I'MS-1ek
2001

Nitrogen, Phosphorus and KCl Fertilizer Management for Oats

Annual report submitted to the Potash and Phosphate Institute of Canada
February 15, 2002

R.M. Mohr[1], C.A. Grant[1] and W.E. May[2]
[1]Brandon Research Centre; [2]Indian Head Research Farm

Background:

Oat production in the eastern prairies has increased in recent years, and currently accounts for more than half of total Canadian oat production and exports. Despite the growing prominence of oats in today=s production systems, limited research on fertilizer management for oats has been conducted in western Canada.

Fertilizers often account for a significant proportion of total input costs in cereal production systems, and may strongly influence crop growth, development, yield and quality. Therefore, a better understanding of the nutrient requirements and responses of oats is needed in order to develop fertilizer management strategies which optimize fertilizer use efficiency and crop yield, and thereby increase returns to producers. Moreover, improved fertilizer management of oats may help to enhance crop quality and thus the potential for producing high-quality oats that are suitable for more specialized milling and horse feed markets offering price premiums.

A three-year field study was initiated in 2000 in order to:
1) determine the effect of nitrogen, phosphorus and KCl on the growth, yield and quality of oats, and
2) determine the impact of varying combinations of N, P, and KCl on the growth, yield and quality of oats.

Materials and Methods:

In 2001, field experiments were established at two sites in the Brandon area. One site was located north of Brandon at AAFC's Phillip's Farm, on a Newdale clay loam containing low levels of soil nitrate-N and extractable-P (Table 1). The second site was located near Brookdale, MB on a producer's field containing low levels of soil nitrate-N. Extractable-P levels were higher at Brookdale than at the Brandon site, but considered marginal based on soil test results (Table 1).

Experiments were arranged in a randomized complete block design with five replicates. Treatments consisted of a factorial combination of four nitrogen rates (0, 40, 80, 120 kg N ha^{-1} as urea), three phosphorus rates (0, 30, 60 kg P_2O_5 ha^{-1} as monoammonium phosphate) and two KCl rates (0, 40 kg K_2O ha^{-1} as KCl). (For each treatment, N rates were adjusted such that each treatment received a background N application equivalent to the quantity of N supplied by the highest rate of monoammonium phosphate, in addition to the indicated nitrogen rate.) In addition, a control treatment containing no fertilizer was included in the study. Plot dimensions were 3.6 m x 14 m.

Oats (cv. AC Assiniboia) were direct-seeded in mid May using a 12' ConservaPak seeder equipped with hoe openers. At time of seeding, urea was sidebanded, and monoammonium phosphate and KCl were placed with the seed. Weeds were controlled using recommended herbicides and rates.

Various crop growth parameters were measured during the growing season. Plant density (3-4 leaf stage) and panicle density (after heading) were determined by counting the number of plants and panicles, respectively, per 1 m length of row at two locations within each plot. Crop lodging, on a scale of 1-9 was determined in early August after crop heading, and at grain harvest. In addition, plant height was determined at two locations within each plot after the crop was completely headed.

Biomass yield was determined at the tillering stage (approximately 4 wk after crop emergence) and at the late boot to early heading stage by harvesting aboveground oat growth from a 1 m length of row at two locations within each plot. In addition, 50 flag leaves were collected from each plot at the late boot to heading stage. Plant tissue samples were oven-dried (60EC), and the oven-dry weight of the biomass samples was determined. Plant tissue samples were then ground to pass a 2 mm sieve in preparation for nutrient analysis. Determination of plant tissue P concentration for tillering samples, and plant tissue N, P and K for heading samples, has not yet been completed. Flag leaf samples were stored for future analysis. Plant nitrogen status was assessed in-season at or near the late boot to early heading stage using a SPAD meter.

Grain yield was determined by straight-combining the entire plot with a small-scale commercial combine. Grain samples were cleaned using a Carter-Day dockage tester, and grain moisture determined. Grain quality parameters including test weight, thousand kernel weight, % plump kernels and % thin kernels were then determined.

Results and Discussion:

In 2001, wet conditions early in the growing season delayed seeding until mid May. However, sufficient rainfall contributed to good crop establishment and growth overall. As in the previous year, heavy rains contributed to crop lodging later in the growing season.

Crop establishment

Plant stand was not affected by fertilizer treatment at the Brookdale site. However, at the Brandon site, application of 60 kg P_2O_5 ha^{-1} resulted in a higher plant density (231 plants m^{-2}) than the control (217 plants m^{-2}); no other effects of fertilizer treatment were evident.

Although fertilizer treatment had minimal effects on plant density, fertilizer application frequently increased panicle density. At the Brookdale site, both N and KCl additions increased panicle density. Panicle density averaged 291, 365, 385 and 389 plants m^{-2} for the 0, 40, 80 and 120 kg N ha^{-1} treatments, respectively. For the 0 and 40 kg K ha^{-1} treatments, panicle density averaged 351 and 365 plants m^{-2}, respectively.

At the Brandon site, N, P and KCl each resulted in an overall increase in panicle density. However, a significant N*P interaction suggested that effects of N varied as a function of P fertilization (Fig. 1). Effects of KCl were similar to those observed at the Brookdale site, with panicle densities averaging 345 and 365 plants m^{-2} for the 0 and 40 kg K ha^{-1} treatments, respectively.

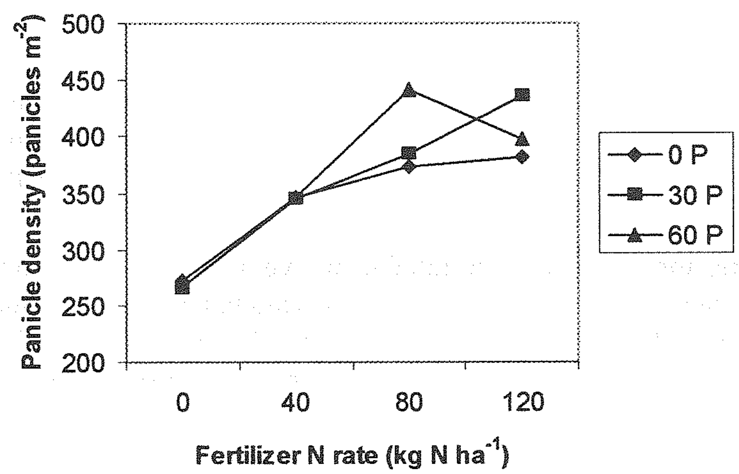

Fig. 1. Effect of N and P application on panicle density of oats at Brandon in 2001.

Crop Lodging

Crop lodging was assessed at both sites in early August and again at grain harvest.

At the Brandon site, application of N and of P resulted in an overall increase in crop lodging both in early August and at crop maturity. Typically, N had a more pronounced effect on lodging that P. For example, at crop maturity, lodging rating averaged 2.1, 3.9, 6.5, and 7.7 for the 0, 40, 80 and 120 kg N ha^{-1} treatments, respectively. In contrast, lodging rating averaged 4.5 where no P had been added and 5.3 where P had been applied. A significant N*P interaction evident for the early August rating suggested that effects of N application on lodging were more pronounced where P had been applied (Fig. 2). In part, reduced plant growth in treatments not receiving P may have made the crop less susceptible to lodging, even where N had been added. A significant P*K interaction was also evident at the Brandon site both in early August and at crop maturity

(Fig. 3). Based on preliminary analysis, it appears that the addition of KCl may have slightly reduced lodging where no P had been applied, but slightly increased lodging where P had been applied.

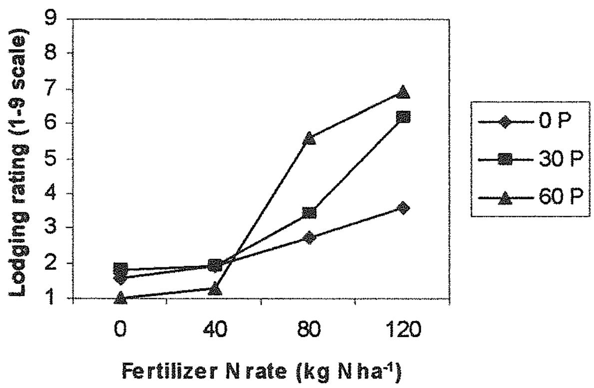

Fig. 2. Effect of N and P application on lodging rating at Brandon in August 2001.

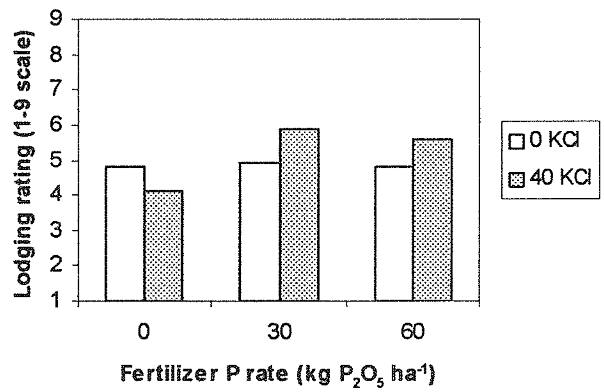

Fig. 3. Effect of P and KCl application on lodging rating at Brandon at grain harvest in 2001.

At the Brookdale site, application of N resulted in an overall increase in crop lodging both in early August and at crop maturity (Figs. 4 and 5). At both sampling times, a significant N*KCl interaction was evident. Preliminary results suggest that the application of KCl may have slightly reduced crop lodging, but only in 0 N treatments where lodging pressure was relatively low.

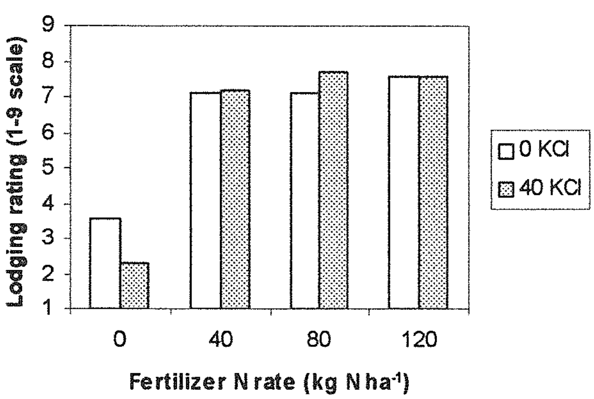

Fig. 4. Effect of N and KCl application on lodging rating at Brookdale in August 2001.

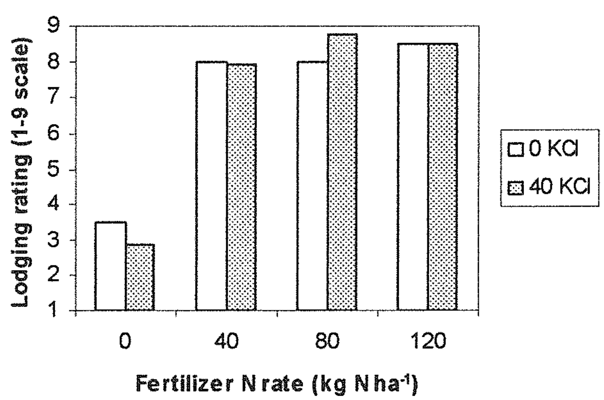

Fig. 5. Effect of N and KCl application on lodging rating at Brookdale at grain harvest in 2001.

Biomass and Grain Yield

Application of N and P improved oat growth at both field sites in 2001, as measured by increased biomass and/or grain yield. A significant interaction among the nutrients applied was evident only at the Brandon site at tillering.

Nitrogen application resulted in an overall increase in biomass yield at tillering and at crop heading at both sites (Table 2). Nitrogen application also increased grain yield. At the Brookdale site, grain yield increased with N additions of up to 40 kg N ha^{-1}. At the Brandon site, grain yield increased with N additions of up to 80 kg N ha^{-1}. At both sites, soil NO_3^--N levels were quite low prior to plot establishment, ranging from less than 11 to 21 kg NO_3^--N ha^{-1} to 60 cm (Table 1).

Phosphorus application resulted in an overall increase in biomass yield at tillering at both field sites (Table 2). Presumably, marginal soil P levels, particularly at the Brandon site, contributed to this marked early-season response to P. By crop heading, effects of P application on biomass yield were no longer evident at Brookdale. However, at Brandon, biomass yield at crop heading increased linearly with increasing P rate. Despite positive effects of P application on early-season crop growth, P application had no effect on grain yield at either site, suggesting that P was not a limiting factor in terms of grain yield (Table 2).

At the Brandon site, a significant N*P interaction was evident at tillering (Table 2). The same trend was also evident at heading but was not statistically significant (P=0.06). Preliminary results suggest that effects of nitrogen on biomass yield were more pronounced where P had been applied.

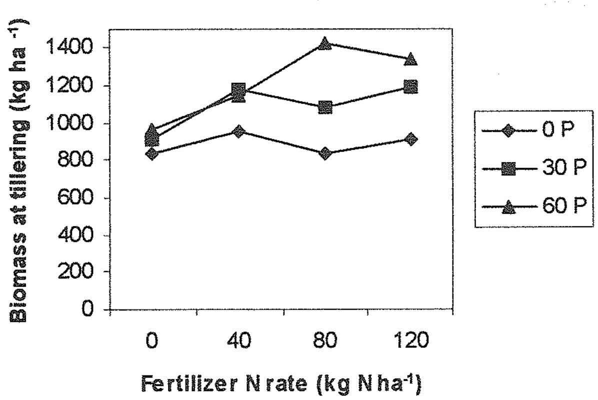

Fig. 6. Effect of N and P application on biomass yield at tillering at Brandon in 2001.

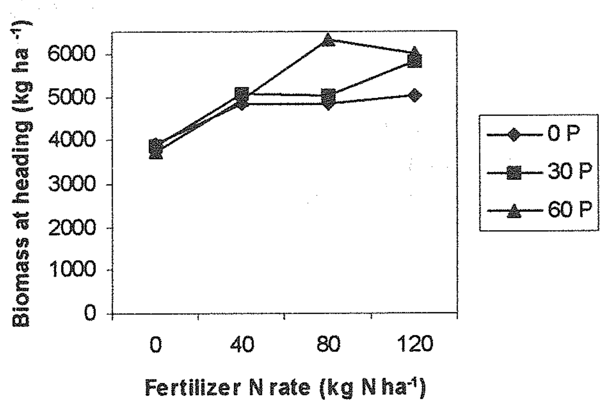

Fig. 7. Effect of N and P application on biomass yield at heading at Brandon in 2001.

Effects of KCl on yield were inconsistent. At Brandon, KCl application resulted in a small but statistically significant reduction in biomass yield at tillering only. In contrast, at the Brookdale site, KCl application produced a small but statistically significant increase in grain yield, although the site contained adequate levels of soil K according to soil testing. (Soil Cl^- levels have not yet been determined.)

Grain quality

Fertilization influenced various grain quality parameters (Tables 3 and 4). In general, N application often appeared to have a negative effect on grain quality, while effects of P application were minimal. Application of KCl appeared to enhance grain quality in some cases, particularly at the Brookdale site; however, effects of KCl on grain quality parameters were generally less pronounced that those of N. In a few cases, interactions among the nutrients applied were evident.

At Brandon, N application resulted in an overall reduction in grain quality, as measured by decreases in test weight and percent plump kernels, and increases in dockage and percent thin kernels (Table 4). Phosphorus application resulted in a small reduction in dockage, but had no other effects on quality parameters. Application of KCl resulted in a statistically significant reduction in test weight; however, the effect was very small and likely not of agronomic significance. In the case of percent plump kernels, a significant P*K interaction was evident; however, the difference in percent plump kernels among treatments was only about 1% and not likely to be of agronomic significance.

At Brookdale, N application also appeared to reduce grain quality, resulting in an overall decrease in test weight and percent plump kernels, and increase in dockage (Table 3). Phosphorus application resulted in a very small, but statistically significant decline in percent plump kernels, but had no effect on other quality parameters. Application of KCl appeared to enhance grain quality overall, as measured by increases in test weight and percent plump kernels, and decreases dockage and percent thin kernels (Table 3). In general, the observed effects of KCl on grain quality appeared to be less pronounced than those of N. In the case of percent plump kernels, a significant N*P*K interaction was evident; however, the agronomic significance of this interaction is somewhat unclear. A significant N*K interaction was evident for thin kernels; however, regardless of treatment, the percentage of thin kernels was less than 1% and, as such, not likely to be of agronomic significance.

Summary

Application of N and P improved oat growth at both field sites in 2001, as measured by increased panicle density, biomass yield and/or grain yield. A significant interaction among nutrients applied was evident for biomass yield at one site, but not for grain yield.

Nitrogen application increased crop growth throughout the growing season resulting in increased biomass yield both at the tillering and heading stages, and in increased grain yield. However, reductions in grain quality parameters were frequently associated with N application.

Phosphorus fertilization enhanced early-season crop growth at both experimental sites; however, despite this marked early-season response, P application had no effect on grain yield and a very limited effect on grain quality.

Application of KCl appeared to have limited effects on in-season crop growth. However, KCl application resulted in a small increase in grain yield at Brookdale, and in increases in test weight and percent plump kernels, and declines in dockage and percent thin kernels.

Overall, preliminary findings from 2001 are similar to those observed in 2000. Nitrogen application appears to have the greatest influence on biomass and grain yield, and on grain quality. Phosphorus application, while shown to enhance early-season growth, has been found to have no effect on grain yield and little effect on grain quality in experiments conducted to date. Application of KCl on sites considered to have adequate levels of soil K have sometimes been shown to produce small increases in grain yield and in grain quality parameters. Overall, relatively few interactions among the nutrients applied have been observed in terms of biomass and grain yield.

Studies will continue in 2002 to assess the impacts of N, P and KCl on oat yield and quality.

Table 1. Soil characteristics of field sites in 2001.

Characteristic*	Brandon	Brookdale
pH	7.8	6.8
E.C. (dS m^{-1})	0.78	0.36
nitrate-N (kg ha^{-1} to 60 cm)	<11	21
extr. P (kg ha^{-1} to 15 cm)	13.4	46
extr. K (kg ha^{-1} to 15 cm)	551	484

*Soil analysis is based on soil samples collected in fall 2000 (Brandon) or spring 2001 (Brookdale) from the general location of the experimental site. Additional soil samples were collected from the plot area in the spring of 2001; however, nutrient analysis has not yet been completed.

Table 2. Effect of N, P and KCl fertilization on the biomass yield of oats at tillering and a heading, and on the grain yield of oats at two field sites in 2001.

	Brookdale			Brandon		
	Biomass yield[1]		Grain yield[2]	Biomass yield[1]		Grain yield[2]
Treatments	Tillering	Heading		Tillering	Heading	
	-----------------kg ha^{-1}	-----------------				
Nitrogen rate (kg N ha^{-1})						
0	1587	4932	4155	905	3831	3175
40	1749	5708	4776	1095	4946	4204
80	1986	5774	4656	1116	5352	4551
120	1849	5766	4602	1145	5612	4699
Phosphorus rate (kg P_2O_5 ha^{-1})						
0	1616	5466	4555	886	4649	4080
30	1854	5392	4511	1090	4943	4239
60	1908	5778	4574	1220	5214	4138
KCl rate (kg K_2O ha^{-1})						
0	1780	5531	4455	1112	5052	4131
40	1805	5559	4639	1018	4818	4175
P-value						
N	0.0001*	0.0003*	0.0001*	0.0006*	0.0001*	0.0001*
P	0.0001*	0.11	0.49	0.0001*	0.03*	0.20
N*P	0.38	0.71	0.57	0.04*	0.06	0.90
K	0.58	0.86	0.0001*	0.04*	0.16	0.67
N*K	0.24	0.84	0.09	0.62	0.55	0.98
P*K	0.29	0.34	0.51	0.14	0.39	0.30
N*P*K	0.86	0.91	0.89	0.74	0.55	0.78
Contrasts						
N linear	0.0001*	0.0004*	0.0001*	0.0002*	0.0001*	0.0001*
N quadratic	0.001*	0.01*	0.0001*	0.07	0.01*	0.0001*
N cubic	0.03*	0.37	0.0001*	0.36	0.46	0.13
P linear	0.0001*	0.11	0.73	0.0001*	0.007*	0.38
P quadratic	0.05*	0.17	0.25	0.43	0.95	0.12
C.V.	13.6	15.4	5.3	22	19	9.4

[1]Biomass yields were determined by harvesting the above-ground portion of the plant at the tillering stage (approximately 4 weeks after emergence), and at the late boot to early heading stage

Table 3. Effect of N, P and KCl fertilization on grain quality parameters of oats at Brookdale in 2001.

Treatment	% plump kernels	% thin kernels	% dockage	test weight (g 0.5 L^{-1})
Nitrogen rate (kg N ha^{-1})				
0	96.2	0.74	3.3	231
40	95.5	0.67	3.5	228
80	94.5	0.78	3.8	225
120	93.9	0.79	3.9	220
Phosphorus rate (kg P_2O_5 ha^{-1})				
0	95.3	0.69	3.7	226
30	95.1	0.76	3.6	226
60	94.7	0.79	3.6	226
KCl rate (kg K_2O ha^{-1})				
0	94.7	0.85	3.7	225
40	95.4	0.64	3.5	228
P-value				
N	0.0001*	0.24	0.004*	0.0001*
P	0.007*	0.21	0.42	0.74
N*P	0.14	0.53	0.67	0.58
K	0.0001*	0.0001*	0.04*	0.0007*
N*K	0.28	0.004*	0.97	0.25
P*K	0.63	0.06	0.09	0.13
N*P*K	0.03*	0.11	0.65	0.23
Contrasts				
N linear	0.0001*	0.22	0.0004*	0.0001*
N quadratic	0.81	0.40	0.87	0.66
N cubic	0.45	0.16	0.52	0.76
P linear	0.002*	0.08	0.24	0.97
P quadratic	0.41	0.73	0.54	0.43
C.V.	0.90	34.4	18	2.1

Table 4. Effect of N, P and KCl fertilization on grain quality parameters of oats at Brandon in 2001.

Treatment	% plump kernels	% thin kernels	% dockage	test weight (g 0.5 L^{-1})
Nitrogen rate (kg N ha^{-1})				
0	97.0	0.48	2.1	236
40	96.1	0.53	2.0	234
80	94.7	0.62	2.3	228
120	94.1	0.64	2.5	225
Phosphorus rate (kg P_2O_5 ha^{-1})				
0	95.4	0.58	2.5	230
30	95.5	0.58	2.1	231
60	95.5	0.54	2.1	231
KCl rate (kg K_2O ha^{-1})				
0	95.4	0.60	2.2	231
40	95.5	0.54	2.3	230
P-value				
N	0.0001*	0.009*	0.0001*	0.0001*
P	0.97	0.48	0.0001*	0.64
N*P	0.75	0.65	0.12	0.27
K	0.52	0.10	0.08	0.04*
N*K	0.90	0.75	0.60	0.45
P*K	0.01*	0.87	0.57	0.15
N*P*K	0.49	0.52	0.34	0.34
Contrasts				
N linear	0.0001*	0.0009*	0.0001*	0.0001*
N quadratic	0.53	0.63	0.02*	0.30
N cubic	0.25	0.55	0.11	0.01*
P linear	0.81	0.28	0.0001*	0.35
P quadratic	0.96	0.57	0.02*	0.93
C.V.	1.4	36	16	1.7