YIELD RESPONSE TO NITROGEN APPLICATION BY CONTINUOUS SPRING WHEAT

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SUMMARY

Following 3 previous cereal crops, various rates of nitrogen as nitrolime were applied annually to a further four crops of Aotea wheat grown in succession on a Wingatui recent alluvial silt loam. No decline in grain yields with time was observed over the period studied.

Grain yields were positively correlated with rate of nitrogen applied and nett profit was maximised by application of about 80 kg N/ha annually.

INTRODUCTION

In Britain, continuous wheat production is well known and is technically feasible on some soils. Selman (1971) growing winter wheat in a monoculture system showed that grain yields tended to decline initially, but thereafter they appeared to stabilize and, in some cases, slowly improve. Compared with the first crop, there were reductions of the order of 20-30%, the low point being reached by the fourth or fifth crop in succession, after which the yields levelled off.

However, continuous wheat production in New Zealand is comparatively recent, although the practice of growing up to 3 crops in succession was firmly established in South Otago according to Jagger (1971). There is only one reference (Field Research Section, 1971) to research on continuous wheat cultivation in New Zealand. In the fifth season of a trial at Lincoln, the grain yield of the "second" crop was 11% higher than that of the "first" crop after pasture, but thereafter the yield decreased by about 5-8% "annually" up to the "fifth" successive crop; application of nitrolime had no effect. In the fourth season of a second trial in South Canterbury, the "second" and "third" crop yields were about 22% higher compared with the "first" crop, the yield of which was similar to that of the "fourth" crop; a small response ($P > 0.05$) was obtained to application of nitrolime.

The experiment reported here was set up to investigate the effects on grain yields of a long period under wheat cultivation and to determine the nitrogen requirements of such crops.

EXPERIMENTAL

The experiment was carried out on a Wingatui recent alluvial silt loam with a previous history of 3 cereal crops. The trial started in Spring 1967 and 4 crops of spring wheat were grown successively.

Nitrogen as nitrolime was applied annually at 0, 25, 50 and 75 kg/ha in 4 non-replicated main plot areas. Within each of the main plots, annually-shifting replicated sub-plot areas received 0, 37 or 75 kg N/ha in addition. The main-plot nitrogen was mechanically broadcast on the soil surface and the nitrogen applied to the sub plots was hand broadcast immediately after sowing.

The sub-plot areas contained 4 replicates of each of the 3 nitrogen treatments arranged in randomized blocks. Individual plots were 2.4 m wide and 20 m long. Aotea wheat was sown in both the main- and sub-plot areas at the rate of 200 kg/ha using a 16-coulter combine drill with 15 cm spacing between rows. Superphosphate at the rate of 22 kg P/ha was drilled in with the wheat each year. The plots were header-harvested in March each year and grain yields were adjusted to 15% moisture before statistical analysis.

Costs of production were assessed following Jagger (1971) and Feyter (pers. comm.) by employing a gross value for the grain at 5.5 cents/kg. The net profit was calculated by deducting a) 1.23 cents/kg in respect of post-harvest operations (grain harvesting, drying, handling and cartage) and b) 7.83 cents/kg for the cost of the fertilizer (allowing for transport, spreading and the appropriate subsidies).

RESULTS

Grain yields for three out of the four seasons studied are shown in Table 1. Data for 1969/70 have been excluded partly because of bird damage and partly because of accidental mixing of grain from various adjacent plots.

TABLE 1: The effects of different rates of nitrogen as nitrolime on the yields of spring wheat

Nitrogen (kg/ha) Main plots	Sub plots	Grain yields* (kg/ha) 1967/68	1968/69	1970/71	Mean
	0	3983 B	4344 B	4372 C	4355 C
0	37	4808 A	5289 A	5046 B	5048 B
	75	5165 A	5332 A	5746 A	5414 A
	0	4573 C	4949 b	4794 B	4773 C
25	37	5042 B	5160 b	5771 A	5326 B
	75	5471 A	5969 a	5784 A	5743 A
	0	4967 b	5484 a	5598 a	5352 b
50	37	5376 a	5611 a	5678 a	5557 ab
	75	5502 a	5653 a	5704 a	5622 a
	0	5180 b	5477 a	5652 a	5440 b
75	37	5510 a	5841 a	5704 a	5689 ab
	75	5669 a	5809 a	5977 a	5822 a

* Yields adjusted for differences between main plots (see Appendix)

Duncans lettering: Lower case indicates differences between the members of each group of 3 sub-plots at the 0.05 level whilst capitals indicate difference at both the 0.05 and 0.01 levels.

Both in the absence of applied nitrogen and at the various rates of nitrogen tested, there was no evidence of a decline in grain yields over the period studied. The yields in 1968 tended to be somewhat lower than in 1969 or 1971. Climatic differences might have accounted for this, though Belman (1971) noted an improvement in yield in some cases which was not attributable to climatic factors.

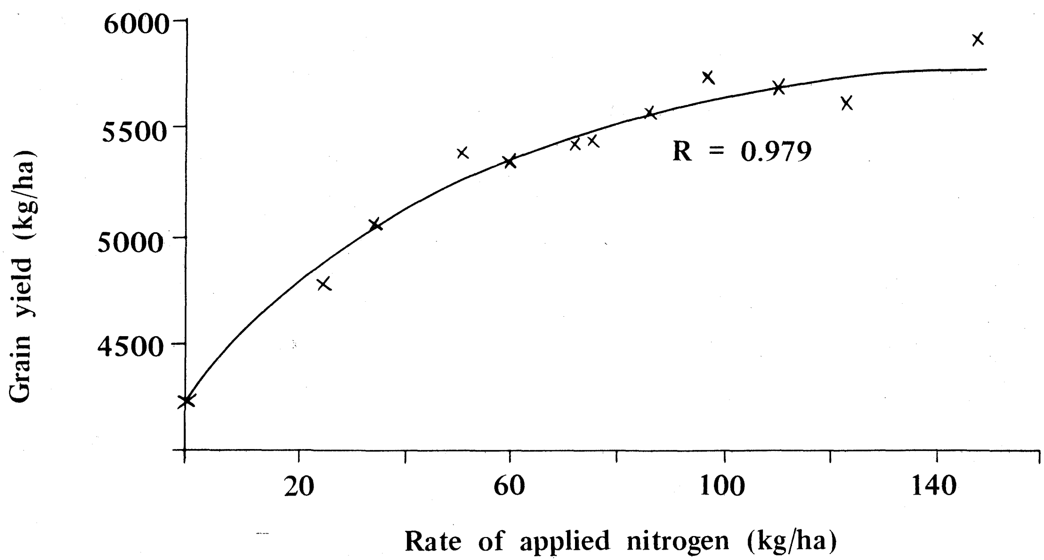
Within both the nil and 25 kg N/ha main plots there were significant responses to the additional nitrogen applied to the sub-plots in each year in almost every instance. With one exception, yield responses to the 37 kg N/ha rate were relatively large. Increase in the rate applied to the sub plots from 37 to 75 kg N/ha tended to show higher yields in most cases, but the differences were small and failed to reach significance in 2 out of the 3 years in the nil-nitrogen main plot and in one year in the 25 kg/N/ha main plot.

Averaging the results over the 3 years for the nil and 25 kg N/ha main plots showed 16 and 12% increases respectively at the 37 kg N/ha rate and 24 and 20% increases respectively at the 75 kg N/ha rate compared with the appropriate controls.

Where 50 or 75 kg N/ha were applied to the main plots, the yield responses to the additional 37 kg N/ha rate applied to the sub plots were smaller than those obtained in the nil - and 25 kg N/ha main plots, and reached significance (P 0.05) only in 1968. Increase in the rate of nitrogen applied to the sub plots from 37 to 75 kg/ha had no significant effect compared with the lower rate. When the data were averaged over the three years, addition of 37 kg N/ha had no significant effect compared with the appropriate nil-nitrogen sub-plot control; at the higher rate of N, however, the increases of 5 and 7% for the 50 and 75 kg N/ha main plots respectively were significant, though only at the 5% level.

Quadratic regressions of yield, adjusted for differences between main plots (see Appendix), were determined for each year individually and for the means of the three years. A significant relationship was found in each case and, since the curves were similar, only that for the mean of the 3 years is presented in Fig. 1.

Fig. 1 : Relation between rate of applied nitrogen and spring wheat grain yields (3 - yr means adjusted for main plot differences)



The data in Fig. 1 showed that yields tended to increase with increase in the rate of nitrogen applied. However, there was a steadily decreasing response from a rate of 29 kg grain/kg nitrogen obtained from the first 20 kg increment of nitrogen applied down to a rate of less than 3 kg grain/kg nitrogen obtained from the seventh 20 kg nitrogen increment.

The decision to apply nitrogen at a particular rate ultimately depends on the profit margin. Table 2 shows the relationship between yield response, gross value and costs of production.

TABLE 2: Grain yield response, gross value and cost of the extra production at various rates of applied nitrogen.

N rate (kg/ha)	Yield Response kg/ha	Gross Value $	Cost of Production $	Profit $
20	579	31.87	13.15	18.72
40	900	49.49	23.12	26.37
60	1131	62.21	31.98	30.23
80	1303	71.64	40.11	31.53
100	1428	78.54	47.68	30.86
120	1515	83.34	54.78	28.56
140	1569	86.32	61.46	24.86

The data in Table 2 indicated that increase in the rate of nitrogen applied up to about the 80 kg N/ha level was increasingly profitable in so far as the gross value exceeded the costs of production. At rates of nitrogen above this level, however, where yield responses were still evident, the costs of production exceeded the gross value of the extra grain obtained and hence the profit margin was reduced.

CONCLUSIONS

1. The study showed that continuous wheat production was technically feasible on the Wingatui silt loam used in this trial and may be worthwhile on other soils.
2. During the 4 years studied, representing the fourth to seventh cereal crops in succession, there was no apparent decline in yields either in the absence or presence of applied nitrogen.
3. Optimum economic yields could be sustained by application of about 80 kg nitrogen/ha annually, provided that other factors (e.g. moisture, other nutrients, weed control and disease) were non limiting.

ACKNOWLEDGEMENTS

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APPENDIX

Notes on Statistical Analysis

by

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1. Assumed form of regression

The response regression was assumed to be of the form:

$$\text{Expected response} = b_1\ N^{0.75} + b_2\ (N^{0.75})^2$$

where the exponent 0.75 has the effect of making the curve approach its maximum more rapidly than it falls away (a characteristic feature of nitrogen response curves in this kind of study).

2. Adjustment for block (i.e. main plot) effects

Since the total nitrogen levels were staggered from block to block, differences between block means can be attributed only partly to differences between the blocks themselves, the rest being attributable to the effect of nitrogen. Moreover a response regression fitted to treatment means as they stand (i.e. disregarding blocking) could be affected by block effects in such a way as to be seriously misleading, in fact could conceivably give rise to a wholly spurious regression due to block effects rather than nitrogen response. It was therefore necessary to fit a regression model which included block effects to the treatment means. This was equivalent to fitting parallel regression curves (i.e. curves differing only in their heights above the axis) to the treatment means as illustrated in Fig. 2; the differences for which adjustment can then be made by moving the curves and points associated with them upwards or downwards until they coincide. Fig. 1 was constructed by making such adjustments to the level of the block containing the control treatment, with a view to ease of interpretation. This method of analysis is equivalent to building up the regression curve piecemeal from response increments fitted to within-block differences between treatment means, and it is to establish the reality of the latter that the particular use of Duncan's letters in Table 1 has been adopted.

Fig 2: Parallel nitrogen response curves fitted to separate blocks