SELECTING A NITROGEN SOURCE FOR OPTIMUM FERTILIZER EFFICIENCY IN NO-TILL WINTER WHEAT

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ABSTRACT

Successful production of winter wheat (Triticum aestivum L.) on the Canadian prairies requires that the crop be no-till seeded into standing stubble so as to increase the opportunity of trapping an insulating layer of snow. Deficiencies of soil nitrogen (N) associated with stubble fields must be corrected by the addition of fertilizer N if optimum yields are to be achieved. While ammonium nitrate N fertilizer has been the commonly recommended N source for application to the surface of unworked fields, it has become increasingly more difficult to obtain with the current domination of the dry fertilizer N market by urea. As a result winter wheat producers have had to consider alternate N forms for application to no-till fields. In this study replicated fields trials were established at ten locations over two years (1986-1987) to evaluate the effects of the N forms urea, ammonium nitrate and urea ammonium nitrate (UAN) solution either early spring broadcast or surface banded on no-till fields of winter wheat. Late (3 week delay) broadcast applications of urea and ammonium nitrate were also included in the second year of the study. Grain yield, protein concentration and grain protein yield data was collected and analyzed for comparison of treatments. Both years of the study were characterized by early season moisture deficits and in 1986 high levels of residual soil NO_3-N. While significant responses to N rate were obtained for all variables at most sites, very few significant differences were recorded between the N treatments. In general early broadcast applications of urea and ammonium nitrate increased grain and protein yields over late application dates. This lower yield associated with late application was accompanied by significantly increased grain protein concentrations, indicating uptake of the N was occurring after the yield potential of the crop had been determined. Dribble bands of UAN solution produced higher grain and protein yields than surface spray applications, indicating increased losses associated with the broadcast spray to no-till fields. Calculated N recovery for treatments indicated that while the late applied treatments showed a high recovery of N in grain and grain + straw samples this was not reflected in grain yield.

INTRODUCTION

The increased interest in the production of winter wheat in Saskatchewan has developed as a result of the crop being successfully overwintered by no-till seeding into standing stubble (Fowler and Gusta, 1978). While seeding into standing stubble aids in trapping snow to insulate the crop against damaging low temperatures stubble fields are usually always low in plant available nitrogen (N). Correction of this N deficiency is critical if optimum yields are to be achieved. As a result N fertilizer represents a major input cost in the production of no-till winter wheat (Fowler and Entz, 1986).

Rapid early season growth of winter wheat results in a high N demand. On average about ninety percent of the total N in the plant at harvest is taken up by anthesis around the end of June (Schewe and Fowler, 1987). Fertilizer N must be applied so that it is available for uptake during this early growth period.

Nitrogen availability also has an influence on the protein concentration of winter wheat. Fowler (1986) reported that N fertilizer additions resulted in significant grain protein yield increases. Grain protein has been suggested as an effective post-harvest indicator of adequate N nutrition, with protein concentrations of less than 12% indicating that yields were most likely limited by an N deficiency (Goss et al., 1982).

Spring broadcast applications of ammonium nitrate N fertilizer has been the recommended means of applying N to winter wheat (Fowler, 1982). Spring application of N provides the producer with an opportunity to assess both winter survival and spring soil moisture prior to N fertilization. However, with urea now dominating the N fertilizer market ammonium nitrate has become a less desirable product for fertilizer distributors to handle. For this reason both urea and the N solution urea-ammonium nitrate (UAN) are being used to an increasing extent on no-till winter wheat.

The objective of the experiment reported here was to determine the effect of the N forms ammonium nitrate, urea and UAN solution, either broadcast or band applied in the spring, on the grain yield, protein concentration and protein yield of no-till Norstar winter wheat.

MATERIALS AND METHODS

Field trials evaluating the performance of spring applied N treatments to no-till winter wheat were carried out in 1986 and 1987. Farmer fields of Norstar winter wheat were selected at Clair, Hagen, Kelvington, Saltcoats and Paddockwood in 1986 and Clair, Dafoe, Elrose, Hagen and Watrous in 1987.

The N fertilizer forms ammonium nitrate (34-0-0), urea (46-0-0) and urea-ammonium nitrate solution (28-0-0) were applied at rates of 0, 33, 67, 101 and 202 kg N ha^{-1} to plots 2 m x 10 m arranged in a split-plot design, main plots were rates and subplots were N treatments, with four blocks. The early broadcast applications of urea (EBC46) and ammonium nitrate (EBC34) were achieved by hand spreading. Urea-ammonium nitrate solution was sprayed (SP28) at 15 psi from nozzles mounted at 30 cm centers on a small plot tractor mounted sprayer. Surface bands of urea (BD46) were applied using a small plot disc press drill with 15 cm row spacing. Urea-ammonium nitrate bands (BD28) were applied on 30 cm centers by mounting a 20 cm piece of tygon tubing to the sprayer nozzle using a hose clamp to produce a dribble band. Ammonium nitrate was not surface band applied. In 1987 late applications (3 weeks delay) of broadcast urea (LBC46) and ammonium nitrate (LBC34) were also included. The N treatments were applied between April 25 to May 1, 1986 and April 16 to April 23, 1987, with the late treatments applied between May11 to May 14, 1987.

Straw samples were collected at harvest, dried using forced air (35oC) and ground to pass through a 2 mm sieve. Nitrogen concentration of the straw sample was determined using digestion as described by Thomas et al. (1967) and the Technicon autoanalyzer (method # 325-74W) in 1986. In 1987 straw N concentration was determined using the CHN combustion analyzer. Straw N yield was determined by difference calculation using the harvest dry matter sample and the grain yield from the plot.

At harvest plots were harvested using a small plot combine cutting 1 m wide and varying plot lengths. Grain yields were determined from the plot sample collected and a subsample removed for protein concentration determination by the Udy dye method (Udy, 1971). Grain protein yield (grain yield x protein concentration) was also determined for each plot. The percent recovery of applied N in grain and grain + straw was calculated as kg of total N in grain or grain + straw for the fertilized plots minus kg of total N in grain or grain + straw for the control plots, multiplied by 100 and divided by the kg of N applied.

The data was analyzed by analysis of variance to determine the significant N rate and N treatment differences for each site in each year. Significant N treatment effects were then separated using Fisher´s protected least significant difference. An inverse polynomial equation with a modification for yield depression at high N levels (France and Thornley, 1984) was used to illustrate grain and grain protein yield responses to available N. The Gomperetz equation was used to illustrate grain protein concentration responses to available N (Fowler et al., 1988).

RESULTS AND DISCUSSION

Grain yield

The ten sites considered in this experiment for 1986 and 1987 are listed in table 1. A significant N rate effect was recorded at seven of the ten experimental locations (Figure 1). At sites 3, 4 and 8 there was a nonsignificant response to N rate for grain yield. The absence of a rate response at all three of these sites was a result of early season moisture deficits, accompanied by excessive levels of soil residual NO_3-N (sites 3 and 8).

Significant differences between N treatments were recorded for grain yield at only four of the ten locations (Figure 2). In all cases where a significant difference was recorded early broadcast applications of ammonium nitrate produced grain yields that were either the highest yielding or grouped with the highest yielding treatments. With the exception of site 5, late broadcast

Table 1. 1986 and 1987 Spring applied nitrogen rate × treatment trials.
Test locations, soil characteristics, fertilizer application dates and general environmental conditions.

Site	Location	Year	Soil characteristics: Soil classification	Soil characteristics: Association	Soil characteristics: Texture	Early spring residual NO3-N (kg N ha-1)	Date of N application (day/mo): early	Date of N application (day/mo): late	General* environmental conditions
1	Watrous	1986-87	Dk. Br. chernozemic	Weyburn	loam	24	17/4	14/5	poor
2	Clair	1986-87	Black chernozemic	Yorkton	loam	31	20/4	13/5	poor
3	Elrose	1986-87	Dk. Br. chernozemic	Regina	hv clay	88	23/4	11/5	poor
4	Dafoe	1986-87	Dk. Br. chernozemic	Weyburn	loam	38	20/4	13/5	poor
5	Hagen	1986-87	Black chernozemic	Blaine Lake	loam	40	21/4	12/5	poor
6	Kelvington	1985-86	Black chernozemic	Yorkton	loam	41	26/4	+	good
7	Saltcoats	1985-86	Black chernozemic	Yorkton	loam	78	24/4	+	good
8	Hagen	1985-86	Black chernozemic	Blaine Lake	loam	67	28/4	+	poor
9	Paddockwood	1985-86	Dk. Gray chernozemic	Paddockwood	loam	50	1/5	+	average
10	Clair	1985-86	Black chenozemic	Yorkton	loam	73	25/4	+	poor

+ Treatments not included at this experimental site.

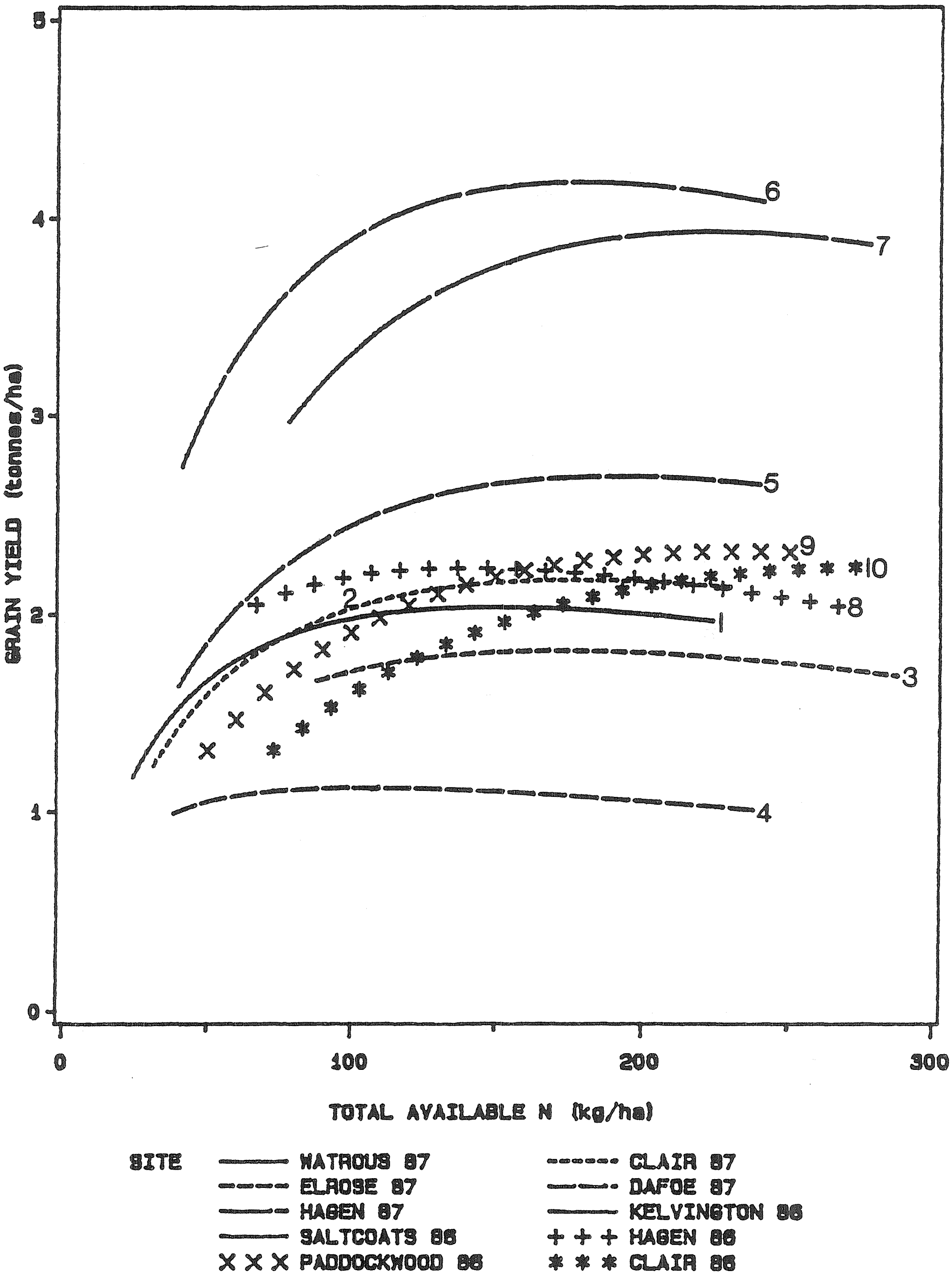
* Good - Above average rainfall that is well distributed during the growing season, moisture reserves adequate to cope with wind and heat stress experienced.

Average - No extended dry periods. Head and/or wind stress may have been yield-reducing factors. Average growing season rainfall in this area.

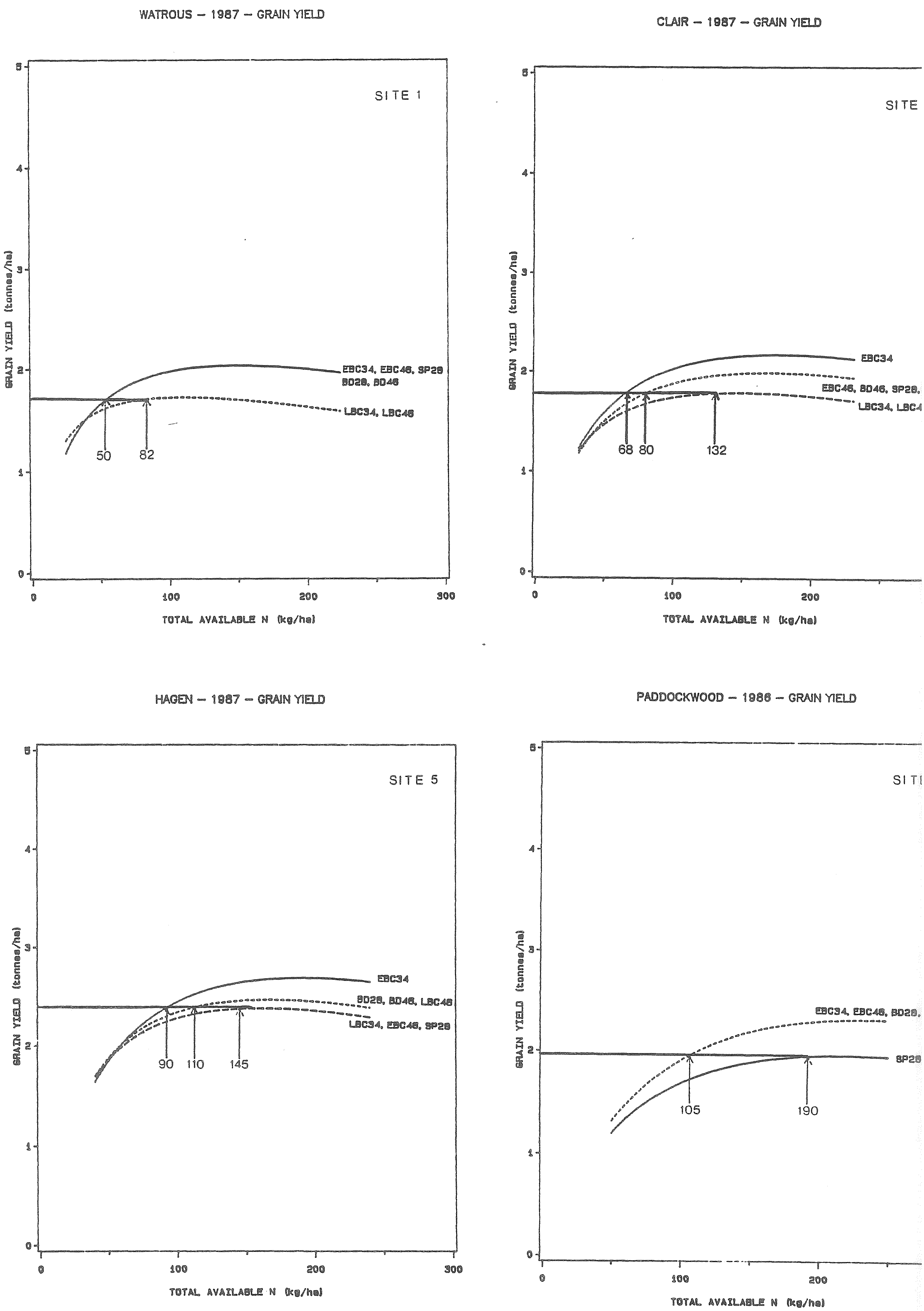
Poor - Periodic drought combined with heat and/or wind stress.

FIGURE 1.

COMBINED SITES – GRAIN YIELD – 1986/87



FUGURE 2.


WATROUS – 1987 – GRAIN YIELD
SITE 1
EBC34, EBC46, SP28
BD28, BD46
LBC34, LBC46
50
82
GRAIN YIELD (tonnes/ha)
TOTAL AVAILABLE N (kg/ha)
CLAIR – 1987 – GRAIN YIELD
SITE
EBC34
EBC46, BD46, SP28,
LBC34, LBC4
68 80
132
HAGEN – 1987 – GRAIN YIELD
SITE 5
EBC34
BD28, BD46, LBC46
LBC34, EBC46, SP28
90
110
145
PADDOCKWOOD – 1986 – GRAIN YIELD
SITI
EBC34, EBC46, BD28,
SP28
105
190

applications of ammonium nitrate and urea produced the lowest grain yields recorded in 1987 (Figure 2). As an example, 32 and 64 fewer kg N ha^{-1} were required at sites 1 and 2, respectively, for EBC34 to produce equivalent grain yields to the late broadcast treatments. These reduced grain yield responses are a clear indication that delaying N application by approximately three weeks from the earliest possible spring application date prevented achieving optimum yield potential. At site 5 (Figure 2) LBC46 produced higher grain yields than EBC46. This site, Hagen´87, was characterized by very low levels of spring soil moisture and no significant precipitation following early N application. Not until 12 days after the late N treatments were applied did a series of successive days of rainfall provide greater than 25 mm of precipitation. As a result the early applied treatments lay exposed on the soil surface for an extended period of time relative to the late applied treatments.

Application of UAN solution as a low pressure spray (SP28) resulted in lower grain yields than dribble banded (BD28) applications at sites 5 and 9. This reduced response associated with broadcast spray treatments of UAN solution on no-till fields has been previously reported (Touchton and Hargrove, 1982) and is attributed to increased N loss by ammonia volatilization.

Protein concentration

A significant N rate response was recorded for grain protein concentration at nine of the ten test locations (Figure 3). Only at site 3 did increasing N rate have no effect on grain protein concentration as a result of high levels of residual soil NO_3-N in combination with poor growing season conditions (Table 1). The general trend of the protein concentration response curve to added N has the pattern of a lag phase, followed by an increase phase and then a tailing off phase (Fowler et al., 1988). The length of the lag phase reflect the total N which is required to increase grain protein above 8.2%.

With the exception of sites 6, 7 and 9 response curves showed no initial lag phase as a result of grain protein concentration for check treatments being in excess of the minimum 8.2% (Figure 3). A combination of both high residual soil NO_3-N levels and poor growing season conditions again produced these high check treatment grain protein concentrations. At two of the three sites where a long lag phase was recorded for the protein concentration response curve (sites 6 and 7) the highest grain yields were also obtained (Figure 1). Good growing season conditions, mainly the absence of a moisture stress, produced high grain yields and the subsequent dilution of grain protein concentration at these two sites. Site 9 (Figure 3) was characterized by very cool early season temperatures, conditions which have been reported to produce an initial depression of the protein N response curve (Partridge and Shaykewich, 1972; Bole and Dubetz, 1986).

At three of the test locations a significant difference between N treatments was recorded (Figure 4). Late broadcast applications of N resulted in significantly higher grain protein concentrations than

Figure

PROTEIN CONCENTRATION — ALL SITES

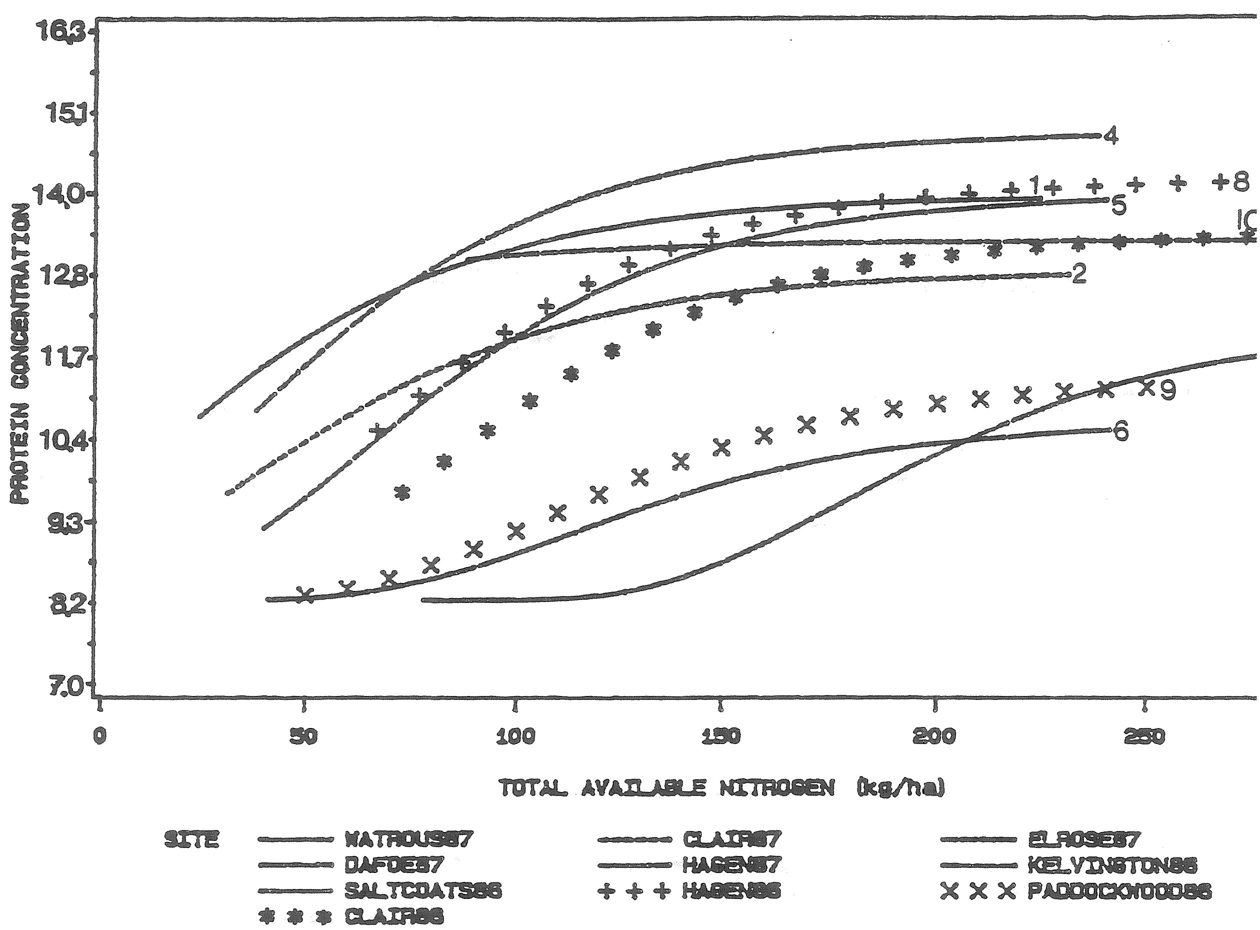
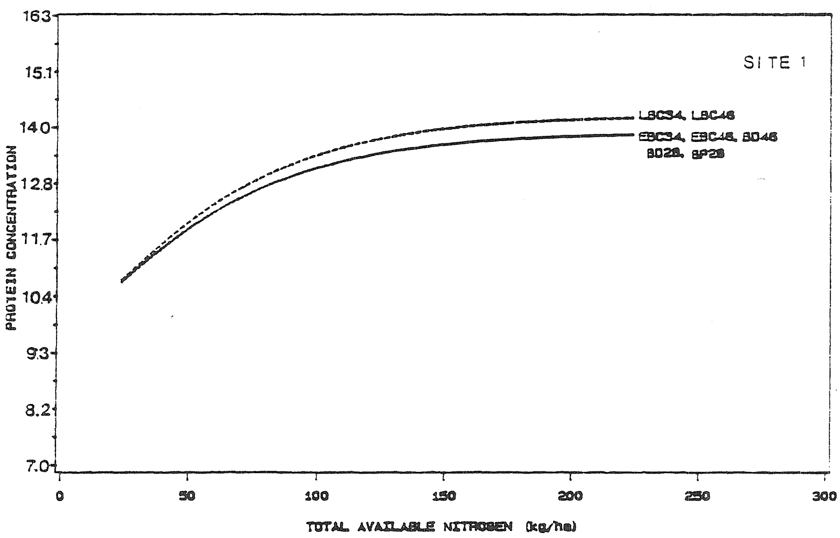
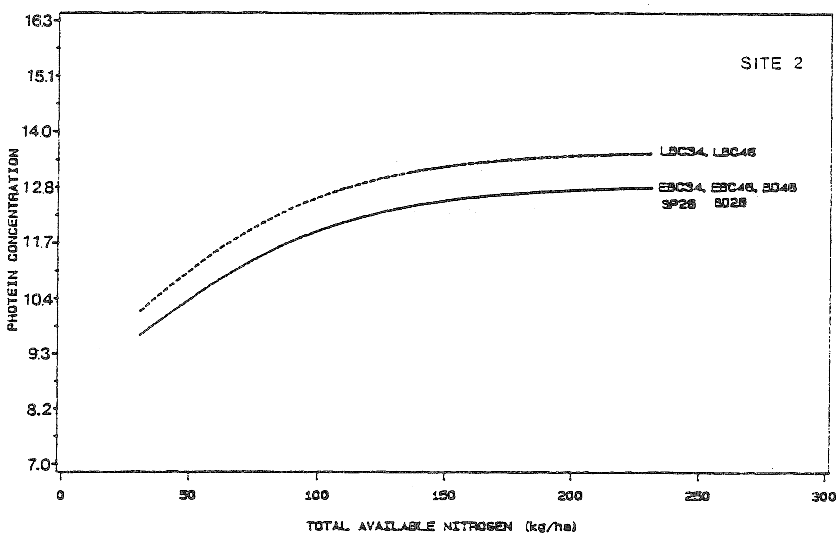


FIGURE 4.

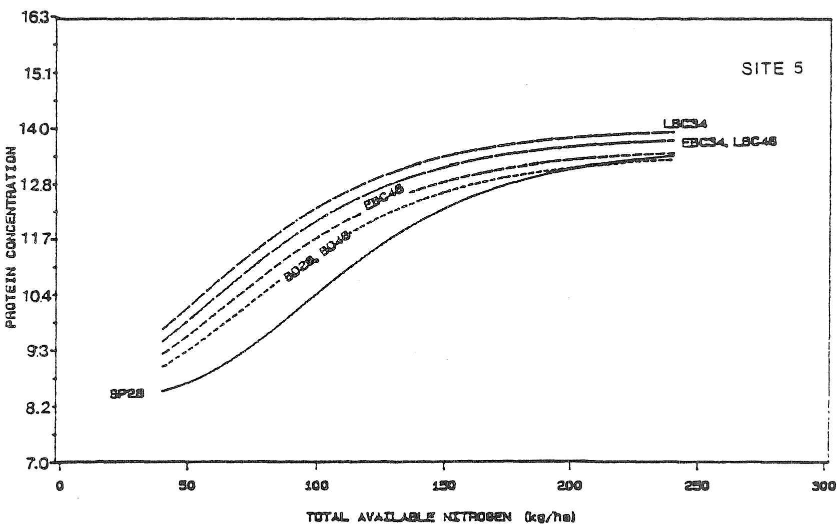
WATROUS – 1987 – PROTEIN CONCENTRATION



CLAIR – 1987 – PROTEIN CONCENTRATION



HAGEN – 1987 – PROTEIN CONCENTRATION



the remainder of treatments at sites 1 and 2 (Figure 4). Thes higher grain protein concentrations are associated with th significantly lower grain yields obtained with the late applie treatments at these sites. These protein responses to lat applications of N are a result of N becoming available to the cro only after grain yield potential had already been lost as a result o early season N deficiencies.

At site 5 (Figure 4) while late broadcast treatments did produce th highest grain protein, the treatment with highest grain yield (EBC34 Figure 2) also produced a high grain protein concentration. Earl broadcast urea, which was grouped with LBC34 and SP28 as the lowes grain yield treatments (Figure 2) produced a lower grain protein tha EBC34. The complete absence of any early growing seaso precipitation at site 5 until 12 days after the late N treatment were applied appears to have resulted in losses from the early ure and UAN nitrogen forms. This loss of ammonia N is further verifie by the sprayed UAN treatment which was not only grouped as th lowest grain yield treatment (Figure 2) but also produced the lowes grain protein concentration (Figure 4). The protein concentratio response curve for SP28 demonstrated somewhat of a lag phas indicating that higher levels of this N treatment were required t initiate an increase in protein response. The surface bande treatments BD46 and BD28, which both produced higher grain yield than EBC46 (Figure 2), had a lower grain protein concentration tha EBC46 (Figure 4).

Protein yield

A significant N rate response was recorded for grain protein yield a nine of the ten experimental sites (Figure 5). Only at site 3 wa the rate response nonsignificant. As was the case for grain yiel and grain protein concentration high levels of residual soil NO_3-] and growing season moisture stress (Table 1) prevented any respons at site 3. Increasing N rate resulted in a curvilinear protein yiel response at the remaining locations (Figure 5).

Nitrogen treatments had a significant influence on grain protei yield response at only three of the ten experimental sites (Figur 6). At site 2 EBC34 produced a greater protein yield than all of th remaining treatments which were grouped together. The EBC3 treatment also produced the highest grain yield (Figure 2), while fo protein concentration it was grouped with those treatments which wer significantly less than LBC34 or LBC46 (Figure 4). The simila pattern between the grain and protein yield response curve illustrates how grain yield is the dominant factor influencin protein yield response.

A significant treatment difference was also recorded at site (Figure 6). As with site 2 the treatment which produced the highes grain yield, EBC34, also produced the highest grain protein yield However, this is where the similarity between the sites ends. As wa discussed previously, site 5 was characterized by no precipitatio until 12 days after the late N treatments were applied. The patter of the grain protein yield response curve to added N for LBC34 an

FIGURE 5.

PROTEIN YIELD

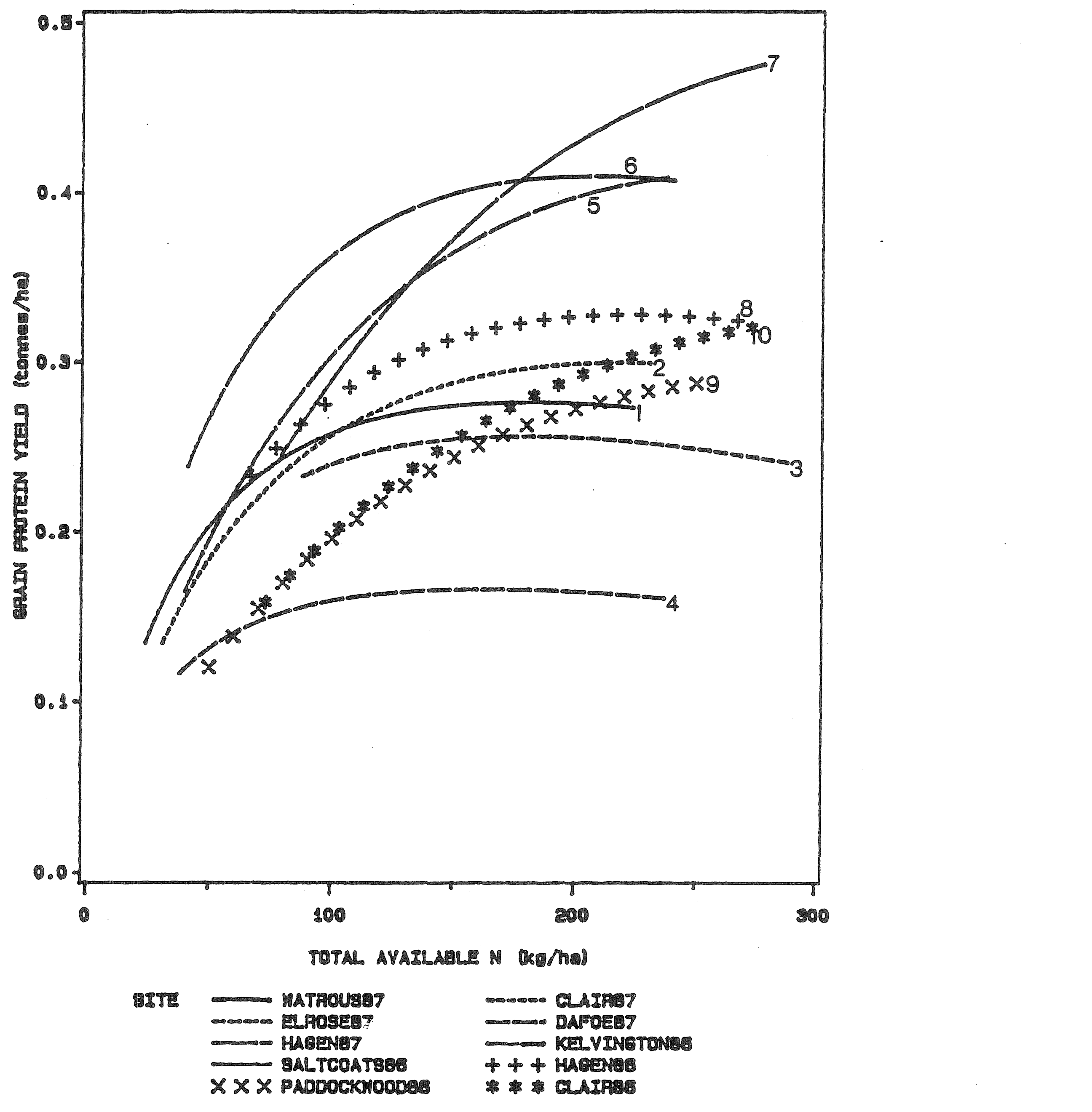
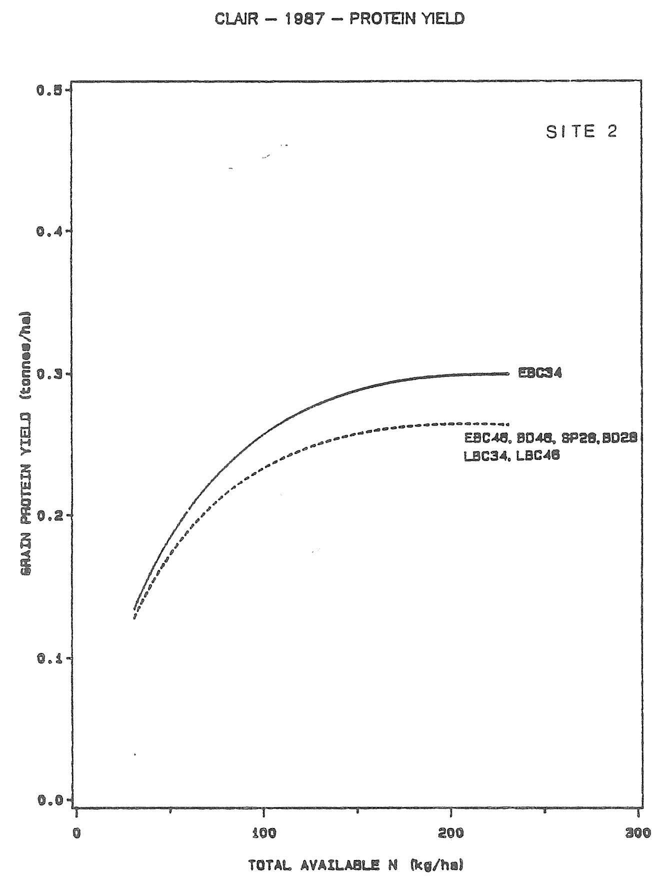
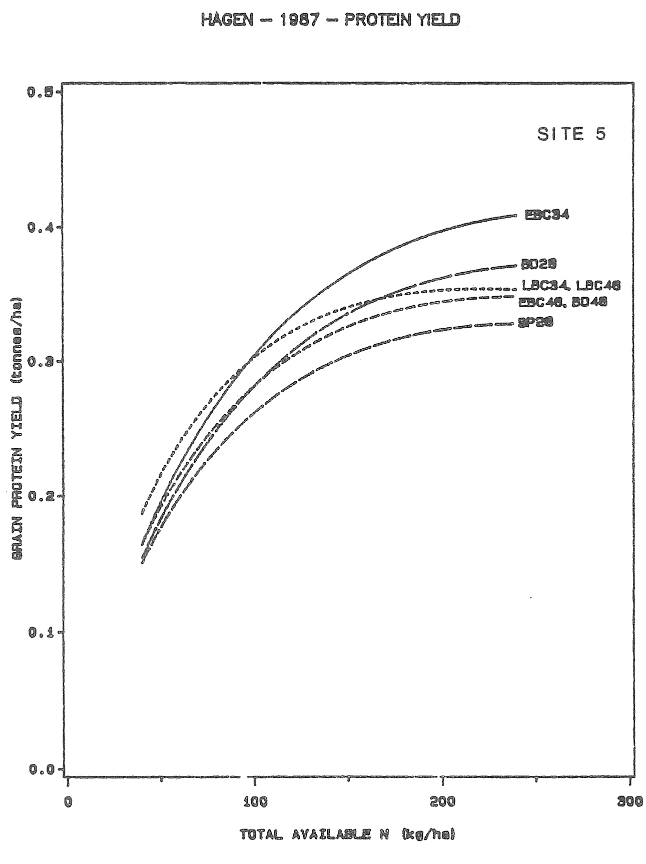
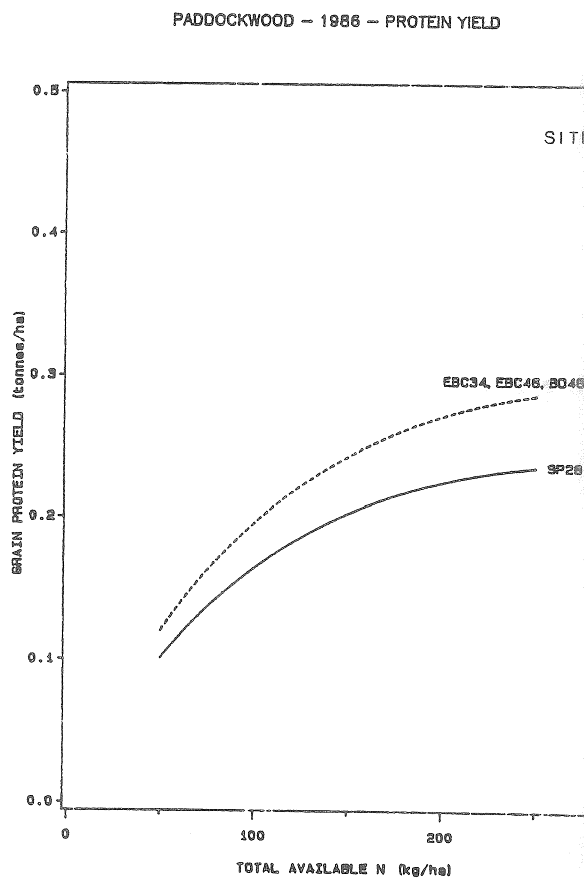


FIGURE 6.


CLAIR – 1987 – PROTEIN YIELD
SITE 2
EBC34
EBC46, BD46, SP28, BD28
LBC34, LBC46
GRAIN PROTEIN YIELD (tonnes/ha)
TOTAL AVAILABLE N (kg/ha)


HAGEN – 1987 – PROTEIN YIELD
SITE 5
EBC34
BD28
LBC34, LBC46
EBC46, BD46
SP28
GRAIN PROTEIN YIELD (tonnes/ha)
TOTAL AVAILABLE N (kg/ha)


PADDOCKWOOD – 1986 – PROTEIN YIELD
EBC34, EBC46, BD46
SP28
GRAIN PROTEIN YIELD (tonnes/ha)
TOTAL AVAILABLE N (kg/ha)

LBC46 differs from the other curves (Figure 6). This is a result of the late broadcast treatments increasing grain protein yield to a greater extent than all other treatments for the second increment of added N, while the forth increment resulted in the lowest grain protein yield. This follows the same pattern as was recorded for grain yield where LBC46 outyielded EBC46 as a result of the extended period that the EBC46 lay exposed on the soil surface. Sprayed UAN solution, which produced the lowest grain yield (Figure 2) and protein concentration (Figure 4), also produced the lowest grain protein yield.

A significant difference was also recorded for the grain protein yield response for site 9 (Figure 6). Sprayed UAN solution resulted in a significantly lower grain protein yield than the remainder of the early applied treatments. There were no late applied treatments at site 9. This difference in response of the protein yield is a direct reflection of the difference in grain yield recorded at the same site (Figure 2) as no difference in grain protein concentration was recorded.

Nitrogen uptake

The uptake of N in grain and grain + straw for the N treatments relative to the check was determined for all sites and is presented for the 67 kg N ha^{-1} rate in Table 2. As with the other data collected considerable variability occurred between treatments and sites over the two years, and only with grain N at site 5 was a significant difference recorded. Comparison of the average values for N uptake show that while EBC34 produced the highest recovery of applied N in grain (Table 2), LBC34 showed the highest recovery when grain + straw values were considered. This tends to indicate that even while producing higher grain protein, a larger proportion of the N taken up by this late treatment remained in the straw and was not transformed into grain yield. If the grain N recovery for EBC34 is considered to be 100, LBC34 and LBC46 would both be ranked as being 92% of the EBC34. However, for grain + straw if EBC34 is 100, LBC34 and LBC46 would be ranked at 115 and 97%, respectively. Broadcast spray applications of UAN solution (SP28) showed the lowest N recoveries for both grain and grain + straw samples indicating a low level of N recovery.

SUMMARY AND CONCLUSIONS

The growing seasons during which this experiment was carried out (1986 and 1987) were characterized by a high degree of moisture stress in the early spring (April-May). As well, the selection of sites with high levels of residual soil NO_3-N seriously limited the response of the winter wheat to the N treatments applied. Of the 10 experimental sites only 7 showed a significant rate response to added N for grain yield, 4 of which became nonsignificant when the check N rates were removed. Grain protein concentration and protein yield proved to be better indicators of response to added N. Significant differences between N treatments were even harder to detect, as in the majority of cases the adverse environmental conditions masked any apparent variation in response.

Table 2. Effect of spring applied N treatments on the uptake of N in the grain and grain + straw of winter wheat at 67 kg N ha^{-1} in 10 field experiments.

Site no.	EBC34	EBC46	BD46	SP28	BD28	LBC34	LBC46	$LSD_{0.05}$
	Percent of applied N recovered in grain							
1	26.1	31.3	30.1	22.6	18.7	27.5	27.5	NS
2	32.5	29.6	27.0	27.0	25.8	26.2	28.6	NS
3	7.2	4.8	0.4	6.3	5.3	6.6	6.0	NS
4	14.7	13.0	12.9	12.9	13.0	13.7	9.9	NS
5	31.3	24.7	22.7	19.6	29.0	35.1	37.4	9.1
6	46.5	36.4	43.2	34.1	40.9	+	+	NS
7	25.3	20.4	20.9	13.6	21.4	+	+	NS
8	11.4	7.2	9.4	7.1	11.4	+	+	NS
9	15.4	17.5	18.9	9.9	22.3	+	+	NS
10	26.7	25.3	20.6	27.2	21.8	+	+	NS
AVE	23.7	21.0	20.6	18.0	21.0	21.8	21.9	
	Percent of applied N recovered in grain + straw							
1	49.5	52.2	49.4	40.4	49.7	65.4	48.3	NS
2	57.2	63.9	49.0	50.6	58.1	58.3	48.1	NS
3	7.9	0.1	2.4	11.2	1.8	10.0	4.5	NS
4	29.7	23.4	23.4	28.5	24.0	26.5	18.7	NS
5	52.0	41.6	51.1	32.8	44.9	55.3	61.1	NS
6	66.2	51.6	65.4	48.6	54.8	+	+	NS
7	35.2	28.4	32.9	21.9	31.6	+	+	NS
8	21.3	16.2	17.2	14.7	24.9	+	+	NS
9	19.5	25.7	38.6	11.4	38.0	+	+	NS
10	32.0	31.7	25.2	32.8	28.6	+	+	NS
AVE	37.1	33.5	35.5	29.3	35.6	42.7	36.1	

+ Treatments not included at this experimental site.

Where significant differences between treatments were recorded a few conclusions can be drawn from the results:

1. At those locations where the late broadcast applications of urea and ammonium nitrate were included they produced both lower grain and protein yields than the early broadcast treatments. This indicates that delaying spring N application beyond the earliest possible date will result in lost yield potential.

2. Broadcast spray applications of UAN solution produced lower grain yields than when UAN was dribble banded in 8 of the 10 trials. This indicates that surface applied dribble bands of UAN solution are a more efficient than broadcast sprays under no-till production conditions.

3. The high levels of applied N recovered in the grain and grain + straw samples for the low yielding LBC34 and LBC46 treatments are a reflection of the high grain protein and straw N concentrations associated with these late applied treatments.

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