PREDICTION OF GRAIN YIELD RESPONSES IN WHEAT TO NITROGEN FERTILISERS

T.E. Ludecke
Soil Science Department,
Lincoln College,
Canterbury.

ABSTRACT

Studies conducted in the 1971-72 and the 1972-73 seasons have shown that there is a very strong correlation between the percentage response or depression in grain yields to nitrogen fertilisers and the levels of nitrogen in the nitrate form (NO_3 -N) under the newly-sown wheat crop in the previous August. The levels of NO_3-N were measured in the soil at various depths down to 60 cm; if the levels of NO_3 -N to 60 cm in August are less than 60 kg/ha of nitrogen then big responses in grain yields to the application of nitrogen fertilisers are very likely. If the levels are greater than 100 kg/ha then depressions in yields are likely.

The correlation coefficients for the regression equations showed that there was a very strong relationship when the NO_3 -N were measured to only 20 cm in the 1971-72 and 1972-73 seasons. The relationship was inferior when ammonium nitrogen (NH_4 -N) plus NO_3 N to 60 cm in August were plotted against the percentage response or depression in grain yield. The relationship was not significant when NH_4 -N was used alone in the regression equation. This non significant relationship supports the earlier observation that wheat plants under field conditions appear unable to utilise NH_4-N. During the late winter and early spring of 1973 there were heavy falls of rain in Canterbury and this resulted in big losses of NO_3 -N from the surface horizons of newly sown wheat paddocks by leaching. Consequently in the 1973-74 season the correlations between the responses and soil NO_3-N levels are poor for shallow depths and in a preliminary study the correlations are only satisfactory for the 0-90 cm depth or the profile depth in stony soils.

INTRODUCTION

The use of nitrogen fertilisers has increased markedly in recent years. Figure 1 records the sales of nitrogen fertilisers by the three South Island Fertiliser Companies in the 11 year period 1963-73. In the five year period 1968-73 the use increased by nearly 800%. Probably the major reason for the very marked increase in sales is that the price of nitrogen fertilisers remained remarkably static over the period 1963-73. In the past year prices have spiralled. In Canterbury in July 1973 the price to the farmer per kilo of nitrogen for ammonium sulphate was 28.9 cents compared with 40.2 cents in July 1974. The corresponding costs for urea were 26.5 cents and 45.9 cents.

Monthly sales records in Canterbury and North Otago by the two fertiliser companies in recent years suggests that the use of nitrogen fertilisers in cereal cropping and grass seed production has increased markedly.

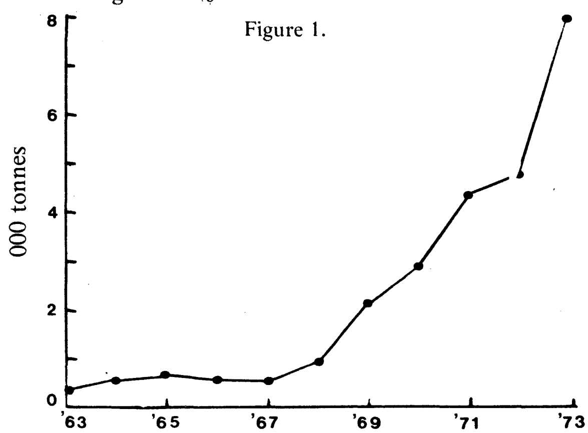
Because of big increases in the price of nitrogen fertilisers and their widespread use in cereal cropping it was considered desirable to develop a soil test to predict grain yield responses in wheat.

PREDICTION OF GRAIN YIELD RESPONSES AND DEPRESSIONS

Previous Investigations

It has been found to be difficult to predict responses to nitrogen fertilisers from previous cropping histories (Walker, 1969; Ludecke, 1972; Ludecke, 1974). Small but statistically significant depressions in grain yields are very likely to occur if nitrogen fertilisers are applied to wheat crops when the nitrogen status of the soil is high; i.e. the first crop after good pasture (Ludecke, 1972).

In Canada it has been shown with barley, that a measure of the levels of No_3 -N to 61 cm at sowing time in the spring, gave an excellent indication whether a grain yield response would result from the application of nitrogen fertilisers. (Soper and Huang 1963, Soper **et al.** 1971). Ward (1971) reviewed the research into the No_3^- -N soil test in the Great Plains area of the United States of America where the climate is sub humid to semi arid and the soils belong to the Chernozem and Chestnut soil groups. Research showed that a measure of No_3 -N to at least 60 cm gave a good indication of the likely responses of cereal crops to nitrogen fertilisers and the likely cereal yields. The No_3 -N test is offered by four Land Grand Universities in the Great Plains States. It is recommended that No_3 -N status be assessed in the late fall or early spring. Soil samples should be air dried as quickly as possible to stop microbial activity and insure little change in No_3-N concentration of the soil.



Investigations in the 1971-72 and 1972-73 Seasons

The levels of No_3-N to 60 cm in August in 16 experiments, conducted by the Ministry of Agriculture and Fisheries and Lincoln College, were measured in the 1971-72 and 1972-73 seasons. It has been found (Figure 2) that there is a very close relationship between the levels of No_3 -N to 60 cm in August and the percentage response or depression in grain yields resulting from the application of 85 Kg/ha of nitrogen as calcium ammonium nitrate in the previous spring. As shown in Table 1 these field experiments were carried out over a wide range of soil and climatic conditions. The trials also covered a wide range of rotations. The percentage main effect response or depression due to nitrogen are given in Table 1 and also statistical analyses of these main effects using Duncan's multiple range test. The sites are arranged in order of decreasing levels of No_3-N to 60 cm.

TABLE 1: Soil types, localities, levels of NO_3-N to 60 cm and main effect percentage response or depression to nitrogen fertilisers.

Soil Type and Locality		NO_3-N Kg /ha 60 cm	% Response or Depression	Statistical Analysis
1. Chertsey sh.si.l.	Kimberley	125	-4.3	-1%
2. Mayfield si.l.	Methven	116	-0.2	n.s.
3. Wakanui cy.l.	Ashburton	112	-7.7	-1%
4. Kowai f.s.l.	Sheffield	109	-1.4	n.s.
5. Wakanui si.l.	Lincoln Coll.	102	0.7	n.s.
6. Lismore st si. l.	Pendarves	101	-0.3	n.s.
7. Barrhill si.l.	Rakaia	101	0.7	n.s.
8. Wakanui cy.l.	Ashburton	88	1.8	n.s.
9. Mayfield si.l.	Methven	78	1.6	5%
10. Wakanui si.l.	Lincoln Coll.	75	6.9	1%
11. Wakanui cy.l.	Ashburton	60	7.6	1%
12. Wakanui cy.l.	Ashburton	51	21.8	1%
13. Lyndhurst si.l.	Methven	51	55.5	1%
14. Lyndhurst si.l.	Methven	49	32.2	1%
15. Aparima si.l.	Aparima	48	65.3	1%
16. Aparima si.l.	Aparima	43	52.7	1%

As shown in Figure 2 if the levels of No_3-N to 60 cm in August are less than 60 kg/ha then big responses to nitrogen fertilisers, in terms of increased grain yields, will occur. If the levels of No_3-N are greater than 100 kg/ha, then depressions in grain yields are likely. It has been found (Ludecke 1972, Dougherty and Langer 1974) that the grain yield depressions follow vegetative responses to nitrogen fertilisers in the spring period. On unirrigated low moisture retentive soils, depressions in grain yield are probably due in part to increased moisture stresses associated with increased vegetative growth following the application of nitrogen fertilisers in September. Dougherty and Langer 1974 showed that with Kopara wheat on an irrigated moisture retentive Wakanui soil poor grain set was the major cause of depressions. The grain set was shown to be probably due to restricted availability of carbohydrate during the development of wheat heads.

In Table 2 the regression equations and correlation coefficients (r values) for the relationship between the percentage yields and the Kg/ha and p.p.m. of No_3-N at different depths are given. Also the relationship between yield and the Kg/ha of NH_4-N + No_3-N and NH_4-N alone to 60 cm are given.

The r values for the different equations using kg/ha or p.p.m. of NO_3 N as the x values were all highly significant; the relationship was a very strong one when the soils were sampled to only 20 cm in the 1971-72 and 1972-73 seasons. The r values for the equations using p.p.m. of NO_3-N as the x values were very similar to those where kg/ha of NO_3-N were used. Thus it does not appear that it will be necessary to determine volume weights. The range in the p.p.m. of NO_3-N 0-60 cm were 18.0 p.m.m. at site 1 to 5.7 p.p.m. at site 16.

As shown in Table 2 the relationship was inferior when NH_4-N + NO_3-N to 60 cm were used as the x values. The relationship was not significant when the NH_4-N

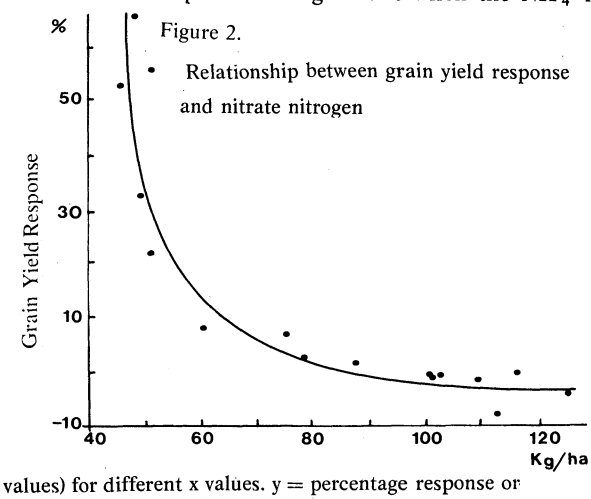


Figure 2.

Relationship between grain yield response and nitrate nitrogen

TABLE 2: Regression equations and correlation coefficients (r values) for different x values. y = percentage response or depression.

x Values	Regression Equation	r Values
NO_3-N kg/ha 0-60 cm	$Y=161.5-3.185x+0.0153x^2$	0.90**
No_3-N kg/ha 0-40 cm	$Y=140.3-3.664x+0.0221x^2$	0.87**
NO_3-N kg/ha 0-20 cm	$Y=86.49-5.556x+0.0799x^2$	0.92**
NO_3-N kg/ha 0-10 cm	$Y=75.14-12.15x+0.04138x^2$	0.77**
NO_3-N p.p.m. 0-60 cm	$Y=153.0-21.60x+0.7372x^2$	0.90**
NO_3-N p.p.m. 0-40 cm	$Y=151.0-19.16x+0.5645x^2$	0.85**
NH_4-H+NO_3-N kg/ha 0-60 cm	$Y=60.83-0.3262x$	0.70**
NH_4-N kg/ha 0-60 cm	$Y=25.67-0.1839x$	0.29 n.s.

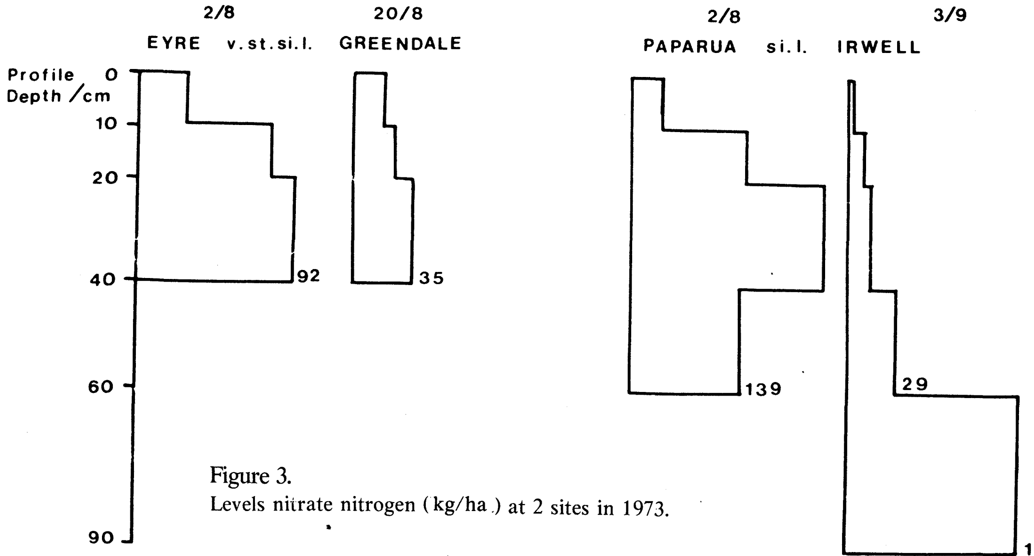


Figure 3.
Levels nitrate nitrogen (kg/ha.) at 2 sites in 1973.

levels to 60 cm were used in the equation. Ludecke (1972) at five sites in Canterbury showed that the Arawa cultivar of wheat appeared unable to utilise the ammonium form of nitrogen in the field. Wheat responded markdely to nitrogen fertilisers applied in the spring, in terms of vegetative growth, yet there was up to 275 kg/ha of nitrogen in the ammonium form to 60 cm under the crop. In growth cabinet studies Young (1972) showed that when there was close contact between roots and NH_4-N wheat utilised this form of nitrogen readily. The apparent inability of wheat to utilise NH_4-N in the field possibly explains the poor relationship between the percentage yield and the NH_4-N levels.

Investigations in the 1973-74 Season

Soils have no ability to retain NO_3-N and this form of nitrogen is readily leached from surface horizons (0-75 cm) during periods of heavy rainfall (Ludecke and Tham 1971). During August and September 1973 there were heavy falls of rain in Canterbury (187 mm at Lincoln College) and this resulted in big losses of NO_3-N by leaching from the surface horizons of newly sown wheat paddocks. Examples of these losses are shown in Figure 3. Because of the leaching of NO_3-N it appears, from preliminary studies, that the correlations between soil nitrate levels to 60 cm and responses will not be as good in the 1973-74 season as in the previous two seasons. The correlations however are very good when soil nitrate levels were determined to 90 cm or the profile depth to stores. The levels of NO_3-N to these depths in August and September 1973, at 24 experimental sites, varied between 6 and 145 kg/ha of nitrogen. The NO_3-N at 60-90 cm is readily available to wheat crops. In Canada, Soper and Huang 1963 showed that NO_3-N and moisture at 100-130 cm is readily available to barley crops and was removed before the crops reached the heading stage of growth.

All the NH_4-N and NO_3-N determinations in these investigations have been carried out on freshly sampled soils. Preliminary studies last year showed that NH_4-N concentrations increased markedly when soils were air dried but NO_3-N concentrations fortunately changed little.

CONCLUSION

It appears that a promising soil test for predicting grain yield responses or depressions in wheat crops to nitrogen fertilisers has been developed for South Island conditions. If the test again proves satisfactory in the 1974-75 season it will be made available to farmers in the spring of 1975.

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