Impact of Nitrogen Source, Anhydrous Ammonia Rate, Opener Type, and Landscape Position on Grain Yield and Grain Protein of Spring Wheat

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Introduction

In most semiarid regions characterized by undulating or hurnmocky terrain, soil properties vary across the landscape (Pennock et al., 1994). Lower landscape positions usually have the greatest soil water and nutrient content, and are generally more productive than upper landscape positions (Stevenson and van Kessel, 1996). One of the most important landscape-scale controls of crop productivity is the redistribution of water toward convergent areas (Pennock et al., 1987). Despite this, landscape position has been reported to either influence (Jowkin and Schoenau, 1996; Stevenson and van Kessel, 1996) or not influence (Solohub et al., 1996) spring wheat grain yield.

Direct seeding or a one-pass placement of seed and fertilizer into untilled land is increasing in popularity (Hnatowich, 1995). Granular urea and ammonium nitrate are the primary forms of N fertilizer used in direct seeding operations. However, considering the widespread usage and relatively low cost of anhydrous ammonia, interest in using anhydrous ammonia in direct seeding operations has been stimulated. Numerous trials conducted throughout western Canada indicate that placement of anhydrous ammonia at seeding may be possible as long as adequate separation between the seed and fertilizer band is achieved (Hnatowich, 1995; Johnston et al., 1995, 1997).

Recently, several new openers and packing systems have been developed for direct seeding. These openers need to be evaluated for their suitability in placing anhydrous ammonia and their subsequent influence on grain yield and grain protein of spring wheat. Nitrogen fertilizer applications across shoulder and footslope positions will enable us to evaluate the magnitude of yield and protein responses to N fertilizer sources, rates, and types of openers across landscapes. Thus, the objective of this study was to evaluate the influence of slope position, N fertilizer source and rate, and type of opener on the grain yield and grain protein content of spring wheat.

Materials and methods

Field trials were conducted at six sites in Saskatchewan during 1996 (St. Louis, Wakaw, and St. Benedict) and 1997 (St. Louis, Hepburn, and Watrous). All sites were characterized by a hummocky surface with a complex assemblage of knolls and pot holes with slopes ranging from 4-6%. The experimental area at each site was classified into two landscape element complexes; shoulders and footslopes (Pet-mock et al., 1994).

Before seeding, soil was sampled to a depth of 20 cm at each sampling point for determination of pH, organic matter, inorganic N, moisture content, cation exchange capacity, particle size, bulk density, and Ap horizon thickness using standard methodologies. Those soil characteristics found to differ consistently between footslope and shoulder positions are presented in Table 1.

Table 1. Soil characteristics of sites.

	Footslope			Shoulder		
Location (year)	Clay (%)	OC* (g kg-‘)	NO_3-N (kg N ha-‘)	Clay (%)	OC (g kg-‘)	NO_3-N (kg N ha-‘)
St. Louis (96)	23	37	20	27	28	17
Wakaw (96)	21	17	11	21	13	8
St. Benedict (96)	28	38	7	21	22	4
St. Louis (97)	20	64	24	23	40	28
Hepburn (97)	23	37	27	25	30	12
Watrous (97)	29	35	14	29	32	12

Spring wheat *(Triticum aestivum cv.* Pasqua) was seeded at a rate of 80 kg ha-‘. Wheat was seeded on flax *(Linum usitatissimum* L.) stubble at St. Louis (both years) and at Watrous, on canola *(Brassica napus* L.) stubble at Wakaw, on pea *(Pisum sativum* L.) stubble at St. Benedict and on wheat stubble at Hepburn. Twenty kg ha^{-1} of P supplied as triple superphosphate (0-45-O) was side banded in all plots. Nine nitrogen treatments (Table 2) were placed on 2.5-m by 15-m strips, covering both shoulder and footslope positions in a randomized complete block design. Each treatment was replicated five times. Roundup (glyphosate) was applied at the recommended rate prior to seeding and any emerging weeds hand pulled. For each treatment, grain yield and grain protein were measured on shoulders and footslopes. A 2-m by 5-m area of each shoulder and footslope in a treatment plot was harvested with a small plot combine. Since the measurements were made on the same experimental unit on both the footslopes and the shoulders, repeated measures analysis over space was used.

Two openers were chosen for evaluation because they represent extremes in soil disturbance: (i) a side banding bolt-on opener and: (ii) a Sweep Wing Tip system. The side banding bolt-on opener is a dual delivery system which places fertilizer below and to the side of the seed row with a minimum separation distance of 2.5 cm in both directions. The Sweep Wing Tip system uses a high disturbance 35 cm shovel with anhydrous ammonia tubes split and extended to the tip of the shovel. Every second shank is equipped with the Sweep Wing Tip system; thus simulating a mid-row fertilizer application. The anhydrous ammonia is applied at the same depth as the seed. Shovels were equipped with froc seed boots which scatter the seed creating a seed row approximately 12.5 to 20 cm wide.

Table 2. Fertilizer treatments.

Nitrogen source	N rate (kg N ha^{-1})	Opener
Unfertilized	0	Side banding
Urea	70	Side banding
Ammonium nitrate	70	Side banding
Anhydrous ammonia	35	Side banding
Anhydrous ammonia	70	Side banding
Anhydrous ammonia	105	Side banding
Anhydrous ammonia	35	Sweep wing tip
Anhydrous ammonia	70	Sweep wing tip
Anhydrous ammonia	105	Sweep wing tip

Results and discussion

Grain yield

Averaged across the six locations, spring wheat yielded higher when fertilized with the granular fertilizers (ammonium nitrate and urea) than with the side banded anhydrous ammonia application (Table 3). The reduced grain yields were due primarily to poor yields at the Wakaw and Hepburn sites (Table 4). While all of the other sites except St. Louis in 1996, did show reduced yields the reduction was slight. Excessive trash cover at Hepburn and lumpy soils at Wakaw interfered with band sealing, causing higher losses of anhydrous ammonia in the side banded applications. Apparently band sealing in the sweep wing tip applicator was not as affected by soil conditions as the side banding opener, as grain yields were higher with the sweep applicator and not different from those resulting from fertilization with the granular fertilizers (Table 3). Side banding anhydrous ammonia resulted in a 9% decrease in grain yields compared to fertilization with the granular forms. The reduction in grain yields caused by side banding anhydrous ammonia was not the result of toxic effects to seedling establishment as grain yields responded linearly to increasing application rate (Table 5; r^2=0.94 and 0.96 for side banding and sweep applications, respectively). If anhydrous ammonia application was toxic, yields would be expected to be reduced with increasing application rate. Separating the landscape into footslope and shoulder complexes also resulted in higher grain yields with the anhydrous ammonia sweep applicator compared to the side banding applicator (Table 6). Regardless of the type of opener used to administer the anhydrous ammonia fertilizer, yields were consistently higher on the footslope than the shoulder complexes, generally reflecting the better soil conditions found in the footslopes (Table 1). However, anhydrous ammonia applied with the sweep opener resulted in average grain yields that were 6% higher than grain yields in plots side banded with anhydrous ammonia.

Table 3. Effect of fertilizer type and applicator on spring wheat grain yield and protein content.

Fertilizer	------- Side banding -------		--------- Sweep ---------	
	Grain yield (kg ha-1)	Protein (%)	Grain yield (kg ha-‘)	Protein (%)
Granular*	2483a†	15.4a	2483a	15.4a
AA‡	2270b	15.0a	2410a	14.5b
Difference (kg ha“)	213	0.4	7.3	0.9
Difference (%)	9	3	3	6

*Granular fertilizers include ammonium nitrate and urea side-banded at 70 kg ha-‘.
‘Within columns, means followed by the same letter are not different (P=0. 10).
‡ AA=anhydrous ammonia applied at 70 kg ha-‘.

Table 4. Grain yield and protein content of spring wheat fertilized with anhydrous ammonia as a percentage of fertilization with granular fertilizers.

Location	Grain yield (% of granular*)	Grain protein (% of granular)
St. Louis (96)	104	95
Wakaw (96)	85	98
St. Benedict (96)	96	97
St. Louis (97)	98	93
Hepburn (97)	86	93
Watrous (97)	97	97

Grain protein

Spring wheat grain protein content was also affected by the type of fertilizer applied and the opener used for application. At all of the sites, grain protein content was reduced with anhydrous ammonia application, regardless of opener type, compared to the granular fertilizers (Table 4). Unlike grain yields, grain protein was unaffected by side banding anhydrous ammonia, but reduced in the sweep application of anhydrous ammonia when both were compared to the granular fertilizers (Table 3). The reduction in protein content in spring wheat fertilized with anhydrous ammonia applied with the sweep opener was attributable to the two highest application rates (Table 5). At the 35 kg N ha^{-1} rate there was no difference in grain protein content between the side banding and sweep openers. The superior soil conditions in the footslope complexes compared to the shoulder complexes (Table 1) are reflected in higher grain protein contents (Table 6). The reduction in percent protein from anhydrous ammonia applied with the sweep opener compared to the side banding opener was only apparent in the footslope complexes.

Table 5. Effect of anhydrous ammonia application rate and opener on spring wheat grain yield and protein content.

	Side banding		Sweep	
Fertilizer rate (kg N ha^{-1})	Grain yield (kg ha^{-1})	Protein (%)	Grain yield (kg ha^{-1})	Protein (%)
0	1846a*	13.4a	1846a	13.4a
35	1925b	13.6a	2153b	13.5a
70	2350c	15.3b	2489c	14.5b
105	2536d	16.2c	2588d	15.6c

* Within columns, means followed by the same letter are not different (P=0.05)

‘Table 6. Effect of anhydrous ammonia opener and landform complex on spring wheat grain yield and protein content.

Opener	Grain yield (kg ha^{-1})		Protein (%)	
	Footslope	Shoulder	Footslope	Shoulder
Side banding	2422a*	2119a	15.2a	14.8a
Sweep	2578b	2271b	14.6b	14.8b
Difference’	156	152	0.6	
Difference (%)	6	6	4	

*Within columns, means followed by the same letter are not different (P=0.05).
‘Difference in grain yield or percent protein between the side banding and sweep openers.

Summary

Although a number of recent studies indicate that anhydrous ammonia can be safely applied at seeding (Hnatowich, 1995; Johnston et al., 1995, 1997) provided that the seed and fertilizer are adequately separated, the present study indicates a difference between anhydrous ammonia applicators, as well as different yield and protein responses among landform element complexes. Overall, at all but one of the sites tested, grain yields were reduced to varying degrees when anhydrous ammonia was applied compared to the granular (ammonium nitrate and urea) fertilizer forms. Similarly, percent grain protein was reduced with anhydrous ammonia applications compared to the granular fertilizers. One complicating factor that arose was that the two openers tested had opposite effects on grain yield and grain protein. In terms of grain yield, the sweep wing tip opener was superior to the side banding opener. However, in the case of protein contents the opposite was true. With both opener types, grain yields and protein contents were higher on the more fertile footslope complexes compared to the shoulder complexes.

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