THE PATTERN OF NITROGEN UPTAKE IN WINTER WHEAT.

B. A. Schewe and D. B. Fowler
Dept. of Crop Science and Plant Ecology and Crop Development Center, University of Saskatchewan, Saskatoon, Sask.

ABSTRACT

The pattern of nitrogen uptake was examined in Norstar winter wheat (*Triticum aestivum* L.) grown at several locations in Saskatchewan during a three year period. Replicated field trials were supplemented with 0, 34, 67,100, and, in the final year, 200 kg of nitrogen per hectare applied as ammonium nitrate (34-0-0) in the early spring. Plant samples were collected at two-week intervals during the growing season and analyzed for dry matter yield, nitrogen concentration and plant nitrogen yield. Modified harvest and nitrogen harvest indexes were calculated by comparing the wheat heads to the total plant material. In general, nitrogen concentration of stems and leaves decreased during the growing season while changes in nitrogen concentration of the wheat heads were more dependent on environmental conditions. Dry matter yield and plant nitrogen yield increased during the season. This increase tended to level off near maturity at some locations, especially when moisture conditions were low. When soil nitrogen levels were low, increased amounts of nitrogen fertilizer increased dry matter yield and yield of plant nitrogen per hectare but had no effect on plant nitrogen concentration. When soil nitrogen levels were high and soil moisture was adequate, addition of nitrogen fertilizer increased only plant nitrogen concentration. At some locations, plant stand variability was too large to detect differences among fertilizer treatments. At most locations there were no differences among the fertilizer rates for harvest and nitrogen harvest indexes, indicating that there was no change in plant efficiency with a change in available nitrogen.

INTRODUCTION

Winter wheat grown on the Canadian prairies is often much lower in grain protein concentration than hard red spring wheat. If changes in the protein content of winter wheat are to be made, a better understanding of the growth and nitrogen use of the crop is necessary.

In Saskatchewan, winter wheat must be planted into standing stubble to insure winter survival of the crop. Application of nitrogen fertilizer is important since the previous crop will have depleted the soil nitrogen reserves. Most of the nitrogen used by winter wheat is required before the end of June (Fowler, 1983) but a more detailed examination of the pattern of dry matter and nitrogen accumulation is required.

Previous studies have indicated that wheat can accumulate dry matter and nitrogen until harvest (Austin et al. 1977; Spiertz and Ellen, 1978; Spratt and Gasser, 1970). However, in many cases, the uptake of nitrogen and production of dry matter decreases or stops after anthesis (Gregory et al. 1981; Karlen and Whitney, 1980; Waldren and Flowerday, 1979). Gregory et al. (1979) suggested that when uptake stopped after anthesis, it may be due to a lack of soil moisture or available soil nitrogen. In a dry year, very little nitrogen is accumulated after anthesis (Gregory et al. 1981). Boatwright and Haas (1961) found that wheat grown with little available soil nitrogen took up nitrogen until maturity but that wheat provided with sufficient nitrogen had most of its total dry weight and nitrogen by heading.

Clearly, then, the pattern of nitrogen uptake and dry matter accumulation by wheat plants varies with environmental conditions. This study was undertaken to examine the pattern of nitrogen uptake in winter wheat under varying rates of nitrogen fertilizer and Saskatchewan conditions.

MATERIALS AND METHODS

Field trials were conducted over a period of three years from 1983-1986. Norstar winter wheat treated with several rates of ammonium nitrate fertilizer (34-0-0) was grown at several locations in Saskatchewan. Plots were laid out in a randomized complete block design with four blocks. Rates of 0 (a check), 34, 67, 100, and, in the final season, 200 kg of nitrogen per ha were used. The fertilizer was broadcast on the plots in early spring.

Samples consisting of total above ground plant material were collected at approximately two week intervals from late May until harvest. When the wheat heads emerged, they were collected separately. The samples were dried, weighed and ground in preparation for analysis. Nitrogen concentration was determined using a Technicon autoanalyzer (Method #325-74W). The digestion procedure prior to analysis was similar to that described by Thomas et al. (1967). The moisture content was determined for each sample and values were reported on a dry weight basis.

At each sampling date and for each plot, the dry matter yield (kg/ha), the nitrogen concentration (%), and the plant nitrogen yield (kg of plant N /ha) were determined.

At harvest, grain yield, grain protein concentration, grain protein yield, test weight and 1000 kernel weight were determined. Values for a modified harvest index and modified nitrogen index were calculated as follows:

$$\text{Modified harvest index(MHI)} = \frac{\text{dry matter yields of heads}}{\text{total plant dry matter yield}}$$

$$\text{Modified nitrogen index(MNI)} = \frac{\text{total N in heads}}{\text{total N in whole plants}}$$

Table 1. Description of research sites.

Location	Year	Soil zone	Residual soil nitrogen (kg/ha)	Rainfall[1] (mm)
Clair	1983-84	black	29	280
Kernen	1983-84	dark brown	103	110
Perdue[2]	1984-85	dark brown	101	116
Saskatoon	1984-85	dark brown	265	147
Saltcoats	1985-86	black	76	260
Clair	1985-86	black	63	190
Hagen	1985-86	black	67	216
Paddockwood	1985-86	black	50	216

1. Amount of rainfall received during the growing season as measured at the nearest weather station.
2. The Perdue site was located on a chemically fallowed field while all of the other sites were located on stubble fields.

RESULTS

Table 1 gives a brief description of each site used during this project. All sites were located in either the dark brown or black soil zones of Saskatchewan. The residual soil nitrogen levels varied from 29 kg/ha at Clair (1983-84) to 265 kg/ha at Saskatoon. Considerable variation was also observed for the amount of rainfall received at each location during the growing season. It is also important to note that the trial located at Perdue was grown on a chemically fallowed field while all of the other trials were grown on stubble fields.

Effects of nitrogen fertilizer treatments.

Consistent significant differences among fertilizer treatments for dry matter yields were found at Clair (1983-84) and in the last half of the growing season at Saltcoats. Differences in nitrogen concentration were observed at Perdue,

Table 2. Grain yield, protein concentration and protein yield for each site.

	N fert. rate (kg/ha)	Clair 1983-84	Kernen 1983-84	Perdue 1984-85	Saskatoon 1984-85	Saltcoats 1985-86	Clair 1985-86	Hagen 1985-86	Paddockwood 1985-86
Grain yield (kg/ha)	0	2320	1681	3150	-	2851	1486	2630	1391
	34	3320	1579	3584	5353	3455	1787	2097	1942
	67	3765	1481	3802	5878	3721	1936	2044	2045
	100	4467	1600	3261	4563	3839	2180	2609	2274
	200	-	-	-	4990[1]	4082	2204	2454	2427
	$LSD_{.05}$	938	NS	NS	710.7	540.7	300.4	NS	955.7
Grain protein concentration (% dry wt.)	0	9.0	14.2	10.2	-	9.6	10.9	12.5	10.5
	34	8.0	14.6	11.1	13.4	10.0	13.2	13.6	10.4
	67	8.6	15.3	11.8	13.9	10.7	14.2	15.1	10.5
	100	8.8	15.0	12.6	14.1	10.8	15.8	15.8	12.0
	200	-	-	-	14.4	13.6	15.8	16.0	13.1
	$LSD_{.05}$	NS	0.50	0.37	0.35	1.65	1.60	2.82	2.17
Grain protein yield (kg/ha)	0	208.0	238.2	322.6	-	250.0	150.4	309.6	135.9
	34	270.2	230.9	395.2	720.1	319.0	217.3	263.5	188.4
	67	324.8	226.5	447.2	815.1	362.3	254.1	285.4	197.9
	100	392.7	239.4	410.6	644.6	383.2	321.0	377.8	254.5
	200	-	-	-	717.0	514.2	322.3	356.4	297.9
	$LSD_{.05}$	84.8	NS	60.5	NS	57.4	44.6	NS	100.8

1. At Saskatoon a rate of 135 kg/ha, not 200 kg/ha, was used.

Saltcoats, Clair (1985-86) and Hagen. Plant nitrogen yields were consistently different at Clair (1983-84) and Saltcoats. Significant differences in nitrogen yields for some dates were also observed at Perdue, Clair (1985-86) and Hagen.

In general, if soil nitrogen levels were low and rainfall was adequate, adding nitrogen fertilizer increased dry matter yields and nitrogen yields. When soil nitrogen reserves were high and rainfall was adequate, added nitrogen fertilizer increased plant nitrogen concentration and nitrogen yields. At the Saltcoats site, all three values were significantly affected by the addition of nitrogen fertilizer. At Kernen, Saskatoon, Paddockwood and most sample dates at Hagen, the rainfall was either too low or the plant stand was too variable to detect differences among fertilizer treatments.

When modified harvest and nitrogen indexes were calculated, the only significant effect occurred at Clair (1983-84) where the modified harvest index decreased when fertilizer rate was increased.

The grain yields, protein concentration and protein yields are summarized in Table 2. The Saltcoats and Clair (1985-86) sites showed significant differences among fertilizer treatments for all three values. At Kernen and Perdue, there were differences for grain protein concentration and protein yield. At Clair (1983-84), adding nitrogen fertilizer affected yield and protein yield. Differences in grain yield and protein concentration were found at Saskatoon. At Paddockwood, there were differences in grain protein yield. At all sites, there were no significant differences for test weight or thousand kernel weight of the grain samples.

Patterns of dry matter production, nitrogen concentration and nitrogen uptake.

The patterns of dry matter production are illustrated in figure 1. At Perdue, Clair (1985-86) and Hagen, the amount of dry matter produced tends to increase until maturity. At the other five locations, the curves for dry matter production tend to level off by about mid-July.

Figure 2 shows the patterns of nitrogen concentration of the stems, leaves and heads. As expected, the nitrogen concentration of the stems and leaves decreased during the growing season at all sites. This resulted from an increase in dry matter, which caused a dilution of the nitrogen, and from translocation of nitrogen from the stems and leaves to the wheat heads. In 1983-84, the concentration of nitrogen in the heads remained constant from head emergence to maturity at both Clair and Kernen. At the Saskatoon and Perdue sites, nitrogen concentration of the heads tended to increase slightly while the reverse was true at the four remaining sites.

Nitrogen uptake during the growing season is illustrated by the graphs in figure 3. At most sites, the nitrogen yields tend to increase until the end of June and then remain constant or increase very slowly until harvest. The one exception is the Perdue site. At Perdue, the nitrogen uptake by the winter wheat plants tended to continue until harvest. This could be due to a larger amount of moisture in the soil since this field was fallowed in the previous season.

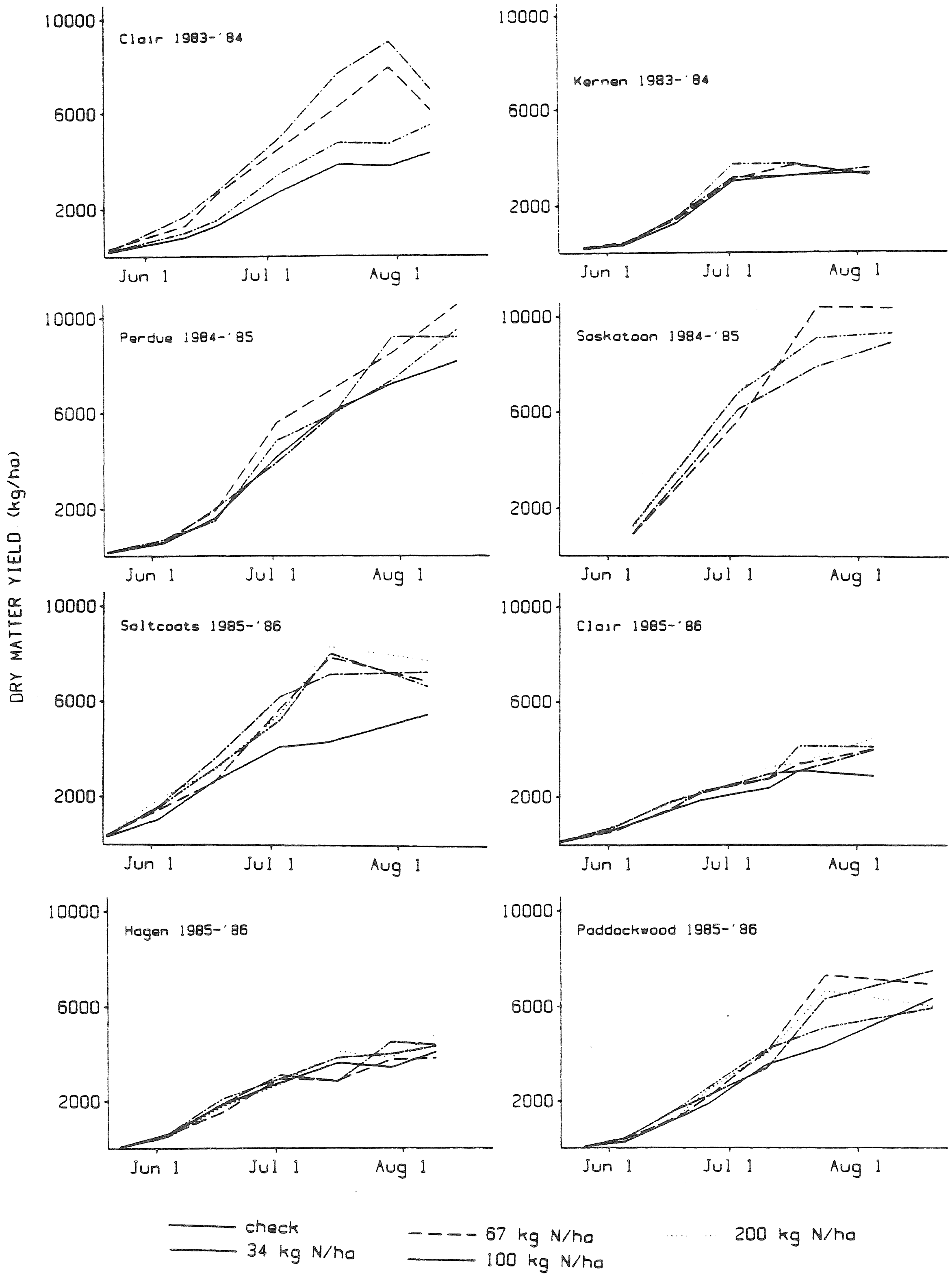

Figure 1. The patterns of dry matter production during the growing season at each site.

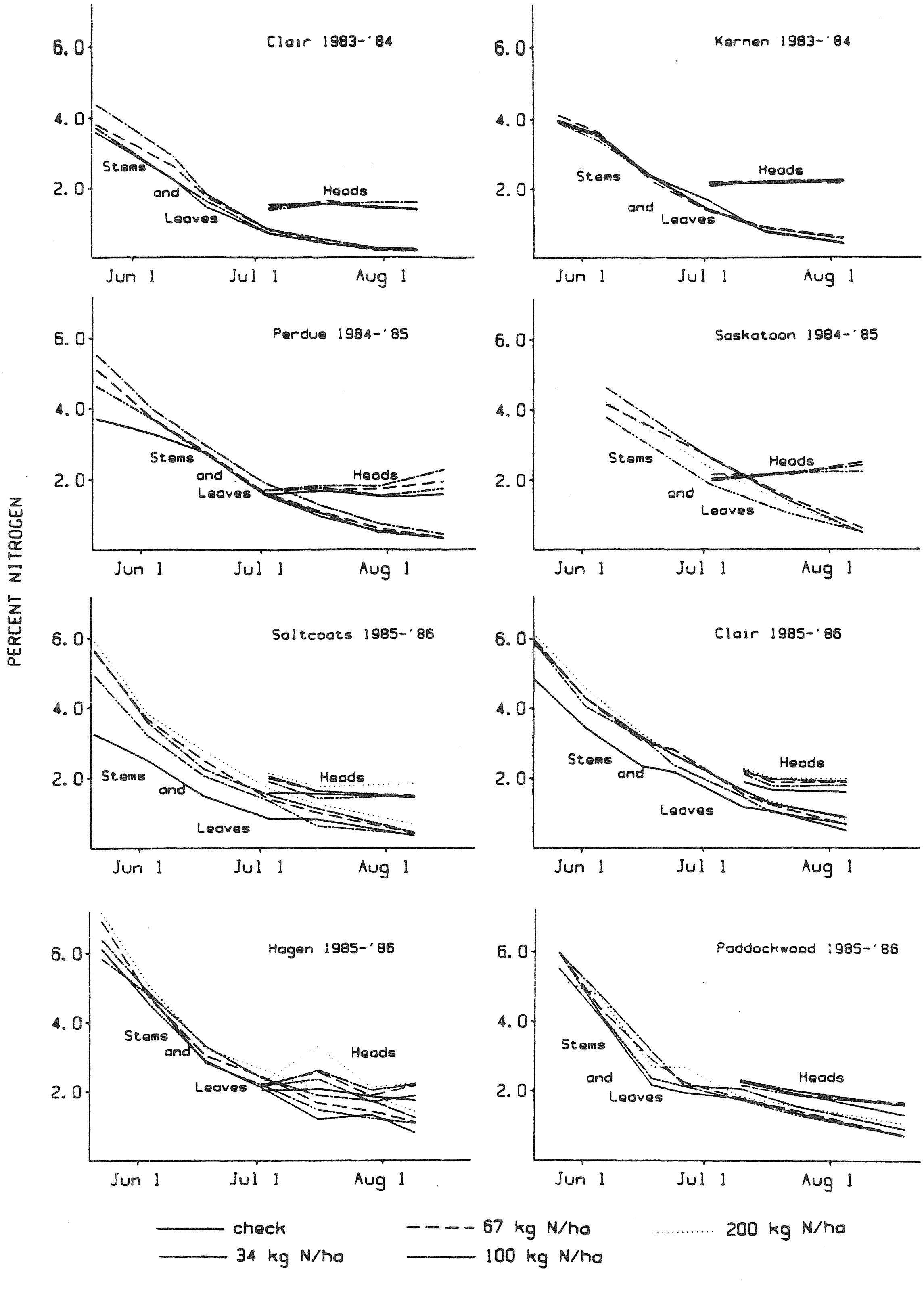

Figure 2. The patterns of plant nitrogen concentration during the growing season at each site.

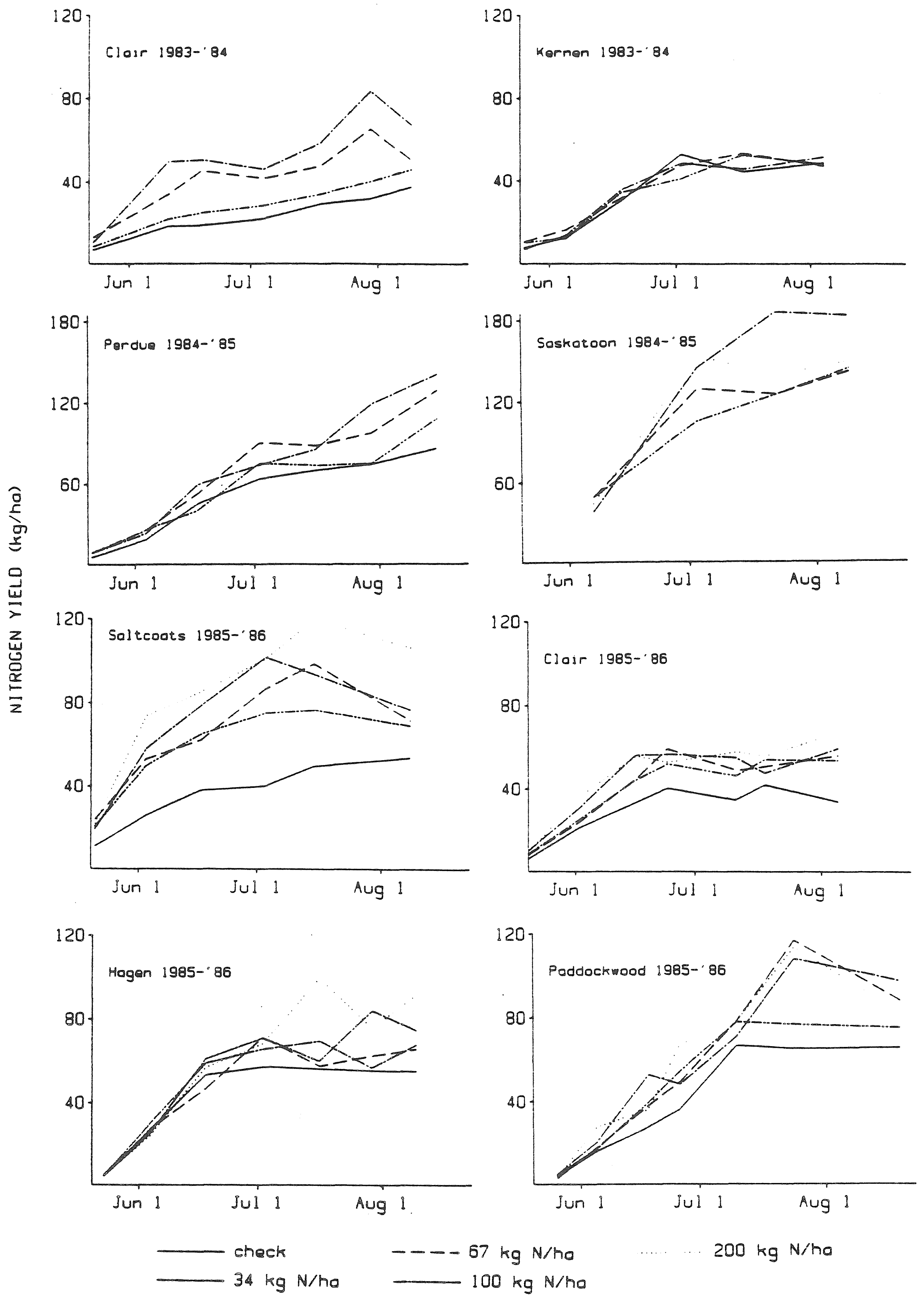

Figure 3. The patterns of nitrogen uptake during the growing season at each site.

To examine the differences in nitrogen uptake among fertilizer rates, the values for nitrogen yield were converted to a percentage of the final or harvest nitrogen yield for each date and plot. When these values were analyzed, there were no significant differences among fertilizer rates. This indicates that the pattern of nitrogen uptake does not vary with fertilizer rate. For each site, the data for nitrogen yield (as a % of final N yield) were averaged to produce a general curve for nitrogen uptake at that site. These curves for the eight locations are illustrated in Figure 4. Note that, in general, there is a rapid increase in nitrogen yield until about anthesis. After anthesis,most of the curves tend to level off and much less nitrogen was taken up until maturity.

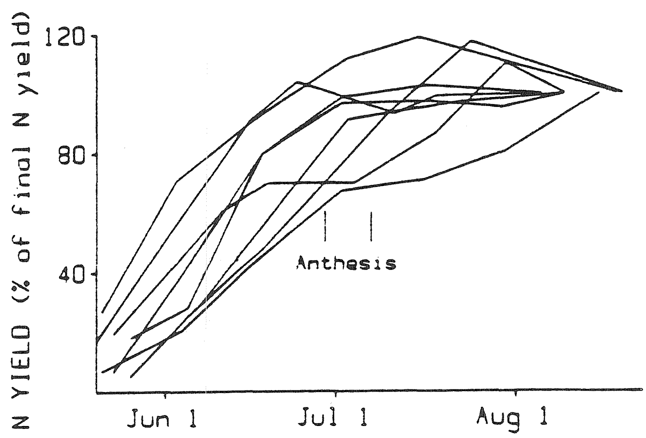

Figure 4. Patterns of nitrogen uptake at all eight locations.

Figure 5 represents a further simplification of these general uptake curves. For each stage of plant growth, the nitrogen yields of the eight sites were averaged to produce the curve found in Figure 5. Note that, on average, about 90% of the total nitrogen in the plant at harvest was already present at anthesis. This value ranged from 70% at Perdue to 106% at the Saltcoats trial.

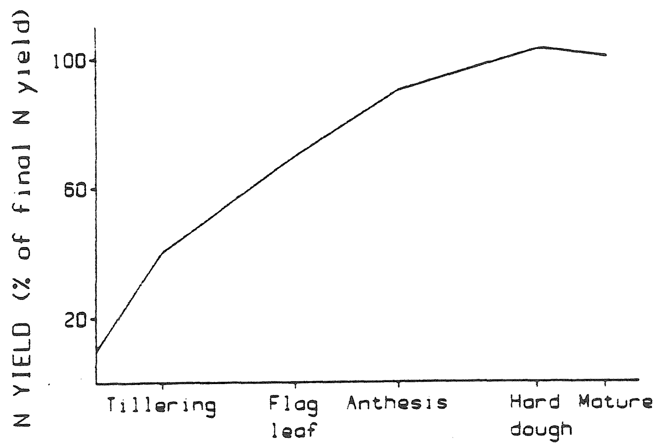

Figure 5. Average pattern of nitrogen uptake during the growing season.

DISCUSSION

Effect of fertilizer treatments.

The effect of nitrogen fertilizer rate on dry matter yields, plant nitrogen concentration and nitrogen yields varied with environmental conditions such as residual soil nitrogen and amount of rainfall received. The influence of the environment is very important (Henry et al. 1986; Spratt and Gasser, 1970). The effects of applied nitrogen on the grain had similar variations. For most locations, there were no differences in modified harvest and nitrogen indexes, indicating that there was no change in plant efficiency with a change in available nitrogen.

In general, when differences among fertilizer treatments were found during the growing season, these differences were also apparent in the grain sample. In some cases, it was possible to detect differences in the grain values that were not found in the plants during the growing season. This may be due to larger sample sizes used for harvesting grain than for collecting plant samples prior to harvest. As a result, variability in the grain samples was reduced and differences were easier to detect. Therefore, when looking for differences in nitrogen use under varying rates of fertilizer, it may be easiest to examine grain samples rather than plant samples.

Patterns of dry matter production, nitrogen concentration and nitrogen uptake.

In this study, the dry matter yields of Norstar winter wheat increased until maturity at three of the eight locations but tended to level off by mid-July for the other sites. These pattern differences may be related to soil moisture. Gregory et al. (1979) found that dry matter accumulation almost stopped four weeks before harvest. They attributed this to limited water supply and to a reduction in photosynthesis in the leaves after translocation of nutrients to the grain. Other authors have also reported a decrease or cessation of dry matter production before harvest (Gregory et al. 1981; Boatwright and Haas, 1961; Cox et al. 1985; Karlen and Whitney, 1980).

Typical patterns of plant nitrogen concentration were observed in this study. The percent nitrogen of stems and leaves decreased during the season as expected. Nitrogen concentration of the heads either decreased, increased or remained constant from head emergence until maturity, depending on environmental conditions. Johnson et al. (1967) found that grain nitrogen concentration either increased until maturity or remained constant, depending on wheat variety. Karlen and Whitney (1980) reported that nitrogen concentration of the wheat heads was fairly constant from heading until harvest. Concentration of nitrogen in wheat heads is dependent on the environment which can also influence the production and movement of carbohydrates to the grain during grain filling.

The pattern of nitrogen uptake was not affected by nitrogen fertilizer rates in this study. This is contrary to a study by Boatwright and Haas (1961) who found that unfertilized plants continued to take up nitrogen until harvest but that plants grown with added nitrogen had a maximum nitrogen yield at heading.

The general pattern of nitrogen uptake (see Figure 5) shows that the most rapid nitrogen accumulation occurred prior to anthesis. An average of 90% of the total harvest nitrogen was already present in the plants by anthesis. This is similar to a studies by Austin et al. (1977) who found an average of 83% present at anthesis and Waldren and Flowerday (1979) who observed that 80% of the total nitrogen was accumulated by grain filling. Some studies have indicated that nitrogen uptake occurs until plant maturity (Spiertz and Ellen, 1978; Spratt and Gasser, 1970). Gregory et al. (1981) found that the pattern of nitrogen uptake varied from year to year. In a dry year, very little nitrogen was taken up after anthesis, but when soil moisture levels were higher, the crop continued to accumulate nitrogen after anthesis. This supports the findings of this study which showed a general increase in nitrogen yield until harvest at one site grown on a fallow field which should contain more moisture than stubble fields.

Fowler, D. B. 1983. The effect of management practices on winter survival and yield of winter wheat produced in regions with harsh winter climates. in New frontiers in winter wheat production. pp 238-282. Division of Extension and Community Relations, Univ. Sask., Saskatoon, Sask.

Gregory, P. J., Crawford, D. V. and McGowan, M. 1979. Nutrient relations of winter wheat. 1. Accumulation and distribution of Na, K, Ca, Mg, P, S and N. J. Agric. Sci., Camb. 93: 485-494.

Gregory, P. J., Marshall, B. and Biscoe, P. V. 1981. Nutrient relations of winter wheat. 3. Nitrogen uptake, photosynthesis of flag leaves and translocation of nitrogen to grain. J. Agric. Sci., Camb. 96: 539-547.

Henry, J. L., Bole, J. B. and McKenzie, R. C. 1986. Effect of nitrogen water interactions on yield and quality of wheat in western Canada. in Wheat Production in Canada--A Review. Proceedings of the Canadian Wheat Production Symposium. pp. 165-191. Division of Extension and Community Relations, Univ. Sask., Saskatoon, Sask.

Johnson, V. A., Mattern, P. J. and Schmidt, J. W. 1967. Nitrogen relations during spring growth in varieties of *Triticum aestivum* L. differing in grain protein content. Crop Sci. 7: 664-667.

Karlen, D. L. and Whitney, D. A. 1980. Dry matter accumulation, mineral concentrations, and nutrient distribution in winter wheat. Agron. J. 72: 281-288.

Spiertz, J. H. J. and Ellen, J. 1978. Effects of nitrogen on crop development and grain growth of winter wheat in relation to assimilation and utilization of assimilates and nutrients. Neth. J. Agric. Sci. 26: 210-231.

Spratt, E. D. and Gasser, J. K. R. 1970. Effects of fertilizer-nitrogen and water supply on distribution of dry matter and nitrogen between the different parts of wheat. Can. J. Plant Sci. 50: 613-625.

Thomas, R. L., Sheard, R. W. and Moyer, J. R. 1967. Comparison of conventional and automated procedures for nitrogen, phosphorous, and potassium analysis of plant material using a single digestion. Agron. J. 59: 240-243.

Waldren, R. P. and Flowerday, A. D. 1979. Growth stages and distribution of dry matter, N, P, and K in winter wheat. Agron. J. 71: 391-397.

Some loss of nitrogen from the plants prior to maturity occurred at Saltcoats, Clair (1985-86), Paddockwood, Clair (1983-84), and Kernen. Previous authors (Boatwright and Haas, 1961) have attributed the loss to sampling error, loss of plant parts or translocation to the roots. In addition, Daigger et al. (1976) suggested that these losses may be due to loss of ammonia gas or other nitrogen gases from the plant.

The results of this research have shown that under Saskatchewan conditions, most of the nitrogen accumulated by winter wheat is taken up prior to anthesis. Though differences among fertilizer rates were found for dry matter yield, plant nitrogen concentration, nitrogen yield and their corresponding values for grain, there were no differences in the pattern of nitrogen uptake during the growing season.

ACKNOWLEDGMENTS

The authors would like to acknowledge the financial support of the Canada-Saskatchewan Economic Regional Development Agreement. The Canadian Wheat Board scholarship awarded to B. A. Schewe was also greatly appreciated.

REFERENCES

Austin, R. B., Ford, M. A., Edrich, J. A. and Blackwell, R. D. 1977. The nitrogen economy of winter wheat. J. Agric. Sci., Camb. 88: 159-167.

Boatwright, G. O. and Haas, H. J. 1961. Development and composition of spring wheat as influenced by nitrogen and phosphorous fertilization. Agron. J. 53: 33-36.

Cox, M. C., Qualset, C. O. and Rains, D. W. 1985. Genetic variation for nitrogen assimilation and translocation in wheat. I. Dry matter and nitrogen accumulation. Crop Sci. 25: 430-435.

Daigger, L. A., Sander, D. H. and Peterson, G. A. 1976. Nitrogen content of winter wheat during growth and maturation. Agron. J. 68: 815-818.