THE USE OF NITROGEN FERTILISERS ON DRYLAND WHEAT

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The use of nitrogen fertilisers on wheat has been widely studied in the past. However from many hundreds of trials throughout the country the major conclusions drawn are that grain responses are variable and often quite unpredictable. Although responses generally increased with increasing cropping intensity, it has always been difficult to predict responses from previous cropping history alone (Lynch, 1959; McLeod, 1962; Douglas, 1968, 1970; Walker, 1969; Ludecke, 1972, 1974).

This of course makes it very difficult to provide any accurate and reliable advice on nitrogen fertiliser requirements for wheat.

This review summarises the results of the last 10 years trial work with nitrogen fertilisers on wheat in North Otago and South Canterbury. It is an attempt to improve prediction of responses by dryland wheat and therefore to increase the efficiency in the use of nitrogen which is becoming an increasingly expensive resource.

ECONOMICS

The use of fertiliser nitrogen must be determined by the relationship between the cost of nitrogen applications and the returns from increased grain yields. This relationship is given in Table 1 in terms of break-even points, which show the increases in yield required to equate with the cost of applied nitrogen.

TABLE 1. ECONOMIC RELATIONSHIPS OF THE MAIN FORMS OF NITROGEN

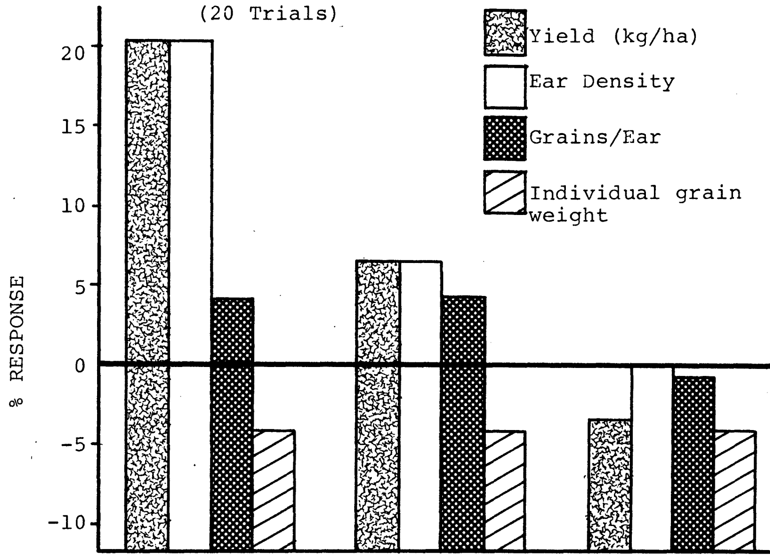
			Break-even points (Kg grain/Kg N)	
	%N	*$/Kg N*	*Kopara, Takahe Aotea etc.*	*Karamu*
Ammonium sulphate	21	0.70	4.1	4.7
Urea	46	0.71	4.2	4.7
Nitrolime	26	1.10	6.5	7.3
D.A.P.	18	2.59	15.2	17.3

The higher nitrogen content of urea makes this form of nitrogen still the most attractive in terms of transport costs and ease of application.

COMPONENTS OF YIELD

In order to examine the effect of nitrogen on the components that make up grain yield, the results of 20 trials have been separated into economic responses (above the break-even point), marginal responses (below the break-even point - uneconomic responses) and depressions (Fig. 1).

Fig. 1. EFFECT OF 90 kg N/ha ON YIELD COMPONENTS OF WHEAT (20 Trials)



Increases in grain yield with nitrogen were due mainly to equivalent increases in ear density through increased tiller production. There were small improvements in grain set giving slightly more grains per ear, but generally this difference was small. Individual grain weight was reduced with nitrogen. This may be the result of increased moisture stress, or, often, increases in mildew occurrence, resulting from the promotion of vegetative growth with nitrogen. It is also thought that reductions in grain weight may be due to an increase in competition between the vegetative and reproductive growth phases for carbohydrates (Dougherty and Langer, 1974).

Yield depressions with nitrogen were the result of a lack of response by tillering and decreases in grain set and individual grain weight.

Overall, most of the variation in yield and response seems to arise from differences in ear density through variations in tiller production which appears to be the function most affected by nitrogen fertiliser.

GRAIN QUALITY

Over a number of trials with records of baking quality the application of nitrogen fertiliser promoted small but consistent increases in baking score (mechanical dough development) and dough strength as measured by the work required to develop the dough (Table 2).

TABLE 2. EFFECT OF NITROGEN ON BAKING QUALITY (14 TRIALS)

	Baking Score (M.D.D.)	*Dough Strength (W.hr/Kg)*
No nitrogen	18.6	6.2
90 Kg N/ha	21.3	7.0
SED	0.7	0.2

Nitrogen therefore appears to have increased the protein content of the grain as this largely determines dough strength.

CULTIVARS

There have generally been only small differences in nitrogen responses between the cultivars Karamu, Kopara, Takahe and

Aotea (Table 3). Although Karamu and Kopara tended to give higher returns per kg of nitrogen there was no consistent trend.

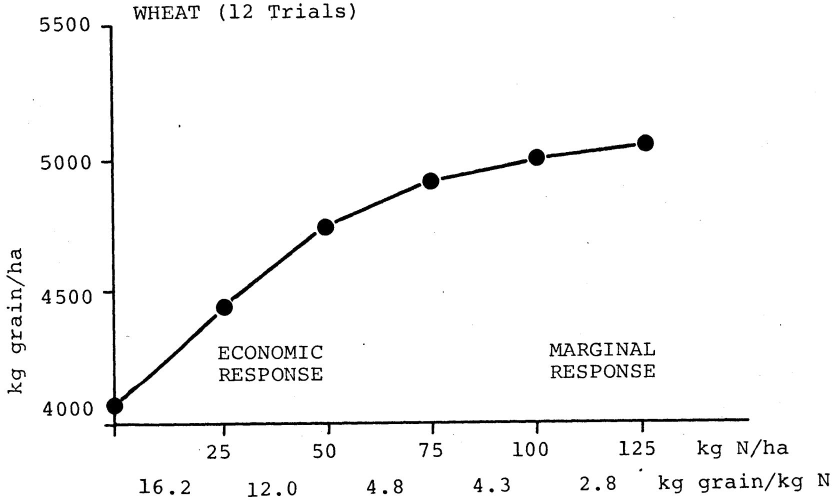
TABLE 3. RESPONSE TO NITROGEN BY FOUR WHEAT CULTIVARS

	Autumn Sown (9 Trials)		*Spring Sown (7 Trials)*	
	% response	*Kg grain/Kg N*	*% response*	*Kg grain/Kg N*
Karamu	21	9.5	15	4.7
Kopara	22	10.1	7	3.1
Takahe	19	8.1	10	3.8
Aotea	17	6.6	9	2.5
SED	3	1	3	1

RATES OF NITROGEN

The average grain yields from 12 trials with second successive wheat crops give the response curve shown in Fig. 2.

Fig. 2. EFFECT OF INCREASING RATES OF NITROGEN ON 2nd CROP WHEAT (12 Trials)



Although total grain yields varied between trials there was very little variation in the magnitude of the response to the various levels of nitrogen.

There were quite high and certainly economic responses to nitrogen up to 50 kg N/ha (equivalent to 110 kg urea/ha). Responses fell quite rapidly with nitrogen applied above this level and from 75 kg N/ha (equivalent to 160 kg urea/ha) any further increase in nitrogen application produced only a marginal response.

TIME OF APPLICATION

As most nitrogen responses originated from increases in ear density, nitrogen applications timed to coincide with tillering gave the greatest increases in grain yield (Table 4). Applying nitrogen following plant emergence or during late tillering gave the greatest yields through increased tiller production. Later applications at ear emergence gave significantly lower grain yields and in some cases depressions, as nitrogen applied at this stage generally promoted vegetative growth but was too late to improve tillering.

TABLE 4. EFFECT OF TIMES OF NITROGEN APPLICATION

	grain yield (Kg/ha)		*grain yield (Kg/ha)*
Plant emergence	5620	July	4120
Late tillering	5560	August	4270
Ear emergence	5100	September	4210
		October	4200
		November	3740
SED (4 Trials)	180	SED (5 Trials)	70

A similar effect is shown with monthly applications from July through to November. Applying nitrogen between July and October gave the greatest grain yields again as a result of increased tiller production as the majority of tillering usually occurs from about early August to mid to late October. Nitrogen applied in November after tillering had ceased consequently resulted in lower yields.

As nitrate-nitrogen is readily leached from the soil, responses to fertiliser nitrogen vary from season to season depending on rainfall.

For example heavy rain during tillering may result in the loss of much of the nitrogen applied at early tillering and restrict the response accordingly. Similarly if nitrogen is applied at sowing heavy rain may leach much of it before the period of maximum tillering, again restricting the response considerably.

In general, however, it appears that to get the maximum response nitrogen should be applied to autumn wheat during tillering.

PREDICTION OF NITROGEN RESPONSES

The main difficulty encountered in the use of fertiliser nitrogen is in the prediction of grain responses.

In attempting to predict the likelihood of an economic nitrogen response by dryland wheat in such areas as Canterbury and North Otago, two factors must be considered.

The first of these relates to the level of soil nitrogen which is largely determined by the previous cropping history and winter rainfall. The second and most unpredictable factor is the availability of soil moisture during the growth of the crop. The latter has a significant effect in restricting nitrogen responses by dryland wheat.

Soil Nitrogen Status

The major factor that determines the level of soil nitrogen is previous cropping history. As the intensity of cropping increases grain yields steadily fall and nitrogen responses increase. Figure 3 illustrates this effect in a trial where wheat was grown for six years in succession. Wheat yields fell rapidly in successive crops and although yields still gradually fell when nitrogen fertiliser was applied annually, it resulted in substantial yield increases. Responses to nitrogen increased rapidly up to the fourth successive crop and then seemed to remain relatively steady.

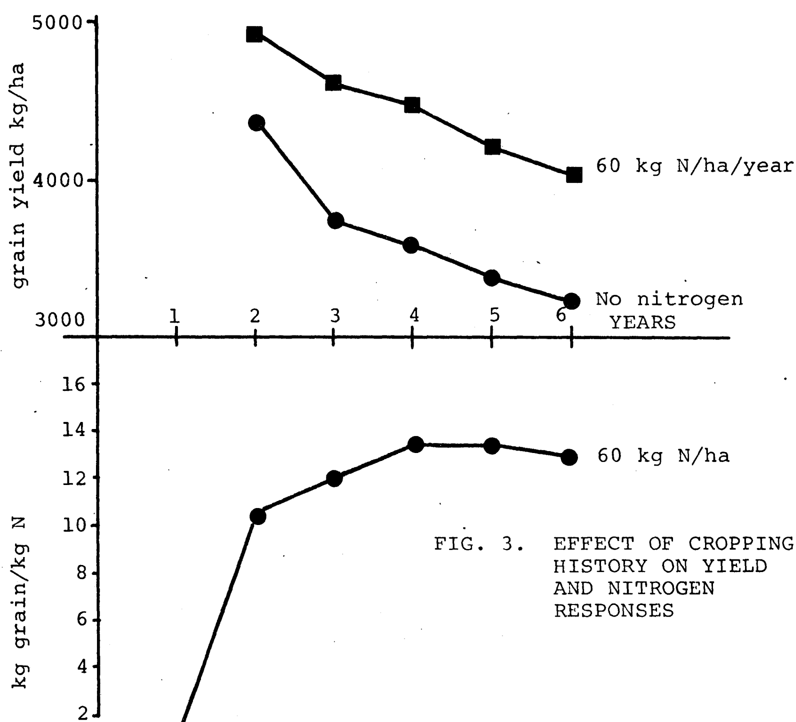


FIG. 3. EFFECT OF CROPPING HISTORY ON YIELD AND NITROGEN RESPONSES

To further evaluate the role that previous cropping history plays in predicting responses, all autumn and spring sown wheat trials have been separated into first, second and third or greater successive crop situations in Table 5.

TABLE 5. EFFECT OF PREVIOUS CROPPING HISTORY ON NITROGEN RESPONSES-DRYLAND WHEAT (55 TRIALS)

		Nitrogen responses (% of trials)		
		1st Crop	*2nd Crop*	*3rd or Greater Crop*
Autumn Sown Wheat	Economic response	0%	80%	100%
	Marginal response	25%	10%	0%
	Depression	75%	10%	0%
Spring Sown Wheat	Economic response	0%	40%	80%
	Marginal response	25%	30%	20%
	Depression	75%	30%	0%

No economic nitrogen responses were recorded in 1st crop wheat when soil nitrogen levels should have been reasonably high. In fact three quarters of all first crop trials showed nitrogen-induced yield depressions.

With increased cropping intensity the number of responses by autumn wheat increased such that economic responses by third or subsequent crops appear to be entirely predictable.

It appears to be the responses by second crop autumn wheat that are difficult to predict as although economic responses do occur, marginal responses and depressions have also been recorded. Responses by spring wheat are less predictable. Responses by second crop spring wheat were quite unpredictable and although a large number of economic responses occurred in 3rd or subsequent crops, marginal responses also occurred.

Nitrogen responses, therefore, appear to be restricted to areas that have grown two or more successive cereal crops, but are difficult to predict for spring wheat and second crop autumn wheat.

Although cropping history can give an indication of the likelihood of economic responses by giving an indirect measure of the soil nitrogen status, responses by second crop autumn wheat and spring wheat remain difficult to predict. This is largely the result of year-to-year variability in rainfall, during both the winter and the growing season.

The technique of measuring the level of nitrate-nitrogen in the soil in August and relating this to an expected level of grain yield response (Ludecke, 1974, 1974a) has been used with some success over the past few years and would be useful mainly in helping to predict responses by second crop autumn wheat. It is unlikely that spring sown wheat responses could be accurately predicted in this way as these responses are more dependent on soil moisture during crop growth.

Soil Moisture During Crop Growth

The major factor limiting nitrogen responses in dry areas and preventing their accurate prediction is the level of plant available soil moisture during crop growth, particularly during late tillering.

Results of trials on soils where moisture stress is common from late spring or early summer, show that nitrogen responses by spring wheat are minimal compared with those of autumn wheat (Table 6).

TABLE 6. EFFECT OF SOIL MOISTURE ON NITROGEN RESPONSES (8 TRIALS)

	(% response, Kg grain/Kg N in brackets)			
	Shallow Soil		*Deep Soil*	
	Autumn Sown	*Spring Sown*	*Autumn Sown*	*Spring Sown*
Yield	20 (9.9)	4 (0.8)	26 (9.6)	19 (7.0)
Ear Density	23	4	28	16
Grain Weight	-3	-7	0	-1

SED'S :	*YIELD*	*EARS*	*GRAIN WEIGHT*
For comparison of sowing dates	4	6	3
For comparison of soil depths	4	5	3

The increase in ear density of autumn wheat with nitrogen is not restricted by dry conditions because tillering is generally completed before dry conditions limit growth. Any subsequent effect of moisture stress in restricting the nitrogen response by reducing either grain set or individual grain weight, is usually offset by the normally large increases in ear density.

Spring wheat however, is often still tillering at the onset of dry conditions which either restrict tillering or terminate it at an early stage, thus preventing any nitrogen response being expressed in terms of increased ear density. Combined with possible reductions in grain set and individual grain weight, this restriction of tillering leads to either very low responses to nitrogen or yield depressions in spring wheat.

When spring wheat has been sown in deep soils where tillering is not restricted by moisture stress the yield response to nitrogen is considerly higher and approaches that of autumn wheat.

The effect of soil moisture stress in limiting nitrogen responses by spring wheat is clearly illustrated in Table 7.

TABLE 7. EFFECT OF IRRIGATION ON NITROGEN RESPONSES BY SPRING WHEAT

	(% response, Kg grain/Kg N in brackets)		
	Yield	*Ear Density*	*Grain Weight*
Dryland	9 (2.9)	8	-3
Irrigation at late tillering	31 (10.1	22	+2
Irrigation at late tillering and grain filling	33 (10.6)	31	+4
SED	4	4	3

Irrigation prolonged tillering and enabled the effect of nitrogen fertiliser to be more fully realised through increased ear density. Further irrigations after tillering did not improve the nitrogen response any further confirming that moisture stress restricts nitrogen responses mainly by restricting tillering.

SUMMARY

Several factors interact with regard to nitrogen responses in wheat and this makes responses difficult to predict.

* Responses depend primarily on the original nitrogen status of the soil and then the previous cropping history. They are then modified, firstly by the winter rainfall and its effect in leaching nitrogen from the soil and secondly by rainfall over the growing season.

* This most recent research indicates that nitrogen is not required for first crop autumn or spring sown wheat but economic responses seem quite reliable in third or subsequent crop autumn wheat. Responses by second crop autumn wheat are less predictable but could be more easily predicted by directly measuring the soil nitrogen status.

* Nitrogen cannot be recommended for spring wheat in dryland areas where moisture stress can develop at any stage during tillering, as responses in this situation are normally minimal and certainly quite unpredictable. Irrigated spring wheat has given nitrogen responses similar to autumn wheat and may be treated in the same way when attempting to predict responses.

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