Fertilizer-Use Efficiency of Point Injected N in Winter Wheat

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Introduction

Nitrogen fertilizer can be applied to winter wheat in the fall prior to seeding or as a topdress in the spring. In the former practise, fertilizer is subject to overwinter loss from leaching, denitrification and volatilization, and has been shown to be recovered less efficiently than spring applications (Christensen and Meints 1982, Grant et al. 1985, Fowler 1982). Furthermore, high rates of N application in the fall tend to increase susceptibility to root rot and winter damage (Grant et al. 1984, Tyler et al. 1981). Spring-applied N can also be used inefficiently because of ammonia volatilization (Keller and Mengel, 1986), N immobilization in surface residues (Sharpe et al. 1988) or "stranding" in a dry surface soil layer (Harapiak et al. 1986).

Point injection may improve the fertilizer-use efficiency over that of conventional methods for N application in winter wheat. Because it places fertilizer directly into the rooting zone with minimal soil disturbance, point injection facilitates effective N placement after crop establishment, thereby providing considerable flexibility in time of application. Recent small plot studies utilizing ^{15}N labelled fertilizers have shown that point injection can result in higher fertilizer-use efficiency compared to broadcast methods (Janzen et al. 1990) and that fertilizer-use efficiency tends to be greatest when applied in N is applied in early spring (Janzen unpublished data).

The objective of this work is determine the influence of time, method and rate of N application on N fertilizer use efficiency in winter wheat. This paper presents preliminary data from the first year of the study.

Materials and Methods

A field study was conducted at three locations in southern Alberta at Cranford (Brown Chernozem), Lethbridge (Dark Brown Chernozem) and Pincher Creek (Black Chernozem) during the 1988/1989 growing season. Soil samples (0-60 cm) taken in the fall of 1988 showed the Cranford, Lethbridge and Pincher Creek sites contained 22,54, and 29 kg ha^{-1} of available N (NO_3-N and NH_4-N), respectively.

The experimental design included four application times (seeding, late fall, early spring, and late spring), four N rates (20, 40, 60 and 80 kg ha^{-1}) and two application methods (broadcast ammonium nitrate [BC] and point-injected urea-ammonium nitrate

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solution [PI]). In addition, a banded urea treatment was included at seeding and two controls giving a total of 38 treatments per site. The treatments were arranged in a randomized complete block design with either four (plot size, 3 m X 20 m) or six (plot size, 3 m X 15 m) replicates . Winter wheat (Triticum aestivum 'Norstar') was seeded no-till into stubble. Growing season precipitation (April, May, June and July) was below normal at Lethbridge (174 vrs 199 mm) and above normal at Cranford (196 vrs 182 mm) and Pincher Creek (279 vrs 192 mm). The plots were harvested with a small plot combine and yields have been reported on a moisture-free basis.

Results and Discussion

Yields

Nitrogen fertilization did not result in a yield response at the Lethbridge site due to high residual soil N and lower than normal growing season precipitation. However, significant yield increases did occur at the Cranford and Pincher Creek sites. Treatment effect, however, varied between sites. Yields were significantly influenced by time (P=0.01) and rate of N application (P=0.0001) at Cranford, and by method (P=0.07) and rate (P=0.001) at Pincher Creek. However, since the interactive effects of time, method and rate were not significant at either site, only the main effects are presented here.

At Cranford, highest grain yields were observed when N was applied in early spring, although yields were only marginally higher than the seeding application (Table 1). Straw showed a similar response, but in this case yields were higher for the seeding application followed by the early spring. Lowest yields occurred when N was applied in late spring. Yields increased linearly with N rate ($r^2 = 0.949$ and 0.936 for grain and straw, respectively) with maximum yields occurred at the 80 kg/ha rate.

Table 1. Effect of time and rate of N application on winter wheat yields at Cranford in 1988/1989.

	Grain yield (kg/ha)	Straw yield (kg/ha)
Time		
Seeding	2364	2671
Late Fall	2194	2545
Early Spring	2398	2637
Late Spring	2150	2150
Rate (kg N/ha)		
0	1849	2081
20	1934	2134
40	2246	2476
60	2397	2627
80	2464	2698

At Pincher Creek, highest yields were observed in the PI treatments and like those at Cranford, yields increased in a linear fashion (r^2 = 0.964 and 0.965, respectively) with maximum yields occurring at the 80 kg N/ha rate (Table 2). However, the response to applied N was not as great. Maximum increases in grain yield at Pincher Creek were 21% compared to 33% at Cranford.

Table 2. Effect of method and rate of N application on winter wheat yields and N uptake in Pincher Creek in 1988/1989.

	Grain yield (kg/ha)	Straw yield (kg/ha)	Total N uptake (kg/ha)
Method			
Broadcast	3995	6393	98.9
Point Injection	4163	6662	104.2
Rate (kg N/ha)			
0	3557	5691	78.7
20	3846	6154	90.9
40	3926	6281	92.8
60	4226	6762	107.3
80	4312	6899	114.4

Inclusion of banding treatments at time of seeding did not improve grain yields over the other application methods (Fig.1). Contrast analysis showed yield response to BC and PI applications to be higher than that from banding at Cranford (P=0.03 and 0.001, respectively) and at Pincher Creek (P = 0.06 and 0.02, respectively). Broadcast and PI applications at either site were not significantly different from each other. The poorer performance of the banding treatments relative to the others may be attributed to drier soil conditions. The banding operation, carried out prior to seeding, caused greater soil disturbance and possibly greater loss of moisture from the surface soil than that of either the BC or PI treatments.

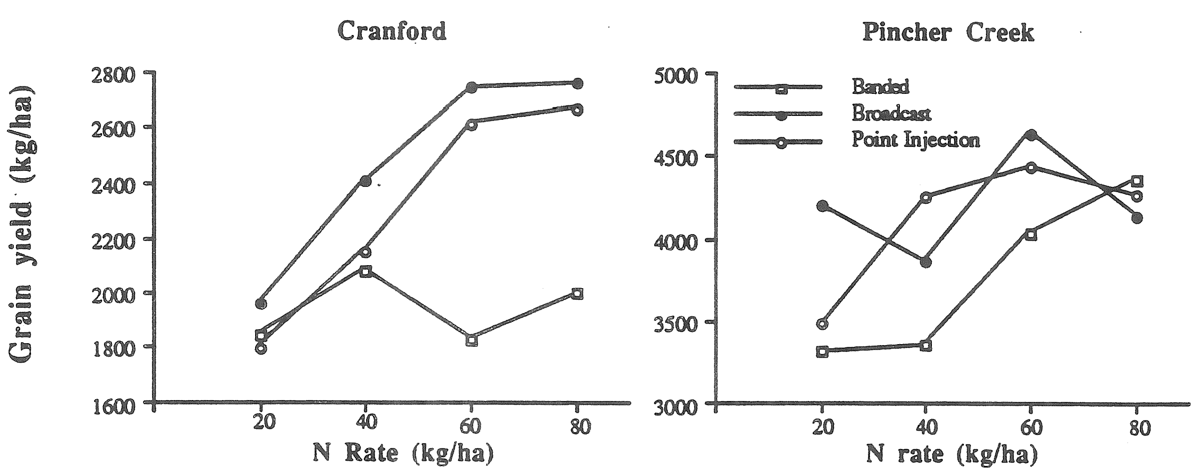

Figure 1. Influence of method of application at seeding on grain yields at Cranford and Pincher Creek in 1988/1989.

N Concentration and Uptake

Nitrogen concentrations in grain and straw at Pincher Creek were not affected by time or method of application, but increased significantly (P = 0.0001) with N rate (Table 3). Concentrations in grain ranged from 1.65 to 1.92 %, which corresponds to a crude protein (%N X 6.25) concentration of 10.3 to 12.0 %. In Alberta , crude protein of fall wheat typically ranges between 9.6 and 17.9 % with a mean of 13.7 % (Alberta Agriculture 1987). The high yields at this site arising from favorable moisture conditions would have contributed to the generally lower N contents by a dilution effect.

Table 3. Influence of rate of N application on N concentration in grain and straw at Pincher Creek in 1988/1989.

	N Rate (kg/ha)				
	0	20	40	60	80
	% N				
grain	1.65	1.72	1.73	1.83	1.92
straw	0.36	0.39	0.39	0.44	0.45

Removal of N by the crop was influenced by method and rate of application but not time of application, nor their interaction. When averaged across time and rate, uptake of N tended to be higher in PI treatments than in BC treatments (Table 2). However, differences were relatively small, but were statistically significant (P = 0.108). Like yields and N concentrations, total N uptake increased linearly with increasing N rate. The 80 kg N/ha treatments removed 45% more N than the unfertilized control.

Grain N uptake averaged 72% of the N removed by the crop and was significantly influenced by method (P = 0.10) and rate of application (P = 0.0001). A significant interaction between time and method was also observed at the 10% probability level. Uptake generally increased with rate regardless of time of application, but differences in uptake between methods were inconsistant (Fig. 2). At seeding BC applications tended to result in greater N uptake in grain than PI, while the opposite occurred when N was applied in early spring. Surprisingly, the highest uptake occurred at the 80 kg N/ha rate with PI in the late spring application. At this rate, grain uptake in the PI treatments were 28% higher than that in the BC treatments.

Discussion

After one year of data, the influences of time, method and rate of application on winter wheat yields were inconsistent among the three sites studied. Wheat at Lethbridge did not respond to applied N, while the response at Cranford and Pincher Creek varied.

Application of N at seeding or in early spring produced the best yields at Cranford while timing of application had no significant effects on yields at Pincher Creek. Differential responses to timing have also been demonstrated in Saskatchewan, where time of application was found to influence winter wheat yields in only 7 of 21 different site locations (Fowler and Brydon 1989).

Differences in method of application were apparent at Pincher Creek, where point injected N produced small but significant yield increases over BC methods. These yields differences are likely due to placing the N directly in the rooting zone where it is immediately available for plant uptake. Surface applied N is dependant on timely rainfall events to move the N into the rooting zone. Therefore, its' availability may not correspond to times of high plant requirements. This was evident in the late spring applications at Pincher Creek, where the PI treatments produced an average yield of 4437 kg ha^{-1} compared to an average of 3958 kg ha^{-1} in the BC treatments.

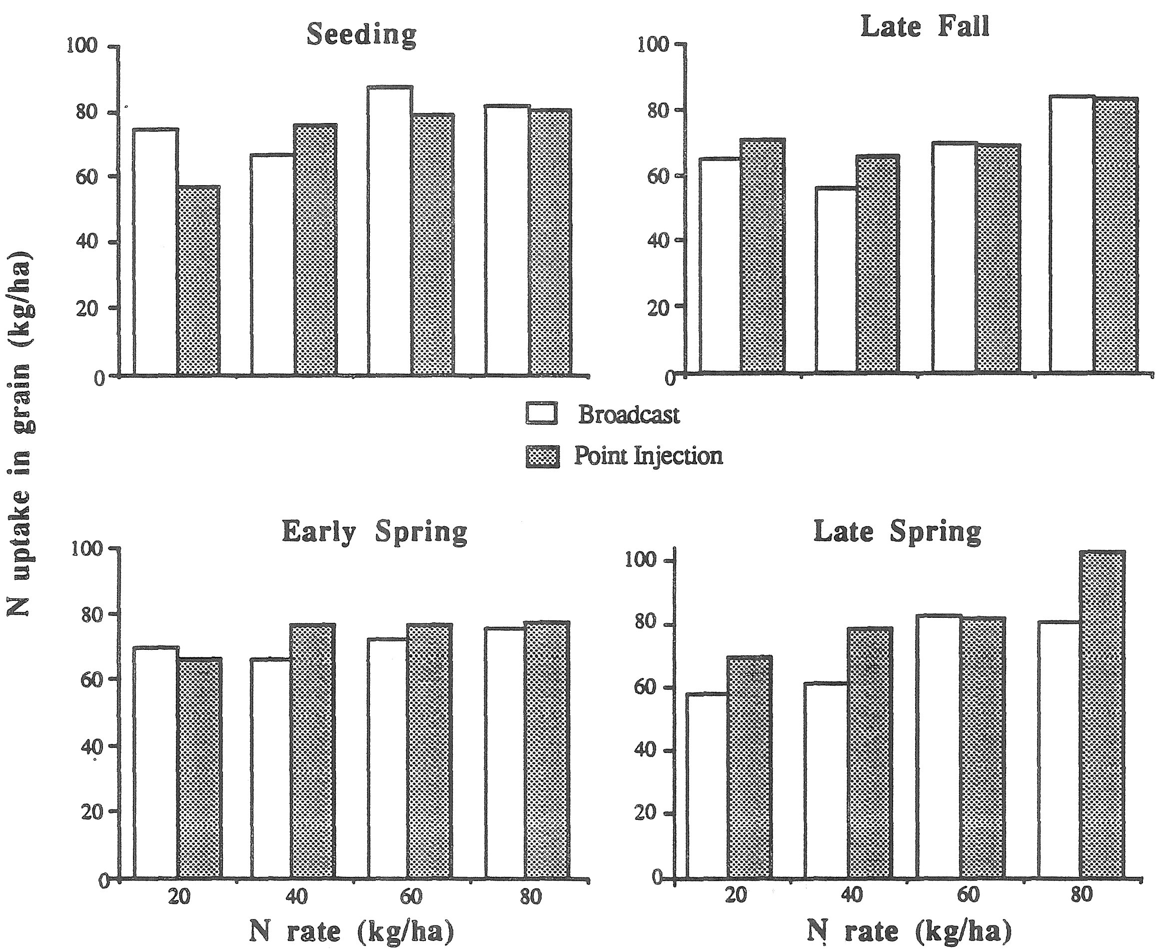

Figure 2. Influence of time and method of application on grain N uptake at Pincher Creek in 1988/1989.

Fertilizer use efficiency at Pincher Creek, as indicated by the difference in N uptake between fertilized treatments and unfertilized controls was also influenced by method of application. Averaged across times and rates of application, the crop removed 28% more fertilizer N from the PI treatments than from the BC treatments (eg. 25.8 vrs 20.2 kg ha^{-1}). This corresponds to fertilizer recoveries of 43 and 57% for the BC and PI treatments, respectively.

In the PI treatments, the % recovery of applied N at seeding, late fall, early spring and late spring averaged 39, 50, 55 and 84%, respectively. This increase in recovery of fertilizer N with delay in application agrees well with earlier ^{15}N studies investigating point injection (Janzen unpublished data). The increased fertilizer efficiency in the later application times likely reflects reduced leaching, immobilization and leaching losses (Malhi and Nyborg, 1983; Powlson et al. 1986).

After one year of study and with only N uptake data available for one site, the results of this investigation are not conclusive, however they do suggest that PI may be a viable method of fertilizer application in winter wheat. The advantage of timing application to suit crop growth requirements and available moisture conditions, and the potential for improved fertilizer use efficiency will potentially enhance winter wheat production and ease environment concerns associated with over-fertilization.

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