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Nitrogen, Phosphorus and KCl Fertilizer Management for Oats

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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 2000, field experiments were established at two sites in the Brandon area containing low to moderate levels of soil nitrate-N and extractable-P (Table 1).

Experiments were arranged in a randomized complete block design with four or 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 late April to early 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 at least once during the growing season. 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 (60°C), 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, is underway. 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 2000, sufficient rainfall contributed to good crop establishment and growth overall. Oats appeared to respond well to cool conditions that prevailed throughout the early part of the growing season. However, heavy rains later in the growing season contributed to crop lodging.

Crop establishment

Plant stand was not affected by fertilizer treatment at either experimental site (data not presented). However, at the clay loam site, treatments receiving KCl tended ($P=0.07$) to have slightly lower plant densities than those not receiving KCl.

Although fertilization had little effect on plant stand, panicle density was influenced by fertilizer treatment (data not presented). At the clay loam site, both N and P application resulted in a statistically significant linear increase in panicle density. At the sandy loam site, a statistically significant N*P*K interaction was evident; however, the agronomic significance of this interaction was not clear. Overall, N and P increased panicle density at the sandy loam site, with a significant quadratic effect evident for both nutrients.

Application of N and P also influenced crop lodging at both sites, but no effect of KCl on crop lodging was evident. At both sites, N application increased crop lodging overall; however, a significant N*P interaction was evident both at the clay loam site at crop heading, and at the sandy loam site at crop maturity (Fig. 1). At the clay loam site, P application increased crop lodging in higher N treatments, but had no effect on lodging in lower N treatments. At the sandy loam site at crop maturity, P application resulted in a significant increase in lodging for the highest N treatment. Lodging was also assessed at the sandy loam site at the heading stage; however, lodging was minimal (averaging 1.8 on a scale of 1 to 9) (data not presented).

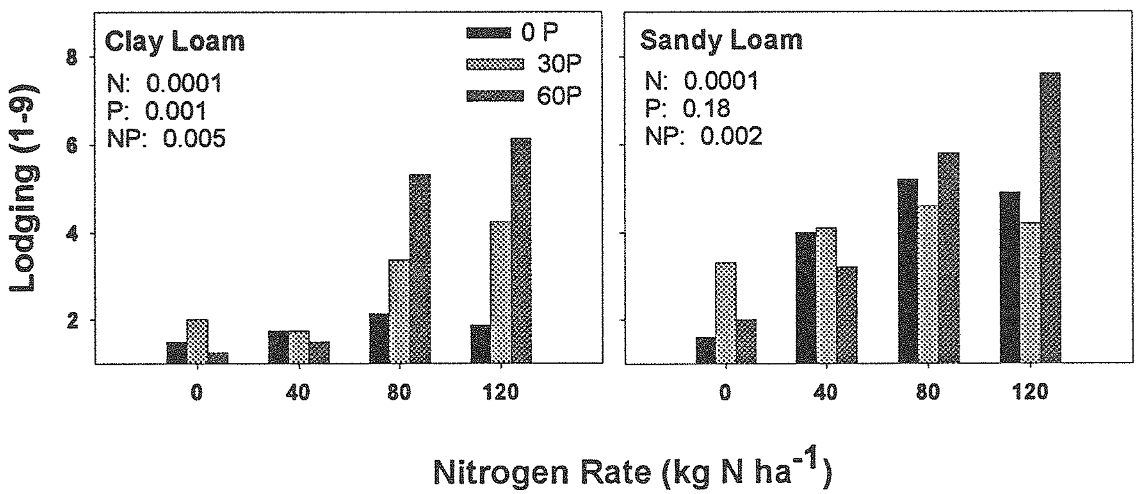

Fig. 1. Effect of nitrogen rate and phosphorus rate on lodging of oats (heading stage) at the clay loam site and oats (at crop maturity) at the sandy loam site.

Biomass and Grain Yield

Application of N and P improved oat growth at both field sites in 2000, as measured by increased biomass and/or grain yield. No significant interactions among the nutrients applied were evident.

Nitrogen application increased biomass yield at tillering and at crop heading at both sites (Table 2). This positive N response was also evident at crop maturity (Table 2). At the sandy loam site, grain yield increased with N additions of up to 80 kg N ha^{-1} and, at the clay loam site, grain yield increased with N additions of up to 40 kg N ha^{-1}. Additional N did not produce additional yield increases. At both sites, soil NO_3^--N levels were quite low, ranging from 20 to 27 kg NO_3^--N ha^{-1} to 60 cm in the fall prior to crop establishment (Table 1).

Phosphorus application resulted in a significant increase in plant biomass yield at crop tillering at both sites (Table 2). The addition of P also appeared to enhance the rate of early-season crop development, which may have contributed to improved early-season crop establishment and competitiveness (data not presented). Presumably, cool conditions early in the growing season combined with marginal soil P levels contributed to this marked early-season response to P. By the time of crop heading, effects of P application on biomass yield had disappeared at the sandy loam site; however, at the clay loam site, biomass yield at crop heading was found to increase 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).

The application of KCl did not have a significant effect on biomass or grain yield of oats at either site in 2000 (Table 2). However, KCl tended (P=0.06) to increase grain yield at the clay loam site. At both sites, the soil levels of K and Cl^- were considered to be adequate to optimal.

Grain quality

Fertilization influenced various grain quality parameters (Tables 3 and 4). Overall, N application often appeared to have a negative effect on grain quality; effects of P and KCl on grain quality were comparatively less consistent. Significant interactions among fertilizer treatments were evident in a few cases, but generally not consistent between sites.

Nitrogen application reduced the percentage of plump kernels at both field sites, and also increased the percentage of thin kernels at the sandy loam site. Both percent dockage and the percent wild oats present in the grain sample were also influenced by N fertilization. At the clay loam site, N application resulted in a significant linear increase in both the percent dockage and the percent wild oats present in the grain sample while, at the sandy loam site, a higher percent dockage and a higher percentage of wild oats in the grain sample were associated with the highest rate of N applied.

Nitrogen alone, and in combination with other fertilizer treatments, also influenced kernel weight and test weight. At both sites, declines in kernel weight were associated with increasing N applications; however, at the sandy loam site, a statistically significant N*KCl was evident. Contrast analysis indicated that KCl caused a significant increase in kernel weight only at the N rate of 40 kg N ha^{-1}. At both field sites, overall declines in test weight were also associated with increasing N rates; however, a statistically significant N*P interaction was evident at both sites (Fig. 2). Contrast analysis revealed that, at the sandy loam site, P application increased or tended (P=0.07) to increase test weight at the low rates of N, but had no effect on test weight at high rates of N. In contrast, at the clay loam site, P application did not have a significant effect on test weight at low rates of N, but decreased test weight at high rates of N. Interestingly, P application increased crop lodging at the high rates of N at the clay loam site; however, the degree to which lodging may have contributed to decreased test weight is unclear.

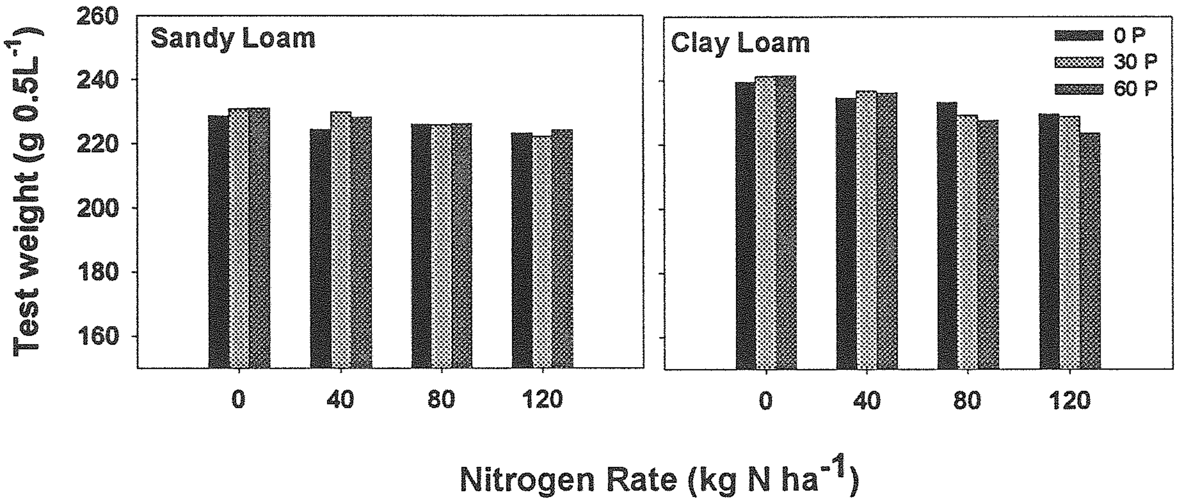

Fig. 2. Effect of nitrogen rate and phosphorus rate on the test weight of oats established at a sandy loam and clay loam site in 2000.

Phosphorus application appeared to have minimal effects on grain quality. The addition of P reduced kernel weight at the clay loam site, and decreased the % dockage at the sandy loam site.

Application of KCl also appeared to have a smaller impact on grain quality than N application, but did result in an overall increase in the percentage of plump kernels and kernel weight at the clay loam site.

Summary

Application of N and P improved oat growth at both field sites in 2000, as measured by increased panicle density, biomass yield and/or grain yield. No significant interactions among the nutrients applied were evident for biomass or grain yield; however, a few significant interactions, particularly between N and P, were evident for factors such as lodging and test weight.

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 little or no effect on in-season crop growth; however, KCl application tended to increase grain yield at the clay loam site, as well as increase kernel weight and the percent plump kernels in the grain sample.

Table 1. Soil characteristics of field sites in 2000.

Characteristic*	Brandon	Shilo
Soil type	Newdale clay loam	Stockton sandy loam
nitrate-N (kg ha^{-1} to 60 cm)	27	20
extr. P (kg ha^{-1} to 15 cm)	14	17
extr. K (kg ha^{-1} to 15 cm)	674	397
Cl^- (kg ha^{-1} to 60 cm)	99	130

*Soil analysis is based on soil samples collected in fall 1999 from the general location of the experimental site. Additional soil samples were collected from the plot area in the spring of 2000; 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 at heading, and on the grain yield of oats at two field sites in 2000.

Treatments	Sandy Loam Site			Clay Loam Site		
	Biomass yield[1]		Grain yield[2]	Biomass yield[1]		Grain yield[2]
	Tillering	Heading		Tillering	Heading	
	---------------------------	----------------	kg ha^{-1} ----	----------------	----------------	----------------
Nitrogen rate (kg N ha^{-1})						
0	494	5021	3503	475	3826	4219
40	535	6342	4652	498	4295	5206
80	577	6892	5166	516	4221	4703
120	527	6991	4914	459	4611	4492
Phosphorus rate (kg P_2O_5 ha^{-1})						
0	475	6325	4634	375	3806	4607
30	538	6331	4492	519	4387	4736
60	587	6278	4551	568	4522	4621
KCl rate (kg K_2O ha^{-1})						
0	544	6277	4535	475	4160	4562
40	523	6345	4583	499	4317	4747
P-value						
N	0.02	0.0001	0.0001	ns	0.004	0.0001
P	0.0001	ns	ns	0.0001	0.0003	ns
K	ns	ns	ns	ns	ns	ns
Contrasts						
N linear	ns	0.0001	0.0001	ns	0.0009	ns
N quadratic	0.01	0.0001	0.0001	0.01	ns	0.0001
N cubic	ns	ns	ns	ns	ns	0.0002
P linear	0.0001	ns	ns	0.0001	0.0002	ns
P quadratic	ns	ns	ns	0.01	ns	ns
C.V.	18.5	11.2	11.9	15.5	16.7	10.2

[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.
[2]Grain yield has been adjusted to 13% moisture, and does not include dockage. Grain yield at the clay loam site includes volunteer barley which could not be removed from the oat sample. (Based on hand-picking of barley from a 50 g grain sample from each plot, barley comprised an average of 2.7% of the weight of the grain sample.)

Table 3. Effect of N, P and KCl fertilization on grain quality parameters of oats at the sandy loam site in 2000.

Treatment	% plump kernels	% thin kernels	% dockage	% wild oats	kernel wt (g 1000^{-1})	test weight (g 0.5 L^{-1})
Nitrogen rate (kg N ha^{-1})						
0	93.1	1.13	2.53	0.71	37.5	230.1
40	92.0	1.38	2.49	0.43	36.8	227.4
80	91.3	1.40	2.54	0.53	36.3	226.1
120	89.9	1.53	2.97	1.02	35.8	223.2
Phosphorus rate (kg P_2O_5 ha^{-1})						
0	91.6	1.34	2.80	0.7	36.5	225.5
30	91.6	1.38	2.66	0.75	36.7	227.1
60	91.6	1.37	2.45	0.57	36.6	227.4
KCl rate (kg K_2O ha^{-1})						
0	91.3	1.38	2.69	0.69	36.4	227.0
40	91.8	1.34	2.58	0.66	36.8	226.4
P-value						
N	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
P	ns	ns	0.0001	ns	ns	0.02
N*P	ns	ns	ns	ns	ns	0.04
K	ns	ns	ns	ns	ns	ns
N*K	ns	ns	ns	ns	0.03	ns
P*K	ns	ns	ns	ns	ns	ns
N*P*K	ns	ns	ns	ns	ns	ns
Contrasts						
N linear	0.0001	0.0001	0.0001	0.005	0.0001	0.0001
N quadratic	ns	ns	0.0001	0.0001	ns	ns
N cubic	ns	ns	ns	ns	ns	ns
P linear	ns	ns	0.0001	ns	ns	0.009
P quadratic	ns	ns	ns	ns	ns	ns
C.V.	1.64	24.5	12.2	65.1	2.71	1.38

Table 4. Effect of N, P and KCl fertilization on grain quality parameters of oats at the clay loam site in 2000.

Treatment	% plump kernels	% thin kernels	% dockage	% wild oats	kernel wt (g 1000^{-1})	test weight (g 0.5 L^{-1})
Nitrogen rate (kg N ha^{-1})						
0	95.1	0.73	1.93	0.58	37.1	240.9
40	94.3	0.71	2.12	0.68	37.1	235.9
80	94.1	0.72	2.21	1.19	36.7	230.0
120	94.4	0.69	2.57	1.38	36.3	227.3
Phosphorus rate (kg P_2O_5 ha^{-1})						
0	94.6	0.75	2.24	1.02	37.4	234.3
30	94.3	0.70	2.21	0.92	36.6	234.1
60	94.5	0.69	2.18	0.94	36.4	232.2
KCl rate (kg K_2O ha^{-1})						
0	94.1	0.78	2.27	0.97	36.4	233.7
40	94.8	0.65	2.15	0.95	37.2	233.4
P-value						
N	0.01	ns	0.0001	0.0001	0.02	0.0001
P	ns	ns	ns	ns	0.0001	ns
N*P	ns	0.02	ns	ns	ns	0.006
K	0.004	0.0009	ns	ns	0.0001	ns
N*K	ns	0.02	ns	ns	ns	ns
P*K	ns	ns	ns	ns	ns	ns
N*P*K	ns	0.02	ns	ns	ns	ns
Contrasts						
N linear	0.02	ns	0.0001	0.0001	0.003	0.0001
N quadratic	0.02	ns	ns	ns	ns	ns
N cubic	ns	ns	ns	ns	ns	ns
P linear	ns	ns	ns	ns	0.0001	0.03
P quadratic	ns	ns	ns	ns	ns	ns
C.V.	1.14	24.3	17.1	50.6	2.45	1.57