SPLIT NITROGEN APPLICATIONS FOR MANAGEMENT OF YIELD AND PROTEIN OF WHEAT GROWN IN DRYLAND

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ABSTRACT

The feasibility of using split-N applications for managing yield and protein of wheat grown on dryland was studied in a field experiment initiated on a sandy loam and silt loam near Swift Current. Spring wheat was grown on wheat stubble and was fertilized at seeding with 0, 20, 40, 60, and 80 kg N/ha. In addition, five N topdressing treatments were applied at the five-leaf, flag-leaf, and anthesis to the plots receiving 0 and 80 kg N/ha at time of seeding. Topdressing treatments were 5 kg N/ha as urea-ammonium nitrate solution (UAN) foliar applied; 10 kg N as urea broadcast or UAN dribble banded onto the soil surface; 20 kg N/ha as urea broadcast; and 20 kg N/ha as UAN dribble banded. One set of plots received no topdressing treatment (Check). In general, because of the low soil NO₃-N and high soil moisture in the spring, and adequate rains during the growing season, grain yields had large responses to N applied at seeding. Grain protein decreased with the first 20 to 40 kg N/ha applied at seeding due to yield dilution, and increased above that of the unfertilized check at fertilization rates of 60 or more kg N/ha. Nitrogen topdressing early in the growing season to unfertilized crops increased both protein and yield, and increased protein only when applied later in the growing season. Nitrogen topdressing the crops that were fertilized with N had no effect on grain yield and caused a small increase on grain protein. Soil applied N topdressings tended to be less effective than foliar application because they did not receive timely rains and adequate surface soil moisture to make the fertilizer available to the crop. Foliar applied UAN, although effective in increasing protein, may produce leaf burn, which in turn may reduce grain yields and protein.

INTRODUCTION

Nitrogen (N) is an essential constituent of proteins, therefore N fertilizer management has an important role in influencing protein content of wheat. Production of high protein wheat requires adequate levels of N (Cowell and Doyle, 1993); however when N is applied at or before seeding, because of the complexity of the protein response to N supply, excessively high N applications may be required to ensure high protein wheat. This may result in inefficient N uptake, excessively high fertilization costs, and residual N in the soil may be lost by leaching or denitrification, with the consequent negative impact in ground water and air quality.

The response of wheat protein to applied N is strongly dependent on weather conditions during the growing season (Campbell et al. 1997), and the inverse relationship between grain yield and protein content has been well established. Thus, when the yield potential is high, such as in cool wet years, grain protein is usually low, and the opposite is true in hot dry years, when the yield potential is low (Simmonds 1995, Campbell et al. 1997).

In general, the application of N at or before seeding has a large effect on vegetative growth and yield, with variable effect on grain protein content. The later the vegetative stage at which N is applied, up to the flowering stage, the less is its effect on vegetative growth and yield, and the larger is the increase in grain protein (Terman et al. 1969). Wheat protein response to applied N in the period between heading and flowering can be large; however, if at this stage the N status of the plant is high, the protein response may be negligible (Stark and Tindall 1992, Tindall et al. 1995).

About two-thirds of the N in wheat grain is taken up prior to anthesis, and one third is assimilated during grain filling (Campbell et al. 1977, Cox et al. 1985). However, the size of this latter portion depends on soil moisture and soil N availability during the grain filling period. Foliar application of urea at heading stage has been shown to be effective in elevating grain protein content (Finney et al. 1957, Terman et al. 1969). By harvest, up to 78% of N that was foliar sprayed as urea at heading was assimilated and translocated into the head (Smith et al. 1991).
Similarly, granular urea spread on the soil at heading, and washed into the soil by irrigation immediately following application, can also be effective in increasing grain protein (Smith et al. 1991), but this N is not used as efficiently by the crop as urea sprayed onto the foliage. In the latter study, only 50% of the N applied as granular urea was recovered in the heads, 30% remained in the soil, and 20% was unaccounted for.

Split N applications are commonly used for cereals grown under irrigation, but they are not widely used under dryland agriculture. Current financial incentives for protein, and several recent years of low protein crops, have prompted producers to inquire as to the feasibility of using this technique.

The objective of this study was to determine the feasibility of using split N applications to manage protein in wheat grown under dryland conditions in southwestern Saskatchewan.

**MATERIALS AND METHODS**

Field experiments were initiated in 1996 to determine the effect of topdressed N on the protein content of spring wheat grown under stubble cropping with various N status at Swift Current on a Swinton silt loam, and at Cantuar on a Hatton sandy loam.

Spring wheat (c.v. Lancer) was seeded on wheat stubble with 0, 20, 40, 60, and 80 kg N/ha. Nitrogen as urea was applied with the seed at rates up to 40 kg N/ha; N in excess of this was sidebanded 2.5 cm to the side and 2 cm deeper than the seed row. At the five-leaf, flag-leaf, and anthesis growth stages, five topdressing treatments were superimposed onto the two base treatments crop. The topdressed treatments were: 5 kg N/ha as urea-ammonium nitrate solution (UAN) diluted with water (1 vol of UAN with 4 volumes of water) sprayed onto the foliage (UAN 5FS); 10 kg N as urea broadcast (UR 1OBR); 10 kg N/ha as UAN dribble banded onto the soil surface (UAN 10DB); 20 kg N/ha as urea broadcast (UR 20BR); and 20 kg N/ha as UAN dribble banded (UAN 20DB). One set of plots received no topdressing treatment (Check). The experiment was laid out as complete randomized blocks with a split-split plot configuration and four replicates. Growth stage were main plots, topdressing treatments were sub-plots, and rates of N applied at seeding were sub-sub-plots. Residual soil N and soil moisture were determined in soil samples (0-120 cm) removed shortly before seeding. In this paper, only the response to topdressing is discussed for the plots receiving no N and 80 kg N/ha at seeding.

**RESULTS AND DISCUSSION**

Soil test nitrogen in the spring was low in both soils (Table 1) because of high yields in 1995 and above average precipitation received since harvest. Indeed, seeding was delayed until May 21 in the sandy loam, and until May 23 in the silt loam due to persistent spring rains. Available moisture in the spring was very high, totalling 45.7 and 39.5 cm in the O-120 cm depth in the Hatton and Swinton soils, respectively. Below the 30 cm depth, the soil at both sites was nearly saturated, with volumetric water contents ranging from 39 to 40%. At the Hatton soil site, it rained 17 mm between the time of soil sampling and seeding so that a large proportion of soil NO3-N measured in

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<th>Swinton silt clay NO3-N (kg/ha) Available water (cm)</th>
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<td>0-30</td>
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<td>30-60</td>
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<td>Total</td>
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surface layers may have been leached further down the profile by the date of seeding. Rain from seeding to harvest was 140 mm at Cantuar and 142 at Swift Current.

**Yield and protein response to nitrogen applied at seeding**

Grain yield response to N applied at seeding was linear at Cantuar, with a yield increase of nearly 1000 kg/ha at the maximum application rate of 80 kg/ha (Fig. 1a). At Swift Current, grain yields increased linearly up to 40 kg N/ha, gaining some 800 kg/ha, and remained nearly unchanged at higher N rates (Fig. 1b).

Grain protein at both sites was low. At Cantuar it averaged 9.3%, and showed a noticeable, though not significant, decrease with applied N up to 40 kg/ha; it then increased above that of the unfertilized check at higher N rates (Fig. 1a). A similar response was observed at Swift Current, but here protein was depressed only when 20 kg N was applied, and increases in protein at higher rates of N were larger than those observed at Cantuar (Fig. 1b).

**Yield and protein response to topdressed nitrogen**

On the sandy loam, topdressing the unfertilized crop with 20 kg N/ha at five-leaf produced significant yield increases (P < 0.05), but had no effect on the yield of the crop fertilized at seeding (Fig. 2a). In this soil it rained 18 mm within three days of topdressing at the five-leaf stage, but little rain followed the applications at flag-leaf and anthesis (Table 2). This likely explains our failure to obtain yield responses to the later topdressed treatments even on the unfertilized crop (Fig. 2).

On the silt loam soil, where it rained only 1 mm within seven days of topdressing at the five-leaf stage (Table 2), dribble banding of UAN had no effect on yields, but broadcasting 10 or 20 kg N/ha of urea at this stage increased yields (P < 0.05) by an average 600 kg/ha (Fig 3a). As observed in the sandy loam, topdressing at later stages or topdressing the fertilized crop had no effect on yields (Fig. 3). The positive response to early topdressing for the unfertilized system, despite little rainfall to move N into the soil, suggests that the excellent spring soil water (Table 1) and rain between seeding and the five-leaf stage had a contributing influence on N uptake at the five-leaf stage. Indeed, between seeding and five-leaf it rained 84 mm at this site.

These results confirm those of previous studies which show increased yields with topdressed N applied early in the growing season, and smaller effects with later applications (Finney et al 1957). The lack of effect of UAN dribble banded on the soil surface on grain yield appears to be due more to lack of rain in the days following application than was the case for urea. Foliar spray of UAN at 5 kg N/ha did not significantly affect yield in either soil, though there was a tendency for this treatment to increase yield of the unfertilized crop when applied at the five-leaf stage (Figs. 2 and 3).

Foliar spray of UAN at 5 kg N/ha produced substantial protein increases (P < 0.05) in the sandy loam, regardless of growth stage, and even on the the crop that was fertilized with 80 kg N/ha (Fig. 4). On the silt loam soil, foliar spray at the five-leaf stage tended to increase the protein of the unfertilized crop, but did not affect that in the fertilized system (Fig. 5). However, when applied at flag-leaf or anthesis, it produced substantial leaf burn, even though we diluted the
fertilizer by a factor of 5. This leaf burning negatively affected crop growth, and tended to reduce grain protein especially when applied later in the season.

Protein responded positively to topdressing with liquid or granular fertilizer applied to the soil, but the results were not consistent. In general, the treatments that produced protein increases in the unfertilized crop produced much smaller increases in the crop fertilized at seeding in both soils. On the sandy loam, in addition to the protein increases obtained with the foliar spray on the unfertilized system, UAN and urea topdressed generally increased protein at 10 and 20 kg N/ha rates, except when applied at anthesis (Fig. 4a). On the fertilized system, protein increases were much smaller than those for the unfertilized crop, and urea and UAN topdressed at 10 and 20 kg N/ha generally increased protein, except when applied at anthesis (Fig. 4b). In the silt loam soil, UAN 10DB applied at five leaf and anthesis, and UR 20BC at five-leaf produced significant (PS 0.05) protein increases (Fig. 5a). On the fertilized crop the same treatments produced smaller protein increases, and only UAN 1 ODB at five-leaf and anthesis increased protein significantly (PI 0.05) (Fig. 5b).

The surprisingly large yield and protein response to 20 kg N/ha as urea broadcast at the five-leaf stage in the sandy loam soil may be due to the fact that at this site we received 79 mm of rain between soil sampling and seeding, and a further 44 mm between seeding (and fertilizing) and the five-leaf stage. This large amount of water may have leached soil and fertilizer N below the depth to which the crop had rooted, thereby forcing the emerging crop to start development under severe N stress. The application of 20 kg N/ha at the five leaf stage may have stimulated the growth of the crop until its roots reached lower soil depths to which N may have been leached. This is supported by the fact that the amount of N in the unfertilized crop receiving the UR 20BC topdressing at the five-leaf stage had 35 kg/ha more N in the grain than the crop that received no topdressing treatment (data not shown).

These results agree with those of a previous study indicating that the protein increases obtained with topdressed N were inversely proportional to the nitrogen status of the crop (Tindall et al. 1995). It was surprising to find that most topdressing treatments applied to the soil produced protein increases early in the growing season while those applied at later growth stages often did not. Finney et al. (1957) and others report that the opposite is common. However, our results appear to be related to the amount of rain received in the days following the topdressing treatment (Table 2).

**CONCLUSIONS**

After one year of field tests, the results suggest that there may be opportunity to use split N applications to manipulate grain yield and protein of wheat grown under dryland conditions more effectively than when all the N was applied at seeding. Top dressing N early in the growing season has the potential to improve the yield and protein of N deficient crops; when applied at later stages it has the potential to increase grain protein. However, because liquid and granular fertilizers applied to the soil surface rely on rain to be incorporated into the soil, their effects are uncertain. Foliar application of N may be a promising technique; however, when using UAN in this manner, care must be taken to avoid leaf burn that may affect crop growth. Topdressing N on crops already supplied with adequate amounts of N does not influence yield and will rarely have a large impact on grain protein.

**REFERENCES**


Figure 1. Yield and protein (13.5% moisture basis) responses to nitrogen applied at seeding in a Hatton sandy loam at Cantuar, and a Swinton silt loam at Swift Current.
Figure 2. Wheat yield increase resulting from topdressing N onto an unfertilized crop (a) and a crop fertilized with 80 kg N/ha at seeding (b), grown on a Hatton sandy loam at Cantuar.
Figure 3. Wheat yield increase resulting from topdressing N onto an unfertilized crop (a) and a crop fertilized with 80 kg N/ha at seeding (b), grown on a Swinton silt loam at Swift Current.
Figure 4. Wheat protein increase resulting from topdressing N onto an unfertilized crop (a) and a crop fertilized with 80 kg N/ha at seeding (b), grown on a Hatton sandy loam at Cantiar.
Figure 5. Wheat protein increase resulting from applying 0 and 80 kg N/ha on a non-internilled crop (a) and a
internilled crop (b).