NITROGEN-FIXATION BY LEGUMES IN INTERIOR ALASKA

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INTRODUCTION

Legumes are notable for their ability to convert atmospheric dinitrogen into forms of nitrogen which are usable by plants. This is done in association with bacteria (called *Rhizobium*) which inhabit nodules of the plant roots. This process is called nitrogen-fixation. Legumes are important as forage and food crops due to their high protein content. Some are also useful for soil conservation purposes.

There was no information on nitrogen fixation by legume crops in Alaska. This research was initiated to determine how much nitrogen different types of legumes can fix in interior Alaska.

PROCEDURES

Field plots were established in the spring of 1988 and 1989 at the AFES research farm at Fairbanks and at the AFES Delta research site at Mile 1408, Alaska Hwy. Seven legumes were planted at both sites in both years. Four of them were large-seeded (often called pulses) annuals—fababeans, lentils, peas and lupines. The other three were small-seeded, forage-type legumes which are usually grown as biennials or perennials—red clover, alfalfa and sweetclover. Barley without nitrogen fertilizer was grown on the plot areas in the year previous to planting the legumes. This was done to deplete the soil of available nitrogen. Phosphorus, and potassium fertilizers were applied to the plots before planting the legumes, but no nitrogen fertilizer was added except for small amount of *tracer* nitrogen added to a small portion of each plot. Treflan herbicide and molybdenum (a micronutrient needed by legumes) was sprayed onto the soil and incorporated before planting. At Delta, we included a lime treatment consisting of about three tons of lime per acre incorporated into the soil before planting. This was done to raise the soil pH from about 5.5 to 6.5. In order to determine if the legumes would respond to inoculation with *Rhizobium* bacteria, inoculated and non-inoculated treatments were included at each location. Inoculation was done by applying a commercial, granular inoculant containing the appropriate *Rhizobium* type for each legume to the soil at planting time.

Small amounts of nitrogen fertilizer labeled with a tracer (^{15}N isotope) were added to a small portion of each plot. This was done to get an estimate of how much nitrogen the crops obtained from the soil. From those values, nitrogen-fixation could be estimated. Periodically during the growing season, plant roots were dug up, washed free of adhering soil, and evaluated for nodulation. At plant maturity or at the end of the growing season, plants were harvested and later analyzed to determine amounts of nitrogen taken up by the plants. This was compared to control plants which did not fix nitrogen to determine the amount of nitrogen fixed by each legume.

RESULTS

Forage yields were higher in both years at Fairbanks than at Delta. This was especially true in 1989 (Tables 1 and 2). The 1989 growing season was considerably drier than the 1988 growing season. This resulted in lower yields at both sites in 1989 than in 1988; this was especially true for most of the legumes at Delta. The soil at Delta is much sandier than the one at Fairbanks and is less able to store water; thus droughty conditions are more severe there. Protein content for some of the legumes were lower than desired for good quality legume forage. Higher protein levels for some of the legumes could have probably been obtained by harvesting earlier in the season at plant growth stages when harvests are normally made for forage purposes. However, the goal of this study was not to maximize protein content but to determine the maximum seasonal N-fixation obtainable by these legumes under interior Alaska conditions.

Nitrogen-fixation values were quite high for some of the legumes at Fairbanks, with

Table 1. Total plant yields, protein contents, and amounts of nitrogen fixed by inoculated legumes at Fairbanks in 1988 and 1989.

Legume	Forage yield (tons/acre)	Protein content (%)	nitrogen fixed (lbs/acre)
		1988	
small-seeded types			
Altaswede red clover	4.3	12.7	108
Nitro alfalfa	2.2	14.6	51
Norgold sweetclover	3.7	12.8	94
large-seeded types			
Frederick fababeans	4.8	17.1	182
Indianhead lentils	2.2	17.1	42
Poneka peas	3.2	16.3	84
Primorski white lupines	3.6	19.1	145
		1989	
small-seeded types			
Altaswede red clover	1.9	14.0	37
Nitro alfalfa	2.3	13.3	56
Norgold sweetclover	3.0	13.6	79
large-seeded types			
Frederick fababeans	3.7	19.0	154
Indianhead lentils	2.7	14.8	64
Poneka peas	3.0	17.7	108
Primorski white lupines	3.2	19.1	131

Table 2. Total plant yields, protein contents, and amounts of nitrogen fixed by inoculated limed and unlimed legumes at Delta in 1988 and 1989.

Legume	Limed: Forage yield (tons/acre)	Limed: Protein content (%)	Limed: Nitrogen fixed (lbs/acre)	Unlimed: Forage yield (tons/acre)	Unlimed: Protein content (%)	Unlimed: Nitrogen fixed (lbs/acre
			1988			
small-seeded types						
Altaswede red clover	1.8	14.7	69	1.7	14.2	67
Nitro alfalfa	1.1	16.0	49	0.8	13.3	29
Norgold sweetclover	3.1	13.3	108	2.3	13.5	86
large-seeded types						
Frederick fababeans	1.8	15.6	82	2.0	16.0	92
Indianhead lentils	1.8	14.7	66	1.4	12.2	46
Poneka peas	3.3	12.8	99	2.5	12.9	71
Primorski white lupines	0.8	17.4	28	1.2	17.0	55
			1989			
small-seeded types						
Altaswede red clover	1.0	11.4	32	0.9	11.0	26
Nitro alfalfa	1.1	11.1	29	0.6	8.7	12
Norgold sweetclover	1.1	10.3	33	1.1	9.9	26
large-seeded types						
Frederick fababeans	1.8	15.9	78	2.5	15.6	115
Indianhead lentils	1.6	11.7	49	1.8	11.7	46
Poneka peas	2.2	14.1	84	1.9	9.9	51
Primorski white lupines	0.7	12.3	64	0.4	10.2	6

several exceeding 100 lbs/acre (Table 1). At Delta, N-fixation levels were lower than at Fairbanks, but were fairly high for some legumes, especially in 1988 (table 2).

At Fairbanks, both the inoculated and uninoculated plants were well nodulated with the exception of white lupines. In this case the inoculated plants performed better than the uninoculated plants. For all other legumes there was no effect of inoculation on plant yield or nitrogen-fixation (data not shown). The soil apparently contained adequate populations of *Rhizobium*. The Fairbanks farm had been cropped to legumes of different kinds for many years; thus *Rhizobium* populations had become established in the soil. At Delta, where legumes had never been grown, the uninoculated plants seldom had nodules whereas the inoculated plants were usually well nodulated. The uninoculated plants grew very poorly at Delta.

The results of the liming experiment were somewhat variable from year to year at Delta (Table 2). In both years, Altaswede red clover and Indianhead lentils performed about as well on the unlimed soil as on the limed soil. Liming improved performance of Nitro alfalfa and Poneka peas in both years; whereas it improved performance of Norgold sweetclover in 1988 but had little effect in 1989. On the other hand, there seemed to be a negative effect due to liming for the Frederick fababeans in both years, especially in 1989. Results for the Primorski white lupines are interesting in that liming appeared to have a negative effect in 1988 but a positive one in 1989.

Several legumes showed potential for high forage yields and high nitrogen-fixation in at least one of the two years or one of the two sites. Of the legumes tested, fababeans appeared to have the highest potential for nitrogen-fixation and performed reasonably well on acid and non-acid soil and under droughty and non-droughty conditions. Peas also performed fairly well under all conditions tested. Red clover, sweetclover, and white lupines performed very well under some conditions but appear to be sensitive to water stress. They do have good potential as forages for interior Alaska under suitable conditions. The cost/benefit ratios of growing these various legumes need to be defined. The cost of growing large-seeded legumes may be excessive, especially if seeds must be imported. However, the expense may be justified when compared to the costs of importing protein for animals feeds. The large-seeded legumes often did better in this study than did small-seeded legumes, but this may be off-set by higher costs.

Work is currently underway to determine how much of the nitrogen that is fixed by legumes in Alaska is utilizable by succeeding crops. Also, research was recently initiated to attempt to find high yielding, high nitrogen-fixing legumes which will survive interior Alaska winters.

CONCLUSIONS

Several of the legumes tested in this study were found to have high potentials for forage production and nitrogen-fixation in interior Alaska. Some were more affected by adverse conditions than others. At Delta, there were inadequate populations of *Rhizobium* in the soil for good nodulation and inoculation was required in order to obtain good legume growth and nitrogen-fixation.

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