AN EVALUATION OF THE NITRATE SAP TEST FOR USE ON SPRING-SOWN WHEAT

N.J. Withers and F. Palenski
Agronomy Department, Massey University,
Palmerston North

ABSTRACT

Nitrate concentration was measured using an nitrate-sensitive test strip on wheat receiving nitrogen at various times and rates at two sowing dates. Nitrate was monitored for approximately 70 days and compared with regular measurements of growth and final yield.

The pattern of nitrate concentration was found to vary widely but in a consistent pattern. Nitrogen fertilizer significantly modified the levels of nitrate but not the overall pattern. Growth rates were increased when nitrate concentrations were greater than about 5000 ppm before GS 5 and about 1000 ppm after GS 5.

Grain yield was influenced by the nitrate status of the plant over the stem elongation phase and nitrogen applied after sowing tended to result in better nitrate levels at this time.

It is suggested that further development of the test for cereals be undertaken.

Additional Key Words: *Nitrogen fertiliser, rate, timing, grain yield, yield components, growth analysis, critical levels*

INTRODUCTION

The problem of assessing the nitrogen fertiliser requirement of crops has attracted a lot of attention for a long time. Despite this, no universal system has been developed. The problem of prediction is a difficult one because of the rapid changes in nitrogen levels that can occur in the soil during the season. One way of assisting with the problem would be to monitor the nitrogen status of the crop during the season so that the adequacy of past nitrogen applications can be assessed and possibly remedial measures taken if the crop requires more nitrogen.

For cereals, the nitrate concentration in the stems has been shown to indicate quite accurately the overall nitrogen status of the crop and its requirement for fertiliser nitrogen (Papastylianou, 1980; Wehrmann *et al.*, 1982). However, the methods used by these workers were not satisfactory for use by farmers or their advisors in the field for they involved laboratory methods which would also mean delay before results could be obtained, or the solutions used were dangerous for widespread use. The development of a paper indicator strip which is sensitive to nitrate has enabled nitrate to be detected in plants quickly, easily and accurately and has been taken up for use in horticulture (Scaife and Bray, 1977; Prasad and Spiers, 1982, 1984). Withers (1982) suggested that the test could be used for cereals also and presented some preliminary data to indicate that it had some potential for barley. Other unpublished work on both wheat and barley indicated that nitrate concentrations in cereals could fluctuate markedly so that it was decided that detailed information on the pattern of nitrate concentration over the season and the response of plant growth to varying levels of nitrate was required before the test could be developed any further. The experiment described in this paper was designed to provide this information.

MATERIALS AND METHODS

The trial was situated on the Tiritea Research Area near Palmerston North. The soil was Tokomaru silt loam which had been cropped each year since 1978/9 in a summer barley seed crop and a winter forage oat crop where the herbage was removed. Nitrogen levels measured by incubation test (Quin *et al.*, 1982) were 7.3 μg/g for initial nitrate, 39 μg/g for final N (NH_4 + NO_3) and 27.4 μg/g for the change in N due to incubation.

There were two adjacent sites sown on 12 October and 7 November with Karamu wheat using a commercial drill. Establishment counts were 340 plants/m^2 for the early sowing and 313 plants/m^2 for the late sowing. Before sowing, 300 kg/ha 30% potassic superphosphate was applied and incorporated with the final cultivation.

Urea was surface applied in a randomised block design with three replications for each experiment. Treatments were:-

No nitrogen (ON)
25 kg N/ha applied immediately after sowing (25N)
100 kg N/ha applied immediately after sowing (100NS)
100 kg N/ha applied at Feekes growth stage 2 (100NE)
100 kg N/ha applied at growth stage 5 (100NL)

The 100NE urea was applied 19 and 22 days after sowing and the 100NL urea was applied 35 and 37 days from sowing for the early and late sowings respectively. At approximately weekly intervals until flowering, four 0.1 m^2 quadrats were harvested from each plot for dry matter yield. Concentration of nitrate in the plant sap was measured using indicator strips (Withers, 1982) from about six plants per plot at least once per week until no nitrate could be detected. Individual plant readings were converted from time to concentration using a standard calibration curve before averaging

Irrigation was applied by overhead sprinklers to minimise water stress but no attempt was made to make water non-limiting.

Final yield was determined by harvesting six 0.1 m² quadrats from each plot. These were threshed in a small stationary thresher and moisture content adjusted to 14%.

RESULTS

Concentration of nitrate in the sap changed rapidly in extent and direction during the season although a similar pattern for all treatments in both sowings was apparent.

Early Sowing

Comparison of the nitrogen treatments applied at sowing (Fig. 1) show that differences in nitrate concentration between the treatments was apparent from the first sampling. Levels quickly built up to a peak at about 30 days from sowing and then dropped rapidly. The peaks differed markedly in height and there was a slight delay in the drop from the peak as nitrogen application rate increased. The reduction in concentration coincided with the beginning of stem extension and early ear development (Feekes GS5). The time when concentration was between 1000 and 2000 ppm was significantly later for the 100 kg N/ha (100NS) treatment.

TABLE 1: Dry matter yield (g/m²) for each harvest and differences between harvests (bold, S.E. of mean in brackets) — early sowing.

Days from sowing	ON	25	100NS	100NE	100NL
20	10.0a*	8.8a	11.1a		
	7(1)	**13(3)**	**14(1)**		
27	17.3a	21.3a	24.8a	21.3a	
	17(4)	**35(6)**	**35(3)**	**46(3)**	
34	34.0c	56.6b	59.3b	67.5a	
	14(7)	**26(5)**	**68(9)**	**48(15)**	**39**
41	47.5e	82.3c	127.1a	115.3b	70.6d
	22(6)	**50(3)**	**86(3)**	**90(18)**	**52(9)**
49	69.4c	132.0b	213.3a	205.2a	122.8b
	79(20)	**57(9)**	**59(29)**	**119(22)**	**77(8)**
56	148.8d	188.6c	272.1b	324.5a	200.2c
	154(14)	**184(28)**	**324(30)**	**341(38)**	**231(26)**
70	303.1e	372.8d	596.4b	665.3a	431.7c

*Duncan lettering applied within harvest only

Visual differences were always apparent between the 100NS treatment and the other two treatments with an initial, but less marked, difference between ON and 25N. A significant difference in dry weight was only apparent after about 30 days from sowing (Table 1) although ON had a lower growth rate earlier than this time. After 27 days from sowing, overall growth rate increased and the differences in dry weight between treatments became apparent. This period coincided with the rapid drop in sap nitrate concentration and the delay in reduction of concentration for 100NS plants below 1000 ppm (Fig. 1). When the nitrate concentration in 100NS fell below 1000 ppm at about 45 days from sowing, the growth rate also fell to a level similar to that of 25N plants (Table 1).

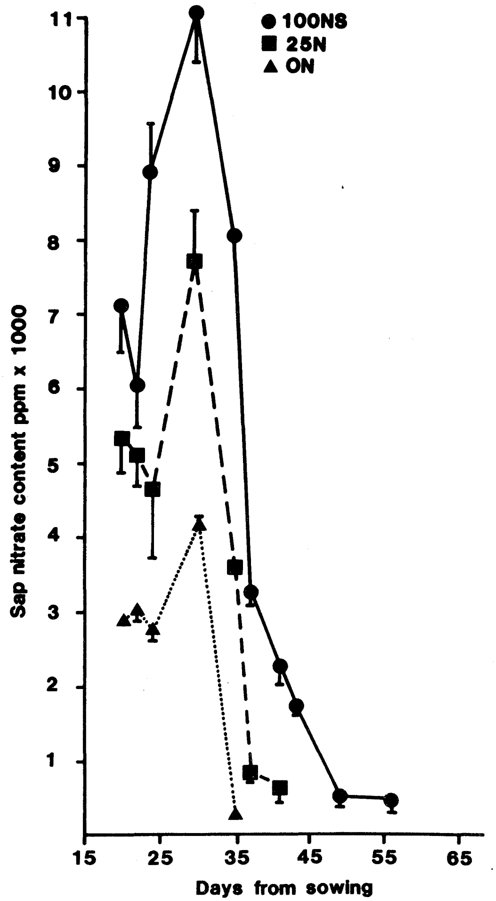

Figure 1: Concentration of nitrate over time for the plants receiving nitrogen at sowing for the early sowing. Bars represent the standard error of the mean.

Comparison of the three treatments where 100 kg N/ha was applied (Fig. 2) shows that the plants receiving nitrogen at early tillering (100NE) had a similar pattern of nitrate concentration to the plants which received nitrogen at sowing (100NS). The main differences were that 100NE plants were initially lower in nitrate concentration than 100NS plants and that there was a slight delay in the reduction of nitrate below 2000 ppm for 100NS plants. The late-applied nitrogen (100NL) however did not significantly increase sap nitrate levels.

The comparison of growth rate and dry matter yield between 100 kg N/ha applied at sowing (100NS) and at early tillering (100NE) (Table 1) shows that the dry weight of 100NE plants quickly caught up to that of 100NS plants.

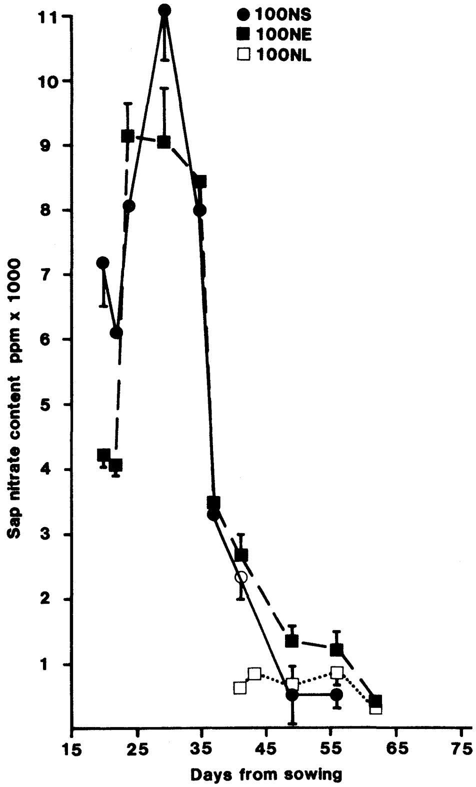

Figure 2: Concentration of nitrate over time for the plants receiving 100 kg N/ha for the early sowing. Bars represent the standard error of the mean.

It also indicates that the slight delay in the reduction of nitrate concentration below 1000 ppm was reflected in a delay in the reduction of growth rate during the period between 49-56 days from sowing so that the dry weight of 100NE plants became greater than that of 100NS plants after 56 days from sowing.

Although the late-applied nitrogen (100NL) did not increase nitrate concentrations, growth rate did increase compared to control plants but growth was not as fast as 100NE plants so that dry matter yields were consistently behind 100NS and 100NE plants.

Final grain yield tended to reflect the nitrate status over the late vegetative stage rather than dry weight at flowering (Tables 1 and 2). The yield improvement occurred through increases in both ear density and the weight of grain per ear. The two treatments where nitrogen was applied after sowing had the highest yield with ON and 25N having similar low yields.

Although the ear numbers from 100 kg N/ha treatments were similar, the latest applied nitrogen significantly increased the weight of grain per ear. Grain weight and the number of grains per ear have not yet been

TABLE 2: Grain yield (kg/ha), the number of ears/m² and the weight of grain/ear (g) at the final harvest for both sowing dates.

	Yield	Ear number	Weight of grain per ear
Early sowing			
ON	1900c	338b	0.55c
25N	2150c	378b	0.57c
100NS	3330b	485a	0.74b
100NE	3950a	530a	0.74b
100NL	4200a	473a	0.89a
Late sowing			
ON	3300b	375b	0.88a
25N	3580b	412b	0.87a
100NS	4170a	425b	0.98a
100NE	4430a	536a	0.82a
100NL	4650a	565a	0.82a

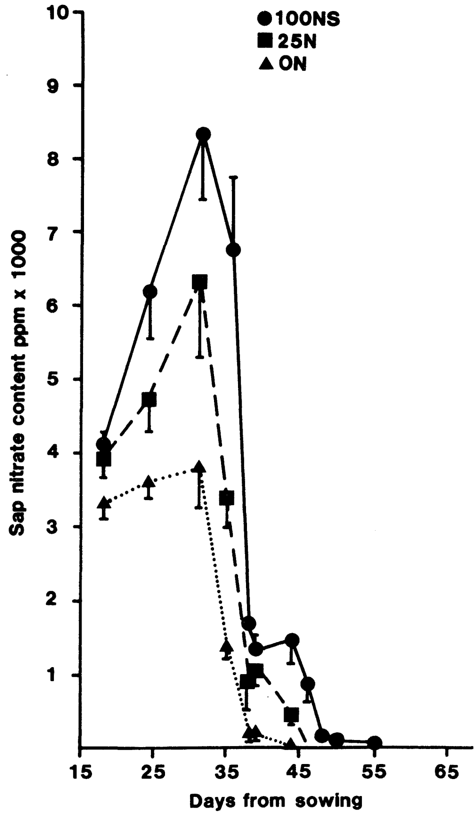

Figure 3: Concentration of nitrate over time for the plants receiving nitrogen at sowing for the late sowing. Bars represent the standard error of the mean.

measured to determine which contributed most to the higher weight of grain per ear.

Late Sowing

The overall pattern of nitrate concentration was similar to the early sowing date (Figs. 3 and 4). However, initial differences between the plants receiving nitrogen at sowing were not as marked which was reflected in their appearance and growth rate at that stage (Table 3). Differences in nitrate levels soon increased although the peak levels were lower than those attained at the early sowing. The peak levels however occurred at similar times and growth stages to the early sowing and were followed by the rapid drop in concentration. The 100NS plants had nitrate concentrations below 1000 ppm soon after the 25N plants in contrast to the delay which occurred in the early sowing. This was reflected in similar growth rates at this time for the late sowing.

Both 100NE and 100NL plants had an extended period when sap nitrate concentration was above 1000 ppm which again resulted in a longer duration of rapid growth compared to plants from the 100NS treatment so that dry matter yields at flowering were also higher. These differences were reflected in higher ear number at final harvest (Table 2) but not in significantly higher grain yield.

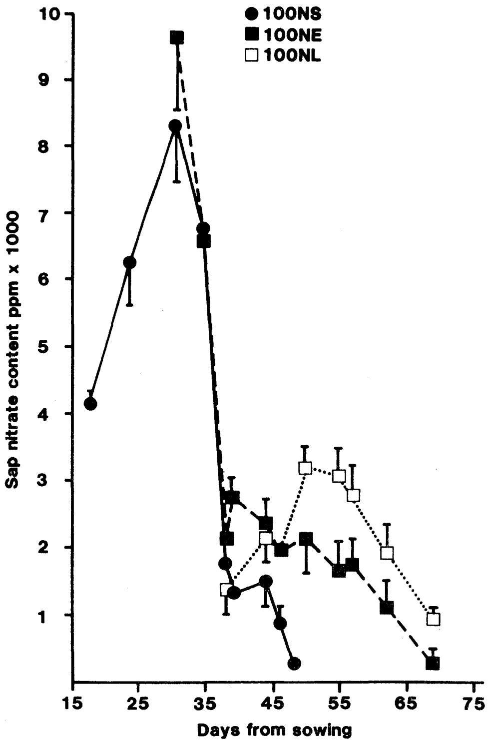

Figure 4: Concentration of nitrate over time for the plants receiving 100 kg N/ha for the late sowing. Bars represent the standard error of the mean.

TABLE 3: Dry matter yield (g/m²) for each harvest and differences between harvests, (bold, S.E. of mean in brackets) — late sowing.

Days from sowing	ON	25	100NS	100NE	100NL
15	9.6a*	9.7a	8.1b		
	10(1)	**8(1)**	**11(3)**		
22	19.3a	17.8a	18.8a		
	26(3)	**36(6)**	**26(1)**		
29	44.9b	53.6a	44.5b	45.0b	
	45(8)	**41(5)**	**80(5)**	**57(11)**	
35	89.6c	94.9bc	124.5a	102.0b	
	19(1)	**39(4)**	**41(7)**	**65(17)**	**56(15)**
42	109.0d	134.0c	165.4a	167.4a	145.2b
	108(25)	**135(29)**	**147(23)**	**155(27)**	**152(32)**
49	217.2d	268.8c	312.4ab	322.7a	297.6b
	68(24)	**125(40)**	**106(21)**	**164(6)**	**158(22)**
56	285.9e	398.8d	418.1c	486.8a	455.8b
	99(31)	**98(14)**	**124(35)**	**149(21)**	**168(36)**
63	385.6d	491.9c	542.3b	636.0a	623.4a

*Duncan lettering applies within harvest only

DISCUSSION

Despite considerable variation in nitrate concentration over time, there was a consistent pattern to the changes. This would indicate that the sap levels could be used as a monitoring tool for cereals provided that recommended levels were linked to the stage of growth. The rapid drop in nitrate concentration occurred at about GS 5 at both sowings which is similar to the trends reported by Papastylianou and Puckridge (1983) and Ismail and Withers (1984). The most obvious relationship between sap levels and growth rate occurred during stem elongation. It seems to be important to delay the decline in concentration and maintain it in the region of 1000-2000 ppm. These conclusions are similar to the practice in Europe where a sap test is used to monitor nitrate status during stem elongation although the test used differs from the one evaluated here. The critical level used in their test approximately equates to 1000 ppm nitrate (Wehrmann *et al.,* 1982). Papastylianou (1980), using a laboratory method to analyse stem nitrate, concluded that 1200 ppm nitrate was a critical level during the stem elongation phase.

Use of the test at this relatively late stage limits its use as a predictive tool as nitrogen applied at late tillering runs the risk of not being available to the plant unless irrigation can be used or unless rainfall is reliable at this time.

Value of an adequate nitrate level and growth rate at this stage depends on the link between them and grain yield. Results from other aspects of this work (to be published later) and that of Masle (1982) and Ismail and Withers (1984) indicate that maintenance of nitrogen status over this period increases the survival and productivity of tillers. Thus late applications of nitrogenous fertiliser may be necessary on soils of low fertility to maintain the nitrogen status of the plant even if fertiliser has been applied at sowing.

It would be desirable to be able to detect inadequate nitrogen at an early stage so that remedial fertiliser applications can be made. Differences in nitrate concentration between treatments were apparent very early in growth. Papastylianou (1980) suggested that if stem nitrate levels fall below 5500 ppm then growth would be reduced. Data from this experiment would tend to support this figure. At both sowing times, growth rates of the treatments were similar when sap nitrate was about or below 5500 ppm. For example, at the early sowing, sap nitrate was above 5500 ppm for treatments 25N and 100NS early in growth and growth rates were similar. The ON plants remained about 3000 ppm with lower growth rates resulting.

Thus these results support the critical levels of about 5500 ppm nitrate at tillering and 1200 ppm at jointing suggested by Papastylianou (1980) and Wehrmann *et al.* (1982) despite the different methods used to derive the levels. The data of Ismail and Withers (1984) indicates similar critical levels. Given these levels, even as tentative figures, it would seem worthwhile to develop the test further with a view to using it widely as a monitoring tool for use by farmers, advisors and researchers.

Users of the test should be encouraged to regard it as a monitoring tool rather than a "once only" test as it is quite important to assess the trend in the values as well as the absolute values.

It is also important to remember that this test measures the nitrogen status of the plant at a particular point in time and that it is the growth of the plant at this time which reflects this status. Whether or not yield would be improved by increasing the nitrate concentration above the critical levels would depend on the nitrogen being applied early enough to influence important yield components and whether other environmental factors allowed the yield potential to be expressed i.e. the test is an indicator of growth not of grain yield.

CONCLUSIONS

1. Although the concentration of nitrate as measured by the sap test varies widely during the growing season, the pattern appears to be reasonably consistent. In addition there appears to be significant modifications in the pattern made by applications of nitrogen fertiliser and these modifications can be reflected in differences in growth rate.
2. Critical levels of about 5000 ppm and 1000 ppm before and after GS 5 respectively were indicated for spring-sown wheat.
3. There appears to be sufficient information from this and other work to allow the further development of this test for use on cereals.
4. Relatively late applications of nitrogen at GS 5 can increase yield of spring-sown wheat in contrast to the normally held opinion that nitrogen should be applied at sowing or very soon after establishment.

ACKNOWLEDGEMENTS

This experiment was carried out during an exchange visit to the Plant Physiology Division, DSIR by N.J.W. Thanks are extended to the Director and staff of the Division for their cooperation and the use of facilities. Special thanks to Dr P. Gandar who was also involved in aspects of the overall experiment for his tolerance and help.

The financial support of the United Wheatgrowers Subsection of Federated Farmers is also gratefully acknowledged.

REFERENCES

Ismail, S.B., Withers, N.J. 1984. The effect of nitrogen managment and paddock history on barley growth and yield. *Proceedings Agronomy Society of N.Z. 14.*

Masle, J. 1982. Influence of nitrogenous nutrition on tiller behaviour in winter wheat (*Triticum aestivum*). *In* "Plant Nutrition 1982". Proceedings 9th International Plant Nutrition Colloquium. CAB, Slough. pp. 366-372.

Papastylianou, I. 1980. Nitrate concentration in cereal stems and its use in evaluating rotations and predicting nitrogen fertiliser requirements. Ph.D. Thesis, University of Adelaide. (Cited by Papastylianou and Puckridge, 1983).

Papastylianou, I., Puckridge, D.W. 1983. Stem nitrate nitrogen and yield of wheat in a permanent rotation experiment. *Australian Journal of Agricultural Research 34:* 599-606.

Prasad, M., Spiers, T.M. 1982. Evaluation of a simple nitrate test for some ornamental crops. *In* "Plant Nutrition 1982". Proceedings 9th International Plant Nutrition Colloquium. CAB, Slough. pp. 474-479.

Prasad, M., Spiers, T.M. 1984. Evaluation of a rapid method for plant sap nitrate analysis. *Communications in Soil Science and Plant Analysis 15(6):* 673-679.

Quin, B.F., Drewitt, E.G., Stephen, R.C. 1982. A soil incubation test for estimating wheat yield and nitrogen requirements. *Proceedings Agronomy Society of N.Z. 12:* 35-40.

Scaife, M.A., Bray, B.G. 1977. Quick sap tests for improved control of crop nutrient status. *ADAS Quarterly Review 27:* 137-145.

Wehrmann, J., Scharpf, H.C., Bohmer, M., Wollring, J. 1982. Determination of nitrogen fertiliser requirements by nitrate analysis of the soil and of the plant. *In* "Plant Nutrition 1982". Proceedings 9th International Plant Nutrition Colloquium. CAB, Slough. pp. 702-709.

Withers, N.J. 1982. Sap tests for measuring nitrogen status of cereals. *Proceedings Agronomy Society of N.Z. 12:* 41-44.