same two runs of high irradiation. An apical bud of larger tubers lost dormancy and extended a sprout 1 to 4 inches (2.5 to 10 cm). This was followed by tuberization at the sprout tip as with tuberization of a stolon.

CHAPTER IV

TUBER CRACKING

Hollow Heart

Hollow heart in Russet Burbank is usually accompanied by second growth. Incipient hollow heart as brown pith is shown in Figure 12. Even though growth cracking and hollow heart occur together on some varieties, Cherokee for example, the two growth conditions in Alaska ususally are not associated. Hollow heart has been most severe in seasons when drought conditions were severe in late June and especially early July. Newly formed tubers lose water to the tops and this water loss from the tuber shrinks and weakens the cell walls of the central pith. Hollow heart results from the pulling apart of the cells of the central pith tissues as the tuber resumes growth (Figure 19). It has a marked resemblance to boron deficiency symptoms in the pith tissue of the stem and branches of cauliflower (Dearborn, 1942).

Shatter Cracking

This is a serious weakness in many clones observed in Alaska (Figure 20). Cortical and periderm tissues burst from pressures within the tubers, in contrast to hollow heart; therefore, it does not necessarily follow that internal cracking (hollow heart) and external cracking (shatter) are associated. At certain times in growth, removal of soil from around the tubers in the hill results in bursting of the periderm and cortical layer. Growth cracks at harvest are merely these early shatters that have healed (Figure 21).

Y-Checking

This is troublesome on breeding lines that show some resistance to common scab (Figure 22). Under some field conditions the Y-checks coalesce to form an alligator-hide appearance. Irritation at the lenticels by some soil-borne fungus or its byproducts probably precedes the cork-tissue formation. Thumbnail cracking is seldom seen on varieties adapted to this region (Figure 23).

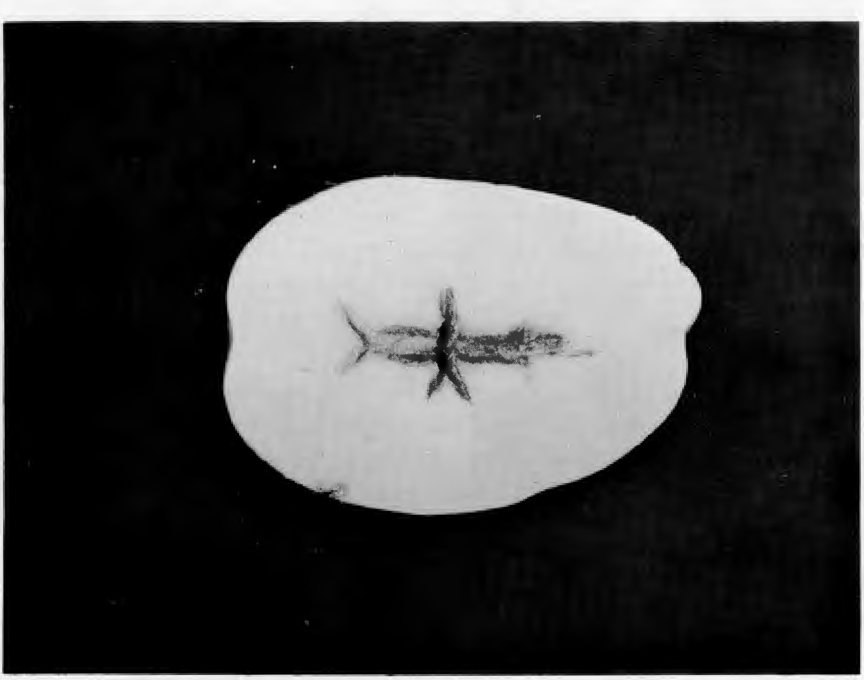

Figure 19. Hollow heart results from the pulling apart of cells of the central pith tissue and in mild cases takes the form of a lense-shaped void. Where the early stress is prolonged later expansion of the tuber pulls the pith tissue apart in several directions.

Figure 20. Shatter cracking that followed a bruise. This is an inherent weakness and can be serious in high dry-matter clones.

Figure 21. Growth crack on the left, split the tuber to the bud group and healed. A later shatter on the right suberized and left a furrow and at harvest the tuber was still under internal pressure enough to shatter and crack across the suberized growth crack.

Figure 22. Y-checking is a type of skin cracking common to some germplasm. It is more common in progenies from crosses that have considerable resistance to scab. Saranac develops a coarse netting whereas Ontario remains smooth.

Figure 23. Thumbnail cracking frequently referred to as air cracking is seldom seen in Alaska because it is largely a varietal weakness and these types are not produced in Alaska commercially.

CHAPTER V

CHARACTERISTICS OF SOME *SOLANUM* SPECIES

Tuberization

The time span between emergence of the sprout and tuber formation in *S. tuberosum* remains fairly constant for a clone irrespective of planting date; however, other species react differently at this latitude. Tuberization of most varieties of potato in Alaska occurs between 20 and 30 days after sprout emergence. It is an interesting process, influenced by several factors that are still not well defined.

In search of frost-resistant parental lines in the mid 1950s, 59 Plant Introduction (P.I.) clones were grown and evaluated. Some clones of *S. demissum* showed frost tolerance but did not tuberize. This raised the question: Did *S. demissum* tops lack the capacity to stimulate tuberization or did the underground parts lack the capacity to utilize the products of the top? Inarch reciprocal grafting of *S. demissum* with seedlings of variety Stately in 1959 demonstrated that *S. demissum* tops did not stimulate tuberization on Stately but Stately tops on *S. demissum* rootstock did produce tubers. Other researchers have reported results from grafting studies (Chapman, 1958).

To broaden the choice of parents for developing frost-resistant potatoes, 232 clones representing 59 species were obtained from P.I. stocks of the Inter-Regional Potato Introduction Station (IR-1) at Sturgeon Bay, Wisconsin, in 1969 and planted at Matanuska. These were noted for frost resistance of the tops, tuber formation, stolon plant development, and fruit set. Field frosting 11 August froze about half of the foliage on all frost-susceptible clones. A max-min thermometer at plant crown height of 20" (50 cm) registered 27^{0} F (-3^{0} C). Characteristics of the P.I. clones in the test in 1969 are shown in Table 2.

Table 2. Notes on Frost Resistance, Tuber Set, Stolon Plant Development, and Fruit Set of Some P.I. Potato Clones Evaluated at the Matanuska Farm, Agricultural Research Center, Palmer in 1969.

Solanum species	P.I. No.	Fr. Resist.	Tubers Set	Stolon Plants	Fruit Set
S. acaule	266386	+	-	+	+
" "	320272	+	-	+	+
" "	320273	+	-	+	+
" "	320274	+	-	+	+
" "	320275	+	-	+	+
" "	320276	+	-	+	+
" "	320277	+	-	+	+
" "	320278	+	-	+	+
" "	320279	+	-	+	+
" "	320280	+	-	+	+
S. berthaultii	310926	-	-	-	-
" "	310927	-	-	-	-
" "	310971	-	-	-	-
" "	WRF1727	-	-	-	-
S. boliviense	310928	+	+	-	+
" "	310974	+	-	-	+
" "	310975	+	-	+	-
" "	WRF1561	+	-	-	-
S. brachistotrichum	320265	-	-	-	-
S. brachycarpum	243344	-	-	-	-
" "	275180	-	-	-	-
" "	275183	-	-	-	-
" "	275261	Slight	-	-	-
S. brevicaule	310930	-	-	-	+
" "	310931	-	-	-	+
" "	310982	+	-	-	+
S. bulbocastanum	275185	-	+	-	-
" "	275187	-	+	-	-
" "	275188	-	-	-	-
" "	275192	-	+	+	-
" "	275193	-	+	-	-
" "	275194	-	+	-	-
" "	275195	-	+	-	-
" "	275196	-	-	-	-
" "	WRF1565	-	-	+	-

Continued on next page.

Table 2 continued.

Solanum species	P.I. No.	Fr. Resist.	Tubers Set	Stolon Plants	Fruit Set
S. cajamarcense	310988	-	-	-	-
S. canasense	246533	+	-	-	+
" "	265864	+	-	-	-
" "	283073	+	-	+	+
" "	283074	+	-	-	+
" "	283080	-	-	-	-
" "	310955	+	-	-	-
S. capsicibaccatum	205560	-	-	-	-
S. cardiophyllum	255519	-	+	-	-
" "	255520	-	-	-	-
" "	275212	+	+	-	-
" "	275214	-	-	-	-
" "	275216	-	+	-	-
" "	WRF276	-	-	-	-
S. chacoense	320282	-	+	+	-
" "	320283	-	+	+	-
" "	320284	-	+	-	-
" "	320285	-	+	-	-
" "	320286	-	-	-	-
" "	320287	-	+	-	-
" "	320288	-	+	-	-
" "	320289	Slight	+	-	-
" "	320290	-	-	-	-
" "	320291	-	-	-	-
S. chiquidenum	275269	+	-	-	-
" "	310942	+	-	-	-
" "	310989	+	-	-	-
S. clarum	283099	+	-	-	-
S. demissum	230589	+	-	-	+
" "	230590	+	-	-	-
" "	230591	+	-	-	-
" "	275206	+	-	-	+
" "	275207	-	-	-	-
" "	275208	+	-	-	+
" "	275209	+	-	-	+
" "	275210	+	-	+	+
" "	275211	+	-	-	+
" "	310967	+	-	-	+

Continued on next page.

Table 2 continued.

Solanum species	P.I. No.	Fr. Resist.	Tubers Set	Stolon Plants	Fruit Set
S. fendleri	255531	-	-	-	+
" "	275159	-	-	-	+
" "	275165	-	-	-	+
" "	275167	-	-	-	+
" "	283100	-	+	-	+
" "	283101	-	-	-	-
S. gandarillasii	218220	+	-	-	-
" "	265866	-	-	-	-
" "	283076	-	-	-	-
S. gourlayi	320340	+	-	-	+
" "	320341	Slight	-	-	-
S. guerreroense	161727	Slight	-	-	-
" "	161730	-	-	-	-
S. hjertingii	186559	Slight	-	-	-
" "	186560	Slight	-	-	-
" "	251065	Slight	+	-	-
S. hougasii	WRF391	Slight	-	-	-
" "	WRF1569	Slight	+	+	-
" "	WRF1736	Slight	-	+	-
S. infundibuliforme	275146	Slight	+	+	+
" "	283077	+	-	+	+
" "	320295	+	-	-	+
S. iopetalum	275181	-	-	-	-
" "	275182	-	-	-	-
S. jamesii	275169	Slight	-	-	-
" "	275265	-	-	-	-
S. kurtzianum	320271	Slight	+	-	-
" "	320296	+	-	-	-
" "	320297	Slight	-	-	-
S. leptophyes	310932	+	-	+	-
S. lignicaule	275273	-	-	-	-
" "	310993	-	+	-	-
S. marinasense	310944	Slight	-	-	-
" "	310945	Slight	-	-	-
" "	310946	Slight	-	-	-
" "	310947	Slight	-	-	-
" "	WRF1533	Slight	-	-	-
S. medians	265872	+	-	-	-

Continued on next page.

Table 2 continued.

Solanum species	P.I. No.	Fr. Resist.	Tubers Set	Stolon Plants	Fruit Set
" "	283081	+	-	-	-
" "	WRF1575	-	-	-	-
S. megistacrolobum	233124	-	-	-	-
" "	233125	+	-	+	-
" "	265873	+	-	+	+
" "	275147	+	-	-	+
" "	275148	+	-	-	+
" "	275149	+	-	-	+
" "	320302	+	-	+	-
" "	320303	+	-	+	-
*S. michoacanum**	255537	No plants			
" "	255542	-	-	-	-
" "	283065	Slight	-	-	-
S. microdontum	320304	-	-	-	-
" "	320305	-	-	-	-
" "	320306	-	-	-	-
" "	320307	-	-	-	-
" "	320309	-	-	-	-
" "	320310	-	-	+	-
" "	320311	-	-	-	-
" "	320312	-	-	-	-
" "	320314	-	-	-	-
" "	320315	-	-	-	-
S. mochicense	283114	-	-	-	-
S. morelliforme	275223	-	-	-	-
S. multidissectum	210043	+	-	+	-
" "	210044	+	-	+	-
" "	210055	+	-	+	-
" "	265876	+	-	+	-
" "	296123	+	-	+	-
S. multiinterruptum	265886	-	-	-	-
" "	275272	-	-	-	-
S. oplocense	265885	-	-	-	-
" "	320322	-	-	-	-
S. pampasense	275274	-	-	-	-
" "	275275	-	-	-	-
S. papita	249929	-	-	-	-
" "	251740	-	+	-	-

Continued on next page.

Table 2 continued.

Solanum species	P.I. No.	Fr. Resist.	Tubers Set	Stolon Plants	Fruit Set
›› ››	251741	-	-	-	-
›› ››	262895	-	+	-	-
›› ››	283102	-	-	-	-
›› ››	283143	-	-	-	-
S. phureja	320348	-	+	-	-
›› ››	320349	Slight	-	-	-
›› ››	320350	+	+	-	-
›› ››	320351	Slight	+	-	-
›› ››	320352	-	-	-	-
›› ››	320353	Slight	+	-	-
›› ››	320354	Slight	-	-	-
›› ››	320355	+	+	-	-
›› ››	320357	-	-	-	-
›› ››	320358	-	-	-	-
S. pinnatisectum	275230	-	+	-	-
›› ››	275232	-	+	-	-
›› ››	275234	-	+	-	-
›› ››	275236	-	+	-	-
S. piurae	310997	+	-	-	-
S. polyadenium	310988	-	-	-	-
›› ››	320342	-	-	-	-
S. polytrichon	255522	-	-	-	-
›› ››	255545	-	-	-	-
›› ››	255546	Slight	-	-	-
›› ››	255547	-	-	-	-
›› ››	275240	-	-	-	-
›› ››	275241	-	-	-	-
S. raphanifolium	210048	+	-	-	-
›› ››	265862	+	-	+	+
›› ››	296126	+	-	-	-
›› ››	310951	+	-	-	-
›› ››	320262	+	-	-	-
S. sanctae-rosae	320324	+	-	-	-
›› ››	320225	+	-	-	-
*S. sandemanii**	265880	No plants			
S. sogarandinum	230510	+	-	-	-
S. sparsipilum	265859	-	-	-	-

Continued on next page.

Table 2 continued.

Solanum species	P.I. No.	Fr. Resist.	Tubers Set	Stolon Plants	Fruit Set
" "	265871	-	-	-	-
" "	310929	-	-	+	-
" "	310972	-	-	+	-
" "	310984	-	-	-	-
S. spegazzinii	310985	-	-	+	-
" "	320299	-	-	+	-
" "	320300	Slight	-	-	-
" "	320301	Slight	-	-	-
S. stenophyllidium	255527	Slight	-	-	-
" "	255528	-	-	-	-
S. stenotomum	234007	+	+	-	-
" "	234010	+	+	-	-
" "	234011	+	+	-	-
" "	234012	Slight	+	-	-
" "	234013	+	-	-	-
" "	234015	Slight	+	-	-
" "	283141	Slight	+	-	-
" "	WRF1285	Slight	+	-	-
" "	WRF1583	Slight	+	-	-
S. stoloniferum	275244	-	-	-	-
" "	275245	-	+	-	-
" "	275246	-	-	-	+
" "	275247	-	-	-	-
" "	275248	-	-	-	-
" "	275249	-	-	+	+
" "	275250	-	-	-	+
" "	275252	-	-	-	-
" "	275253	-	-	-	-
" "	320343	-	-	-	+
S. sucrense	230465	-	-	-	-
" "	283091	-	-	-	-
S. tarijense	217457	-	-	-	-
" "	217458	-	-	-	-
" "	265577	-	-	-	-
" "	275154	-	-	-	-
S. toralapanum	195210	+	-	+	-
" "	310936	+	-	+	+

Continued on next page.

Table 2 continued.

Solanum species	P.I. No.	Fr. Resist.	Tubers Set	Stolon Plants	Fruit Set
S. venturii	320327	-	-	-	-
,, ,,	320328	-	-	-	+
S. vernei	230468	+	-	+	-
,, ,,	320329	+	-	+	-
,, ,,	320330	+	-	+	-
,, ,,	320333	+	-	+	-
S. verrucosum	255544	+	-	-	-
,, ,,	275255	-	-	-	-
,, ,,	275256	-	-	-	-
,, ,,	275258	-	-	-	+
,, ,,	320344	-	-	-	-

*Clones lost in tillage.

Frost Resistance

Seventy-four of the 232 clones were frost resistant. Thirty-three clones showed slight frost resistance and 123 were susceptible. Two clones were destroyed in tillage operations. All of the clones of 12 species were frost resistant: *S. acaule, S. boliviense, S. chiquidenum, S. sanctae-rosae, S. sogarandinum, S. toralapanum, S. vernei, S. clarum, S. leptophyes, S. multidissectum, S. piurae, S. raphanifolium.*

All of the clones of 33 species were frost susceptible: *S. berthaultii, S. brachistotrichum, S. brachycarpum, S. bulbocastanum, S. cajamarcense, S. capsicibaccatum, S. chacoense, S. fendleri, S. guerreroense, S. hjertingii, S. hougasii, S. iopetalum, S. jamesii, S. lignicaule, S. marinasense, S. michoacanum, S. mochicense, S. morelliforme, S. multiinterruptum, S. oplocense, S. pampasense, S. papita, S. pinnatisectum, S. polyadenium, S. polytrichon, S. sandemanii, S. sparsipilum, S. spegazzinii, S. stenophyllidium, S. stoloniferum, S. sucrense, S. tarijense, and S. venturii.*

S. multidissectum P.I. 210044 was the most frost-resistant clone tested.

Stolon Plants

Stolon plant production is a genetic response of clones of some potato species to the climate of this northern latitude. The equilibrium is so delicate in some clones between tuberization and stolon plant production that the structures alternate several times. In others the tuberizing stimulus never predominates. Data presented in Table 2 show 44 clones representing 18 species that did not produce enough tuberizing stimulus to tip the equilibrium to tuberization.

Fruit and Tuber Set

Clones that produced fruits exhibited a positive guide to their behavior, but clones that did not should not be assumed to be sterile in this region. Frosting could have destroyed flowers and buds of many that otherwise would have set fruit. Some frost-resistant clones produced viable pollen long after susceptible clones were killed by freezing.

Tubers were initiated in 43 clones representing 15 species: *S. boliviense, S. bulbocastanum, S. cardiophyllum, S. chacoense, S. fendleri, S. hjertingii, S. hougasii, S. infundibuliforme, S. kurtzianum, S. lignicaule, S. papita, S. phureja, S. pinnatisectum, S. stenotomum,* and *S. stoloniferum.*

CHAPTER VI

SPROUT TUBER AND SPROUT NECROSIS

Sprout Tuber

Sprout tuber is an undesirable type of tuberization that can occur from a seed piece without the production of a top (Moore, 1931). Missing plants in an otherwise normal planting of either whole or cut seed are the first evidence of sprout tuber formation (Figure 24). Close examination of the planted row will show that the soil is cracked over the seed piece but no sprouts are visible (Figure 25). Shallow digging in these cracked hills reveals that one or more small tubers have formed at several eyes of the seed piece (Figure 26). No marketable tubers are produced when the seed piece germinates and grows in this manner. This tuberization, the transfer of energy directly from the seed piece to new tubers, occurs much earlier than normal tuberization. Occasionally a sprout emerges in mid-August from a sprout tuber formed earlier (Figure 27). Internal tuber also develops without the production of foliage (Hardenburg, 1949).

Some evidence (Dyson and Digby, 1975a) shows that some potato varieties whose sprouts develop subapical necrosis in storage remain healthy if calcium is supplied to the sprouts. In other studies (Dyson and Digby, 1975b) tubers planted that had subapical necrosis developed sprout tuber whereas calcium-treated sprouts emerged, developed a top and tuberized. I first observed sprout necrosis in 1963 on numerous clones that had been stored for several months to over six months at 58^0 to 60^0 F (15^0 C) (Figure 28).

Some clones are very susceptible to sprout tuber while others are essentially free from this weakness. Conditions that earlier workers have associated with sprout-tuber growth are storage of seed potatoes at room temperature for several months and planting potatoes into cold soils that remain cold for several weeks. Loss of energy from sprout removal has been considered a contributing factor by others, but my research indicates that long storage at temperatures favorable for sprouting is more conducive to sprout tuber development than energy loss through sprout growth and removal.

Figure 24. Clone in center row produced sprout tuber and no tops. Surrounding clones were treated similarly but were resistant to sprout tuber.

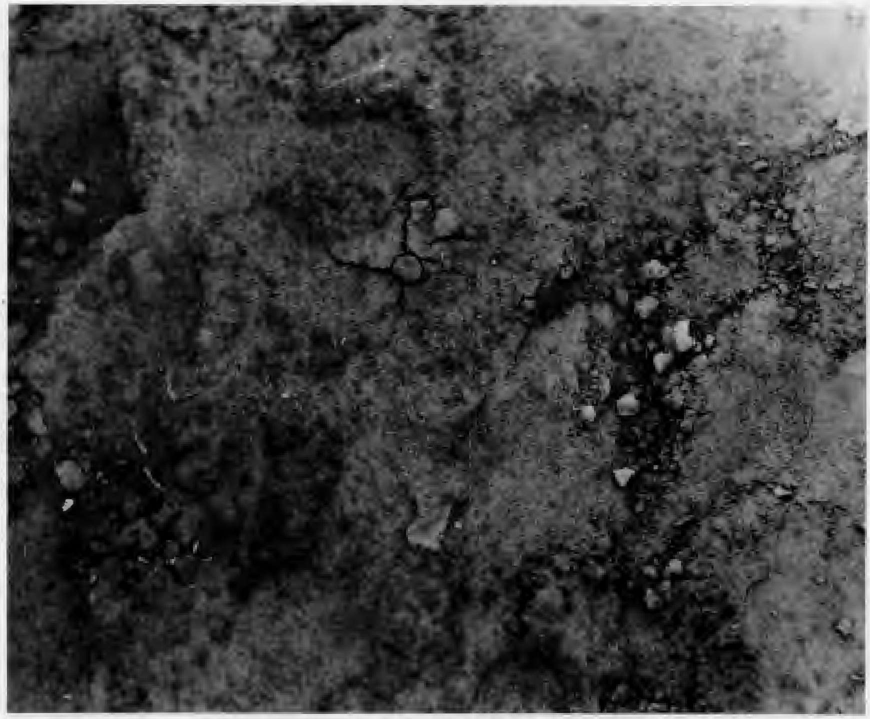

Figure 25. Soil cracked from pressure of one or more new tubers developing on a potato seed piece that had been planted 25 days. This is sprout tuber development and no sprout emerged from this seed piece.

Figure 26. Sprout tuber, the generation of new tubers from the seed piece without a sprout breaking ground. High storage temperatures 50 to 60^0 F induces a physiological change in the mother tuber.

Figure 27. Occasionally a sprout tuber sprouts and produces a small plant in August.

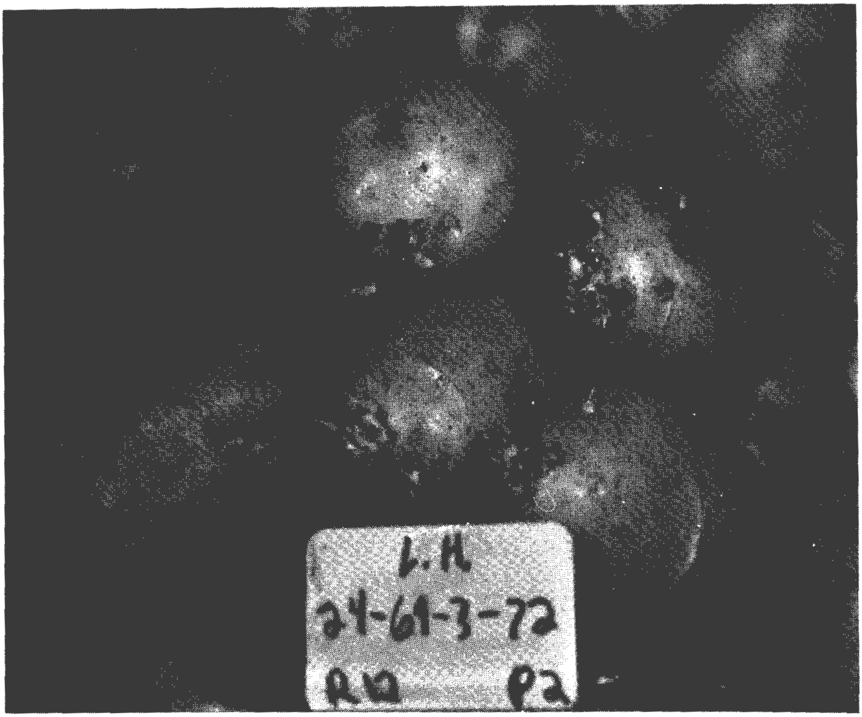

Figure 28. Sprout necrosis following four months storage at 50 or 60^{0} F (11 or 16^{0} C). Sprout tuber has not been observed on this clone throughout 10 years of production.

Inducing Sprout Tuber

Storage studies of clones from the 1977 crop provided an opportunity to learn if clones of diverse parentage exhibited the same weakness for sprout tuber. Sixteen white-skinned and eleven russet-skinned clones were stored at 60° F (15.5° C) from harvest in September to April 28, 1978. At that time, 20 B-size tubers of each clone were desprouted and held in storage at 38° F (4° C) throughout winter storage. The clones genetically susceptible to sprout tubers when stored continually at 60° F (15.5° C) were: 37-68-3-70, 38-68-2-70, Alasclear, 10-71-1-74, B8901-3 AK, B8227-4 AK russet, and B8856-14 AK russet as shown in Table 3. The same clones stored at 38° F (4° C) did not develop sprout tuber. Sprout length at desprouting (column 6) bears little relation to the capacity of a clone to generate a normal top, but total weight of plant and tubers produced appears to be inversely related to sprout length at desprouting.

In 1979, 45 clones from the 1978 variety trials were stored, handled, planted, and noted in a manner similar to those of the 1977 crop except that a sample of each clone was transferred from 38° F (4° C) to 60° F (15.5° C) storage on 5 February. In continuous warm storage, 24 of the 45 clones showed evidence of some sprout-tuber development, whereas the same clones transferred from cold storage to warm storage on 5 February showed sprout tuber in only six clones. They were: 38-68-2-70, Alasclear, Ontario, B7631-3, 6-68-5-72 and B8857-6 (column 2 of Table 3). None showed sprout tuber that were in cold storage continuously up to the week prior to planting. Eight of the 27 white-skinned clones held in warm storage from harvest to planting produced sprout tubers and 6 of these produced no tops. Sixteen of the 27 whites showed essentially no differences in emergence at the two storage-temperature regimes. Seven of the 13 russets in warm storage ranged from no emergence to 35 per cent. In general seed held in warm storage from harvest to planting produced less total weight than seed held in warm storage only from early February to planting. Four whites and two russets from the 5 February warm-storage treatment developed sprout tuber. Ontario and 38-68-2-70 were the most sensitive to sprout-tuber formation. Ten clones in a second planting on 23 June 1979 representing both sprout tuber and nonsprout tuber types performed the same as did the earlier planting. By this time, soil temperatures had risen to 55° F (13° C) so soil temperature was not a major contributor to sprout-tuber development. Seed of all clones held throughout

Table 3. Percentage of Potato Hills Emerging from Seed Tubers Stored Under Three Temperature Regimes from Harvest in the Fall to Planting in the Spring.

Clones	Storage temperature and percent emergence 1979 60° F %	1979 38-60° F %	1979 38° F %	1978 60° F %	1978 38° F %	Sprout length inches
White Skinned						
38-68-2-70	0	5	96	5	96	11
B8901-3 AK	0	—	87	5	100	13
10-71-1-74	0	80	96	10	92	22
Alasclear	0	60	100	20	96	24
Ontario	—	0	92	—	—	—
B8882-11 AK	0	85	96	—	—	—
B8221-6 AK	0	90	92	—	—	—
37-68-3-70	5	85	92	35	100	10
B7631-3	10	60	92	—	—	—
Russet-Skinned						
B8227-4 AK	0	85	96	5	100	16
6-68-5-72	0	75	96	70	92	6
Nampa	5	80	100	—	—	—
Belrus	10	100	96	—	—	—
B8902-7 AK	10	—	92	—	—	—
B8857-6 AK	15	60	100	—	—	—
B8962-6 AK	35	80	83	90	92	6
B8856-14 AK	—	—	—	35	87	12
Other Named and Numbered						
Alaska 114	75	95	100	100	92	11
Alaska Frostless	75	85	96	—	—	—
Atlantic	90	—	92	—	—	—
Bakeking	—	—	—	100	87	24
Denali	90	95	100	100	100	10
Green Mountain	85	85	96	—	—	—
Kennebec	90	70	100	100	100	16
Russet Burbank	85	95	100	100	83	20
Snowchip	90	90	92	90	92	16
13-68-5-72	85	95	87	95	100	4
24-69-3-72	85	85	96	90	100	3

storage at 38° F (4° C) produced normal tops and tubers. Records show that clones 13-68-5-72 and 24-69-3-72 developed sprout necrosis in storage; but did not produce sprout tuber in the field. It is significant to breeders and growers that certain clones emerge and produce at about the same rate when stored either warm or cold whereas other clones develop sprout tuber and no tops if stored warm for 100 days or more.

CHAPTER VII

CONCLUSIONS

Although numerous peculiarities of potatoes have been noted under Alaskan growing conditions, none is a serious deterrent to the production of high-quality potatoes for fresh market, processing, or disease-free seed stocks. We have included the species and tests reported here in order to provide knowledge to potential Alaskan potato breeders in remote areas of this great land mass that otherwise might feel obligated to repeat what already has been researched.

LITERATURE CITED

Chapman, H. W. 1958. Tuberization in the potato plant. *Physiologia Plantarum*, 11:215-224.

Dearborn, C. H. January 1969. Alaska Frostless, an inherently frost resistant potato variety. *Am. Potato Jour.* 46(1)1-4.

Dearborn, C. H. October 1963. "Stitched end," "giant hill" and fasciated stem of potatoes in Alaska. *Am. Potato Jour.* 40(10)357-360.

Dearborn, C. H. June 1964. Perforated leaf of potato and fireweed in Matanuska Valley, Alaska. *Am. Potato Jour.* 41(6)174-177.

Dearborn, C. H. 1942. Boron nutrition of cauliflower in relation to browning. Cornell University Agricultural Experiment Station Bulletin No. 778. 29 pp.

Dyson, P. W. and J. Digby. 1975a. Effects of calcium on sprout growth and sub-apical necrosis in Majestic potatoes. *Potato Res.* 18:290-305.

Dyson, P. W. and J. Digby. 1975b. Effects of calcium on sprout growth of ten potato cultivars. *Potato Res.* 18:363-377.

Hardenburg, E. V. 1949. Potato production. Comstock Publishing Co., Inc., Ithaca, New York.

Laughlin, W. M. and C. H. Dearborn. January 1960. Correction of leaf necrosis of potatoes with foliar and soil applications of potassium. *Am. Potato Jour.* 37(1)1-12.

Moore, H. C. August 1931. Notes on sprout tuber or no-top potatoes. *Am. Potato Jour.* 8(9)189-192.