Effects of Nitrogen and Phosphorus Fertilization on Yield and Protein Content of Oat Forage at Point MacKenzie

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INTRODUCTION

One of the principal forages grown at the Point MacKenzie dairy project about 40 miles southwest of Palmer in Southcentral Alaska is oats. Soils at Point MacKenzie are moderately to strongly acidic, ranging in pH from about 5.0 to 6.0, thus promoting the use of acid-tolerant plants such as oats. These soils have a moderate volcanic ash content whose weathered products have a high affinity for phosphorus (Ping and Michaelson, 1986; Michaelson and Ping, 1986). Soil depth varies from shallow to moderately deep and can be a critical factor during droughty periods.

The research reported here is a continuance of previous work at Point MacKenzie that has provided information on yield and response of oats to fertilizer treatments (Mitchell, 1983; Michaelson et al., 1984). Two series of trials were conducted employing different nitrogen and phosphorus rates with one of the series also testing different times of harvest. This report is concerned with the effect of these treatments on yield and crude protein content in Toral oats.

METHODS

In one series of trials, Trial Series A, a single harvest was taken during the growing season. In a second series, Trial Series B, harvests were taken at different stages of growth during the growing season.

Trial set A

This set of trials was conducted in 1986 and 1987 at the same site testing five rates of nitrogen, with phosphorus and potassium kept constant, and five rates of phosphorus, with nitrogen and potassium kept constant. In 1986, 120 lbs P_2O_5 and 80 lbs of K_2O were applied per acre with five rates of N (0, 60, 80, 100 and 120 lbs N/acre), and 120 lbs N and 80 lbs K_2O with five rates of P (0, 60, 80, 100 and 120 lbs P_2O_5/acre). In 1987, 60 lbs of P_2O_5 and 60 lbs K_2O were applied per acre with five rates of N (0, 30, 60, 90, and 120 lbs N/acre), and 90 lbs N and 60 lbs K_2O with the five rates of P (0, 30, 60, 90, and 120 lbs P_2O_5/acre). An additional treatment containing N and P without any K was applied in both years. A single harvest was taken each year in the late-headed stage.

Trial set B

A second set of trials was conducted over three years to test the effect of N and P rates at different stages of harvest. In 1985 four rates of nitrogen were employed with 80 lbs P_2O_5 and 60 lbs K_2O per acre. Harvests were taken at four different stages. A different location was used for the 1986 and 1987 trials. In these trials three rates of nitrogen were applied with two rates of phosphorus. In 1986, 80 and 120 lbs P_2O_5 were applied per acre at each N rate; in 1987, 40 and 80 lbs P_2O_5 were applied per acre at each N rate. Potash (K_2O) was applied uniformly at 67 and 60 lbs per acre in each year, respectively.

Fertilizer was broadcast and raked into the surface 1-to-2 inches of tilled soil. The oat seed was drilled in rows, either six or eight inches apart. Yield samples were obtained with a sickle-bar mower from a 2 x 12 foot center section of each 4 x 15 foot plot, leaving about three inches of stubble. The 1985 trial

Table 1. Temperature and precipitation data for growing season of 1985, 1986, and 1987 at Point MacKenzie.

	May		June		July		August	
	Prec.	Temp.	Prec.	Temp.	Prec.	Temp.	Prec.	Temp
1985	1.14	43.4	1.20	50.9	0.99	59.0	3.88	53.5
1986	0.68	46.1	0.31	54.7	2.25	56.9	2.63	53.7
1987	1.09	47.1	1.35	52.0	2.33	57.6	0.59	57.7

Note: Data for the last 13 days of August 1985 were missing for Pt. MacKenzie. Data from White's Crossing, a nearby station in the Susitna Valley were supplanted for the missing data. Precipitation is in inches and temperature is in degrees Fahrenheit.

Figure 1
N responses: Toral Oats 1986

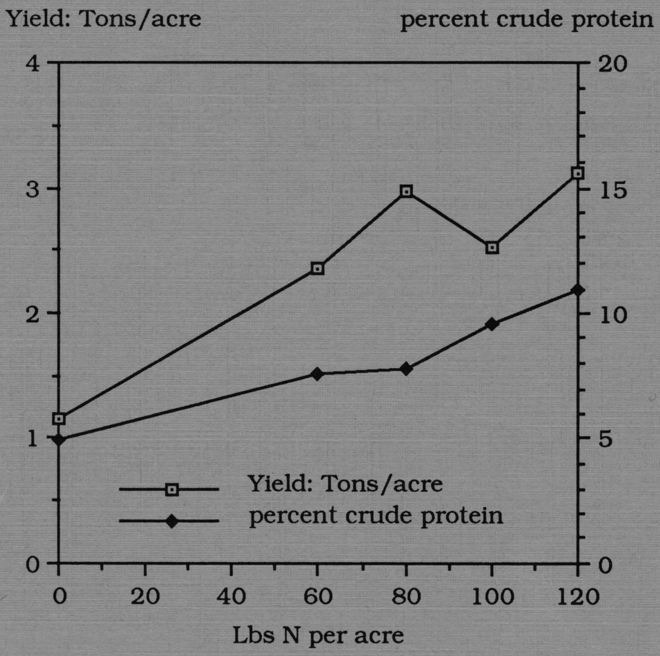
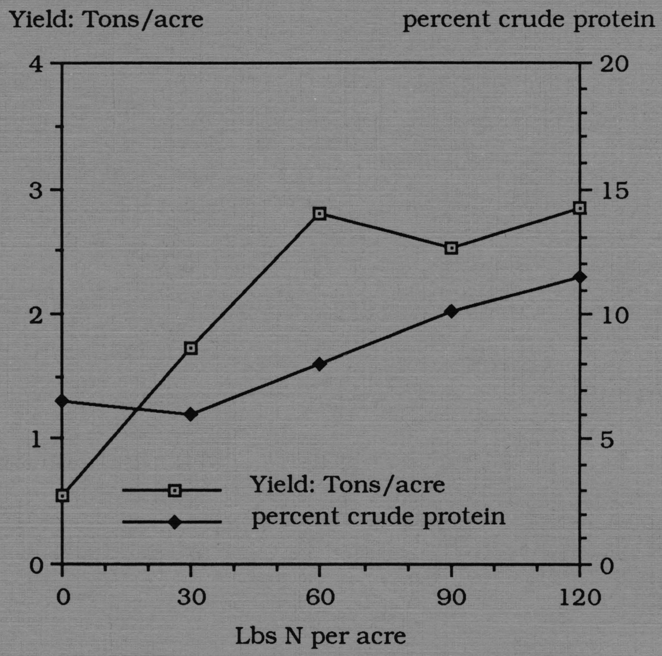


Figure 2
N responses: Toral Oats 1987



contained five replications, while all others contained four replications in a randomized complete block design. Yields are reported on an oven-dry basis (add 12-to-15 percent for hay weights).

Precipitation and temperature data over four months of the growing season for the three years of the trials are presented in Table 1. The 1985 growing season was characterized by cool temperatures early in the season and a droughty period during a critical part of the growing season through July and early August, thus limiting growth. The 1986 growing season featured little precipitation early in the growing season, though soil moisture was good initially, with sufficient July and August precipitation to promote good growth. Precipitation was evenly distributed through the June to August period in 1987, promoting good growth.

RESULTS AND DISCUSSION

Trial set A

Yield responses to increasing levels of nitrogen in Trial set A varied by year. In 1986 responses were obtained to applications of N up to 80 lbs per acre with little or no additional response to higher levels of N (Figure 1). In 1987 no responses were obtained beyond 60 lbs per acre of applied N, (Figure 2). Yield at the nil-N level was much lower in 1987 than in 1986, but at the 60 lb level, it was much higher. Responses to increasing levels of phosphorus were somewhat comparable for the two years, although varying at the highest treatment of 120 lbs P_2O_5/acre (Figures 3 and 4). This treatment increased the yield in 1986, but not in 1987. The results indicated that increasing production may be expected with applications of up to 80-to-90 lbs P_2O_5/acre. This agrees in general with the results obtained by Michaelson et al. (1984). However, the latter study indicated more definite responses to applications of N, up to 120 lbs/acre, than were obtained in these trials, which provided indefinite results beyond applications of 60-to-80 lbs N/acre.

Crude protein contents (%N x 6.25) were influenced both by nitrogen applications and by yield. In 1986 nitrogen treatments resulted in an increase in crude protein content from 4.9 percent with no N applied to 11 percent with 120 lbs N/acre applied (Figure 1). In 1987 comparable increases, varying from 6.5 percent to 11.5 percent were realized (Figure 2). The 1987 data indicated that an application of 30 lbs N/acre was sufficient to produce a large increase in yield, but not sufficient to produce an increase in crude protein content. Increases in both yield and crude protein resulted from the next nitrogen increment. Phosphorus appeared to have little effect or a negative effect on crude protein concentrations (Figures 3 and 4). However, the phosphorus effect was indirect, dependent upon its effects on yield in combination with the amount of nitrogen applied. In 1986, with 120 lbs N/acre applied, crude protein contents appeared little affected by higher phosphorus treatments. However, in 1987, with 90 lbs N/acre applied, crude protein contents manifested a generally negative response to

Figure 3
P responses: Toral Oats 1986

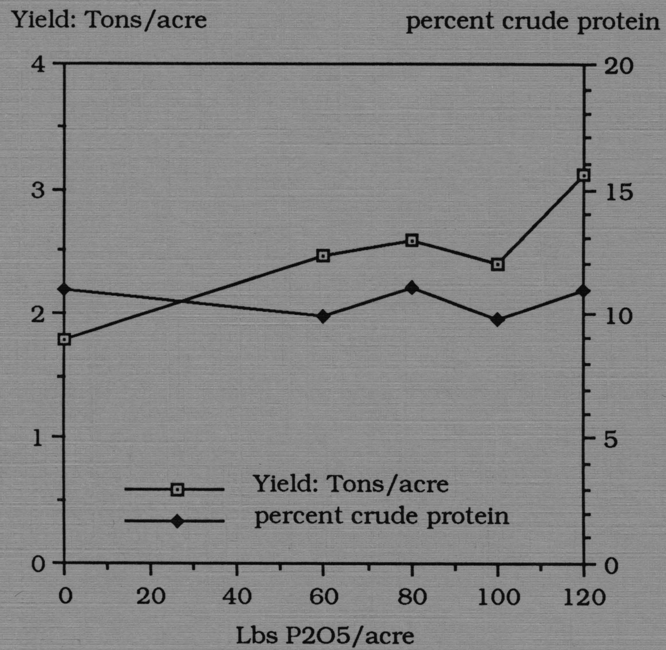
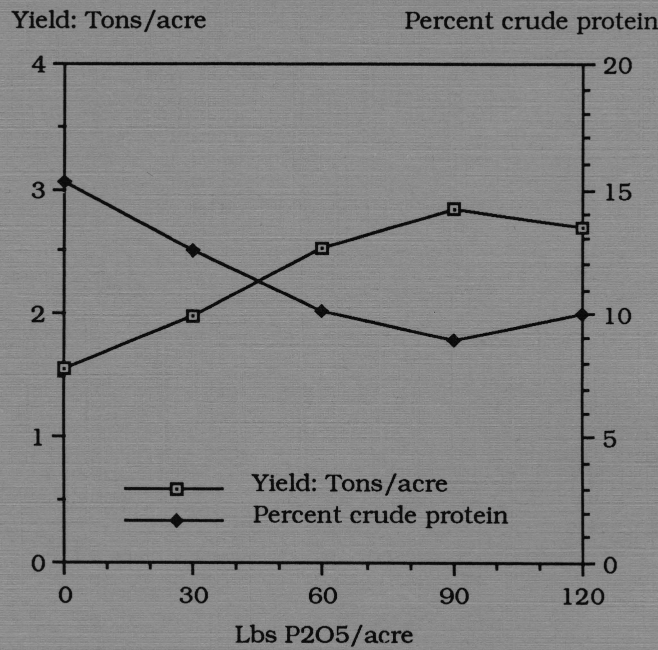


Figure 4
P responses: Toral Oats 1987



increasing phosphorus treatments. This response actually was the result of higher production with each increment of phosphorus, up to 90 lbs P_2O_5/acre. The higher production had a diluting effect; thus in Figure 4, the yield lines and crude protein lines diverge, except at the highest P treatment in conjunction with a decline in yield. In 1986 the application of 120 lbs N/acre apparently was sufficient to compensate for the effects of higher yields, therefore resulting in very similar crude protein contents at the different phosphorus levels.

This latter interpretation is bolstered by the evidence obtained from nitrogen removal data. The amount of nitrogen removed by the harvested forage is a function of yield and N concentrations in the forage. With 120 lbs N/acre applied at the different rates in 1986, much less of the nitrogen was removed, relative to that applied, than was removed in 1987 with 90 lbs N/acre applied (Table 2). Apparently there was a surplus of N available at a number of the treatment levels in 1986, whereas little or no surplus was avail-

Table 2. Nitrogen removal by Toral oats for 1986 and 1987 trials according to fertilizer treatment.

Fertilizer 1986	lbs N removed	%N removed	Fertilizer 1987	lbs N removed	%N removed
0-120-80	18	—	0-60-60	11	—
60-120-80	57	95	30-60-60	33	110
80-120-80	74	93	60-60-60	74	123
100-120-80	77	77	90-60-60	82	91
120-120-80	109	91	120-60-60	104	87
120-0-80	63	53	90-0-60	76	84
120-60-80	78	65	90-30-60	79	88
120-80-80	91	76	90-90-60	81	90
120-100-80	75	63	90-120-60	86	96
120-120-0	81	68	90-90-0	88	98

Figure 5: Toral Oats Yield at Different Harvest Stages (response to N)

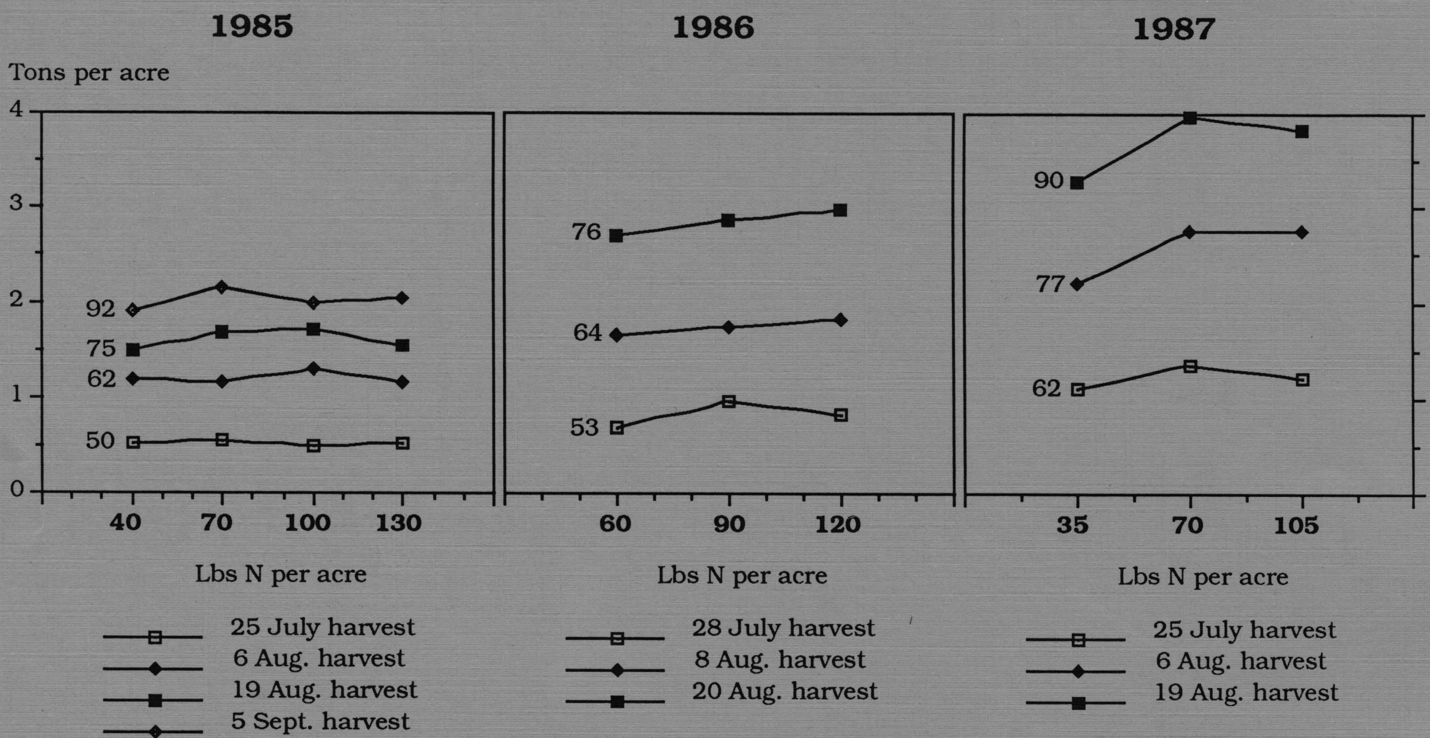


Figure 5. Yield (tons/acre) of Toral Oats at different N rates and harvested in successive months in 1985, 1986, and 1987. Figures to the left of yield lines are number of days after planting until date of harvest. In 1985, harvests were taken in the boot, headed, early milk, and soft-dough stages. In 1986 and 1987, harvests were taken in the emergence, fully headed, and milk stages.

able in 1987 (when possible N losses are taken into consideration).

Not shown in Figures 1-4 are the results of a fertilizer treatment in which potassium was excluded. Potassium appeared not to be limiting in the initial years of production on this newly cleared soil. In 1986 the nil-K treatment (120-120-0) provided 2.86 tons/acre of dry matter (DM), and in 1987 the 90-90-0 treatment provided 2.51 tons/acre. Annual removal of K, however, can eventually deplete enough of the native soil K for it to become limiting. In another trial at Point MacKenzie, barley showed a large response to K additions in the fourth year of cropping (Michaelson and Ping, 1987).

Data from these two trials indicate that oats cut in the fully headed, pre-milk stage (73-to-76 days after planting in these trials) can provide about two tons of dry matter per acre with crude protein content of 10-to-12 percent when fertilized at planting with about 90 lbs N and 30-to-60 lbs P_2O_5 per acre. Yields can be increased with higher rates of P, and crude protein can be increased with higher rates of N.

Trial set B

A trial was conducted in 1985 testing four rates of nitrogen with harvests taken at four different stages. This trial was conducted on a site with shallow soil, varying in depth from 7-to-12 inches. A droughty period occurred during the July to August period, a crucial part of the growing season. Yield responses to N applications above 40 lbs/acre were inconsistent, with some increases of 11-to-14 percent obtained (Figure 5). The dry growing conditions resulted in low yields. Crude protein responses were more definitive than yield responses, being consistently positive to increasing levels of nitrogen (Figure 6). Crude protein contents at 130 lbs N/acre were 18-to-65 percent higher than they were at 40 lbs N/acre at the four harvest stages, with the largest percentage increase occurring at the last harvest.

The 1986 and 1987 trials were conducted on a site with soil depth of 12-to-16 inches. With improved site conditions and more favorable precipitation, yields were much higher than they were in 1985 (Figure 5). In 1986 applications of N above 60 lbs per acre generally produced only small increases in yield. In 1987 applying 70 lbs N/acre increased yields 10-to-15 percent above those obtained at 35 lbs N/acre, but no additional yield increases were produced at 105 lbs N/acre.

Consistent increases in crude protein content were realized with each increment of nitrogen in both

Figure 6: Crude Protein (%) at Different Harvest Stages (response to N)

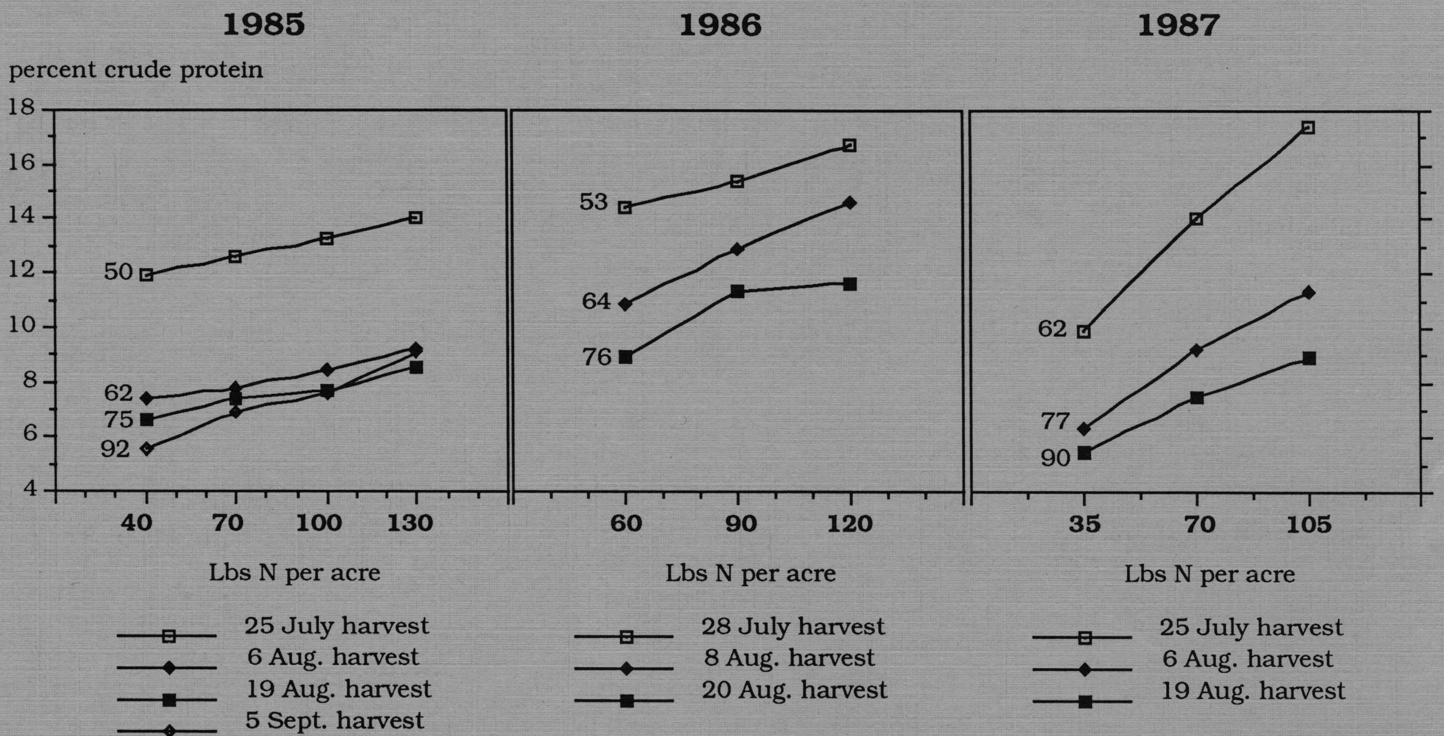


Figure 6. Crude protein content at different N rates and harvested at successive growth stages in 1985, 1986, and 1987. Figures to the left of yield lines are number of days after planting until date of harvest. In 1985, harvests were taken in the boot, headed, early milk, and soft-dough stages. In 1986 and 1987, harvests were taken in the emergence, fully headed, and milk stages.

1986 and 1987 (Figure 6). In 1987 the largest increases were obtained with the first increment of nitrogen above the lowest rate applied; 70 lbs N/acre increased crude protein contents 41-to-46 percent over that obtained with 35 lbs N/acre at the three harvest stages. As a rule, the largest decline in forage quality owing to maturation (time of harvest) occurred between the first two harvests, from the boot or emergence stage to the headed stage, with smaller declines occurring from the headed to later stages of harvest.

It is apparent, however, that growing conditions affected not only yield but crude protein content as well. The degree of response to different nitrogen treatments, as reflected in the slopes of the lines on the graphs in Figures 5 and 6, varied between years for comparable harvest stages. This is largely attributed to differences in growing conditions. The pronounced dry conditions of 1985 depressed the levels of crude protein and the degree of response to increased applications of nitrogen. The generally steeper angle of the lines for 1987 indicated a greater degree of response to added nitrogen than was obtained for the other years. The more even distribution of precipitation in 1987 might have accounted for it. In comparing the 1986 and 1987 trials conducted on the same site, the cooler conditions in the early growth stages of 1987 prolonged the time necessary to reach comparable stages of growth.

Increasing phosphorus treatments in 1986 from 80 to 120 lbs P_2O_5/acre had no apparent effect on yield or crude protein contents (Table 3). In 1987, however, increasing phosphorus treatments from 40 to 80 lbs P_2O_5/acre produced consistent increases in yield equalling 12-to-16 percent of the three harvests (Table 4). Crude protein contents in general were lower at the higher phosphorus treatments.

SUMMARY

Evidence from five trials conducted with oat forage at Point MacKenzie from 1985 to 1987 have indicated the following:

a). little response in yield to nitrogen treatments above 60-to-80 lbs per acre;

b). yield responses to phosphorus up to 80 lbs P_2O_5 /acre;

c). responses in crude protein content to nitrogen up to 120 lbs N/acre;

d). no response in crude protein content to phosphorus treatments except as an indirect effect on yield;

e). dilution of crude protein content by increasing yields without sufficient nitrogen fertilization; in these trials, 90 lbs N/acre was inadequate to maintain crude protein contents when yields were increased with added phosphorus treatments, whereas 120 lbs N/acre appeared adequate to maintain crude protein levels;

f). more rapid decline in crude protein content from boot to headed stages of growth than from headed to later stages; and

g). differences in degree of response to fertilizer rates because of growing conditions; droughty conditions depressed not only yields but also crude protein contents (probably by rendering N less available).

The data indicate that oats cut in the fully headed, pre-milk stage can provide about two tons of dry matter per acre with 10-to-12 percent crude protein content when fertilized at planting with about 90 lbs N and 30-to-60 lbs P_2O_5 per acre. Yields can be increased with higher rates of P, and crude protein can be increased with higher rates of N. Yields of three-to-four tons per acre may be realized by cutting in the milk to soft- dough stage with a concomitant acceptance of lower crude protein vales than when cut at an earlier stage. Values may be lower or higher than those stated above, depending on growing conditions. Though potassium appears not to be limiting in the initial years of cropping on newly cleared ground, it is subject to depletion and maintenance levels of 40-to-60 lbs of K_2O/acre should be applied, particularly after two to three years of cropping.

Table 3. Effect of phosphorus rates on dry matter yield and crude protein contents in 1986 trial with three harvest times

	July 28 Harvest		Aug.8 Harvest		Aug 20 Harvest	
Lbs / Acre P_2O_5	T/acre Yield	C.P. %	T/acre Yield	C.P %	T/acre Yield	C.P. %
80	1.60	15.6	2.30	13.1	3.11	10.9
120	1.64	15.4	2.31	12.5	3.17	10.3

Note: Figures are means of determination for all three nitrogen treatments.

Table 4. Effect of phosphorus rates on dry matter yield and crude protein contents in 1987 trial with three harvest times.

	Aug. 3 Harvest		Aug.18 Harvest		Aug 31 Harvest	
Lbs / Acre P_2O_5	T/acre Yield	C.P. %	T/acre Yield	C.P %	T/acre Yield	C.P. %
40	1.79	14.2	2.76	9.3	3.50	7.5
80	2.04	13.4	3.09	8.6	4.05	7.0

Note: Figures are means of determinations for all three nitrogen treatments.

Literature Cited

Michaelson, G. J., J. R. Offner, and C. L. Ping. 1984. Soil fertility considerations for barley and oat forage production at Point MacKenzie. *Agroborealis* 16:(1)5-8.

Michaelson, G. J. and C. L. Ping. 1986. Extraction of phosphorus from the major agricultural soils of Alaska. *Communications in Soil Science and Plant Analysis* 17:275-297.

———————————. 1987. Effects of P, K, and liming on soil pH, Al, Mn, K, and forage barley dry matter yield and quality for a newly-cleared Cryorthod. *Plant and Soil* 104:155-16

Mitchell, W. W. 1983. Forage yield and quality of cereals at Pt. MacKenzie. *Bulletin 61. Agricultural Experiment Station, University of Alaska Fairbanks.*

Ping, C. L. and G. J. Michaelson. 1986. Phosphorus sorption by major agricultural soils of Alaska. *Communications in Soil Science and Plant Analysis* 17:299-320.

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