AN INVESTIGATION OF WHEAT RESPONSE TO PLANT DENSITY AND NITROGEN APPLICATION IN THE MANAWATU/RANGITIKEI

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ABSTRACT

Forty four wheat paddocks were monitored during the 1980/81 season using a combination of survey and standard experimental techniques.

Yield and fertiliser response were closely associated with ear density. There was a marked effect of cultivar on yield. The response to additional N fertiliser was obtained when the yield of the quadrats not receiving additional N was less than the equivalent of 4.5 t/ha.

Yield, N response and ear density were associated less strongly with sowing date, geographical district, herbage N and P levels and the number of years out of grass.

Plant density was poorly associated with both tiller and ear number possibly because of wet soil conditions early in growth.

It is suggested that the technique used in this study could be useful for both research and advisory purposes.

Additional key words: ear density, waterlogging, seedbed, survey technique, cultivar, herbage N, herbage P.

INTRODUCTION

Much of the work on yield components in wheat has shown that ear number per unit area is the most significant component influencing grain yield. This would seem to be especially so when yields are less than 6t/ha. Detailed work on wheat in the North Island is limited but recent results from Hampton (1981) and Hampton *et al.* (1981) have confirmed the importance of ear number in wheat production for the Manawatu-Rangitikei area.

Hampton *et al.* (1981) have suggested that the most efficient way of obtaining the desired ear population (between 600 and 800 ears/m²) is to establish an optimum plant population. They suggested that this optimum could be within the range of 250-300 plants/m², a range generally recommended for winter wheat in Canterbury (Dougherty *et al.*, 1978). McCloy (1980), however, has proposed 400 plants/m² for spring-sown wheat. Doughtery *et al.* (1978) found the cultivar Karamu unresponsive to plant populations between 170-580/m². Hampton (1981) has calculated that sowing rates regarded as normal for the Manawatu/Rangitikei would establish plant populations between 330 and 600 plants/m² which could produce excessive ear numbers.

The relationship between plant and ear density in data presented by Hampton (1981) is inconsistent over the two seasons he studied. The maximum plant population achieved in the experiments conducted in 1979 was 367 pl/m² which resulted in 811 ears/m², considered by Hampton to be too high although it resulted in the highest yield. The experiments in 1980 produced higher plant populations (up to 443 pl/m²) but ear numbers produced were lower and a strong curvilinear relationship between plant number and both ear number and yield was apparent, indicating that plant numbers greater than 350/m² may be undesirable. These trends would suggest a strong environmental influence on the plant number-ear number association and, because of this, it was decided that further work in this area was warranted, preferably over a wide range of conditions.

Farmers can influence ear population by the use of nitrogen fertiliser. Significant responses to N applied at rates of 100 kg N/ha or more at tillering have been obtained on winter-sown wheat in Canterbury (Dougherty *et al.*, 1978; Fraser & Dougherty, 1978). Spring-sown crops may not be so responsive (Sheath and Galletly, 1980), possibly because critical growth stages occur later when mineralisation can supply more of the crop requirement. In addition, yield depressions can result from N application (Dougherty and Langer, 1974). Thus some caution is needed when considering high rates of N, especially on spring-sown crops. However, with greater intensification of cereal cropping on arable farms in the Manawatu/Rangitikei and because modern cultivars are more responsive to N, it seemed worthwhile to investigate whether rates of N greater than those presently used by farmers would result in grain yield increases.

Normal methods of experimentation require that a small number of inputs be investigated while holding all others constant. While information from this work is important for the elucidation of principles in crop management, little information on the relative importance of those principles amongst the diversity of inputs on a farm or district basis is provided. For farmers and advisors, the relative significance of an input would seem to be important. The work reported in this paper was undertaken in an attempt to determine the significance of plant density and an application of N in addition to that used by the farmer. We used a technique not commonly used in agronomy so a further objective of the paper is to describe an example of the technique to stimulate discussion and possibly further use of it.

MATERIALS AND METHODS

The technique used contained elements of both survey and experimental methods. Forty-four paddocks in the Manawatu/Rangitikei cropping districts were studied in the 1980/81 season. These paddocks were on 36 farms which were obtained from lists submitted by advisory and commercial personnel. The farms were distributed within 3 geographical regions centred on Marton, Feilding and Kairanga. The specific paddocks used on each farm were largely determined by being at the required stage (Feekes Growth Stage 2-3) at the time of the initial visit.

In each paddock, 3 sets of 2 adjacent 0.5m² quadrats were marked by pegs at each diagonal so that all plant measurements could be made on the same plants. The equivalent of 50 kg N/ha was applied to one of each quadrat pair, with a similar 50 kg N/ha applied over another 0.5 m² around the quadrat to minimise edge effects. Thus each paddock had 3 quadrats receiving only the nitrogen applied by the farmer (N_0) and 3 receiving an additional 50 kg N/ha as nitrolime (N_{50}).

Plant numbers in each permanent quadrat were counted at the time they were pegged out, herbage samples were taken randomly from within the paddock and the seedbed was scored on a 1-5 scale. Details of paddock history were obtained from the farmer. Twenty farms were revisited prior to ear emergence for tiller counts to be taken. Quadrats were harvested at maturity, productive ears counted, threshed and the seed weighed after oven drying.

The statistical analysis of the data took the form of a number of multiple regression studies. One set of studies was aimed at explaining the variation in grain yield between paddocks in terms of plant density, ear density, cultivars, geographical area, level of nitrogen applied by farmer, sowing date, the number of years since the paddock was last in pasture and levels of nitrogen, phosphorus and potassium in sampled herbage. Separate analyses were performed for the mean yields from the N_0 and N_{50}quadrats. Regression analyses were also conducted with ear density as the dependent variable.

The second set of multiple regression studies was aimed at modelling the response to nitrogen, i.e. the dependent variable was the mean of the differences in grain yield between the N_{50} and N_0 quadrats. The independent (or regressor) variables were as listed above, except that ear density was replaced by the difference in ear density between the N_{50} and N_0 quadrats, plant density was the mean density over the six quadrats per paddock and the grain yield from the N_0 quadrats was included as a covariable. The covariable was included so that the relationships between the nitrogen response, adjusted for N_0 yields, and the regressor variables could be examined.

RESULTS

The 1980/81 season was characterised by a very wet spring which quickly turned dry during December and early January (Table 1). The monthly water deficit for January was 183mm compared with the long term average of 13mm. Temperatures were generally slightly above the long term average.

TABLE 1: Rainfall for Palmerston North (DSIR) for June 1980 to January 1981 and the long term average (Meteorological Office, 1973)

	June	July	Aug	Sept	Oct	Nov	Dec	Jan
Rainfall 1980	56.6	81.6	94.5	121.9	129.6	145.7	54.7	15.5
Av.	99	91	84	69	89	79	104	84

The mean plant densities for N_0 and N_{50} were similar (Table 2) and were only slightly below the number recommended by Hampton (1981). Although the range of plant density is quite wide, most of the values were grouped close to the mean (Fig. 1). Mean ear density was below that recommended but some exceeded the minimum 600 ears/m² recommended for high yields. The additional nitrogen (N_{50}) resulted in a mean increase of 46 ears/m² and a mean increase of 35 g of grain/m² but the response in grain yield varied from a depression of 100 g/m² to an increase of 184 g/m².

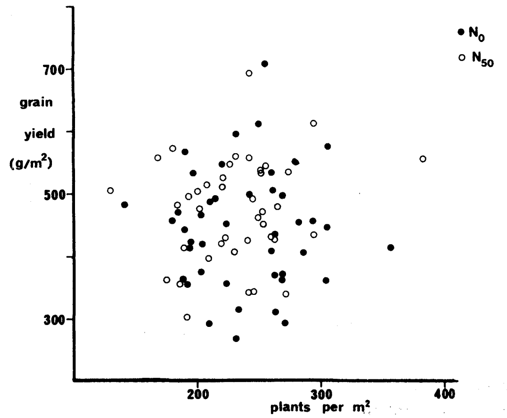

Figure 1: Relationship between grain yield and plant density.

TABLE 2: Mean values and range for the variables used in the regression analysis.

	Mean	Range
Plant density/m² N_0	236	143-353
N_{50}	229	167-384
Ear density/m² N_0	501	299-682
N_{50}	547	339-758
Ear density response to N_{50} (/m²)	46	-28-115
Grain yield (g/m²) N_0	440	269-705
N_{50}	475	303-691
Grain response to N_{50} (g/m²)	35	-100-184
N applied by farmers (kg/ha)	19	0-46
Years out of grass	2.1	0-8
Herbage N (%)	5.6	4.3-6.3
Herbage P (%)	0.45	0.26-0.54
Herbage K (%)	4.7	3.3-5.9
Sowing date	12 Oct	20 Sept-7 Nov

The simple correlation coefficients between yield components and some of the measured variables are presented in Table 3 while a summary of the regression analysis using grain yield as the dependent variable is given in Table 4.

It is clear from these data that, as in previous studies, grain yield is closely associated with ear number. The cultivar effect was, however, also strong. This was due to the greater yield of Karamu (Table 5). Rongotea had the lowest yield apparently because of the relatively low ear density. It should be noted also, however, that Rongotea had a lower plant number than the other cultivars but a similar number of ears per plants. Although Karamu had the highest yield, it has a lower ear density than Oroua but greater weight of grain per ear. Despite a large response of ear density to N_{50}, Karamu yield response was relatively much smaller due to reduced weight of grain/ear.

Sowing date appeared as a significant variable only in the N_0 treatment (Table 4). This trend appeared to occur largely through a reduction in the weight of grain per ear (Table 3) which was less important in the N_{50} treatment.

The independent variables with only moderate association with grain yield differed between N_0 and N_{50} treatments. It is of interest that plant density had only a weak association with grain yield in the N_0 treatment but this association improved slightly when nitrogen was applied. This trend is apparent in the correlation coefficients also (Table 3). Another aspect to note is the relative importance of herbage P when additional nitrogen is applied.

The effect of district on grain yield was that the Kairanga district tended to produce the highest yields and the Feilding district the lowest yields with the Marton district intermediate.

When the response of grain yield to N_{50} was used as the dependent variable (Table 4), it was most strongly associated with the yield of N_0 (Fig. 2) and with the response in ear number obtained. Thus the biggest responses to nitrogen were obtained when yields of the N_0 plots were below about 450 g/m² and this would indicate that lack of nitrogen was a significant factor contributing to low yields in this season. Herbage N and P both had strong associations with response to N_{50}. However, because they were highly correlated (r = 0.58), they were entered into separate equations. Herbage P accounted for slightly more of the variability. In this analysis, plant density became relatively more important than when the two treatments were considered separately (see Tables 3 and 4).

Another trend in the pattern of nitrogen response is apparent when the grain yield response to N_{50} is grouped according to seedbed scores taken at early tillering (Table 6). The response to the additional N declined and the number of depressions to N increased as the seedbed "deteriorated" according to the seedbed score.

Another notable trend in Table 6 is that paddocks with the higher seedbed score had a lower plant density apparently caused by a lower effective field emergence. It may be this trend which contributed to the improved association of plant density with N response compared with grain yield (Tables 3 and 4).

As ear density was so well associated with grain yield and nitrogen response, an attempt was made to determine the factors influencing it (Table 7). The values of R^2 were low so inputs other than those measured had an important influence on ear density. The cultivar effect is apparent in Table 5, with Oroua producing more ears/m² than Karamu

TABLE 3: Simple correlations between yield, yield components and some measured variables.

	Grain Yield (g/m²)			Wt. Grain/Ear (g)		Ear density/m²	
	N_0	N_{50}	N response	N_0	N_{50}	N_0	N_{50}
Plant density/m²	- 0.08	0.22	0.35	- 0.19	0.06	0.04	0.22
Herbage N (%)	0.35	0.36	0.1	0.07	0.09	0.39	0.34
Herbage P (%)	0.26	0.5	0.25	0.06	0.24	0.31	0.38
Ear density/m²	0.79	0.69	0.57	- 0.11	-0.26	—	—
Sowing date	- 0.31	- 0.29	0.21	- 0.44	- 0.26	- 0.05	- 0.12
Wt. grain/ear (g)	0.51	0.51	—	—	—	—	—

TABLE 4: Ranking of the independent variables in the regression equations that had strong or moderate association with the dependent variable. In brackets is the sign of the associated partial regression coefficient.

Dependent variable	N_0 Grain Yield	N_{50} Grain Yield	N_{50}-N_0 Grain Yield
Squared multiple correlation (R^2)	0.85	0.73	0.69
Variables with strong association	Ear density (+) Cultivar Sowing date (-)	Ear density (+) Cultivar	N_0 grain yield (-) Ear density response to N_{50} (+) Herbage N (+) or Herbage P (+) Plant density (+)
Variables with moderate association	Year out of pasture (-) District	Herbage P (+) Plant density (+) District Sowing date (-)	

TABLE 5: Mean yield components of each cultivar.

		Karamu	Rongotea	Oroua
Yield (g/m²)	N_0	478	406	439
	N_{50}	506	437	479
Plant density/m²		247	209	248
Ear density/m²	N_0	488	453	578
	N_{50}	560	501	614
Ear number/plant	N_0	2.1	2.2	2.4
	N_{50}	2.4	2.5	2.6
Weight of grain/ear	N_0	0.98	0.90	0.75
(g)	N_{50}	0.90	0.87	0.78
Number of paddocks		18	15	7

TABLE 6: Some plant variables classified according to a seedbed score made when additional nitrogen was applied. SE of mean in parenthesis.

	Seed Score*		
	1	2	3+
Grain response to N_{50} (g/m²)	51 (25)	24 (15)	15 (19)
Number of yield depressions to N	1	3	8
Plant density/m²	258 (15)	238 (10)	213 (9)
Number of scored paddocks	11	11	13

* 1 = friable with no surface crusting and minimal compaction.
5 = compacted and/or with a marked surface crust.

and Rongotea. The district effect was due to higher ear densities in the Kairanga district than in the Feilding or Marton districts.

The association between ear density and plant density was low. An indication that the cause of this occurred early in growth is apparent from the low association that was obtained between tiller density and plant density (Table 8).

TABLE 7: Ranking of independent variables in the regression equation with strong or moderate association with ear number. Sign of the associated partial regression coefficient in brackets.

	N_0	N_{50}
Squared multiple correlation (R^2)	0.42	0.47
Variables with strong association	Cultivar	Cultivar
Variables with moderate association	District Herbage N (+) Sowing date (-)	District Herbage P (+) Plant density (+) Sowing date (-)

TABLE 8: Means and simple correlations using individual quadrat data from the 20 paddocks where tiller counts were taken.

Means	Plant density	Tiller density	Ear density	Tiller Survival (%)
N_0	237	628	499	79
N_{50}	232	692	543	78
Correlations				
Plant density		0.079	0.177	0.002
Tiller density	-0.085		0.439	-0.644
Ear density	0.034	0.595		0.380
Tiller survival	0.127	-0.413	0.469	

N_0 (below diagonal); N_{50} (above diagonal)

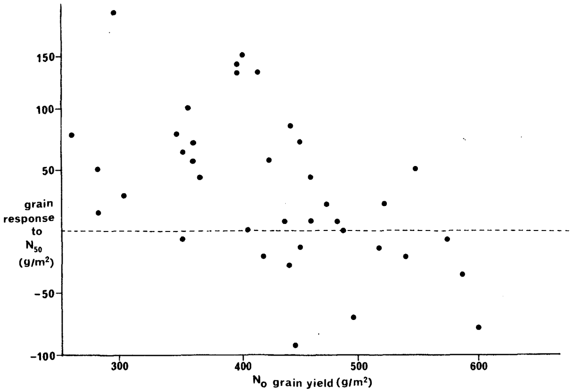

Figure 2: Relationship between the grain yield response to N_{50} and yield of N_0 quadrats.

DISCUSSION

Factors Associated with Yield

This study supports previous work (e.g. Hampton *et al.,* 1981) which showed that a strong association existed between ear density and yield. However, an association between plant density and ear density, often assumed to be present (e.g. McCloy, 1980; Hampton, 1981), was not apparent in the season under study. There were indications that environmental factors early in growth had a dominating influence on tiller and ear density and that some modification of this influence was obtained by the application of higher than normal rates of nitrogenous fertiliser.

Weather conditions early in the season were poor and one of the environmental conditions dominating tiller development may have been excessive soil moisture (Watson *et al.,* 1976; Belford and Cannell, 1978) possibly due to low oxygen concentrations in the soil. (Trought and Drew, 1980a). It has been shown that one of the main effects of excessive soil moisture is a reduction in the ability of the plant to absorb nutrients, especially nitrogen (Leyshon and Sheard, 1974; Trought and Drew, 1980b). Thus responses to nitrogen fertiliser have often been recorded when soils are waterlogged; completely or partially compensating for the effect of waterlogging (Watson *et al.,* 1976; Belford and Cannell, 1978; Drew and Trought, 1978). The responses to nitrogen fertiliser found in our study, therefore, may have been due to some compensation for wet soil conditions. Greater responses to N were found in apparently better drained or aerated seedbeds. This is consistent with the findings of Drew *et al.* (1979) who found that a layer of aerated soil was necessary for a good response to N under wet soil conditions.

An aspect of the study which may have contributed to the lack of association between plant density and yield, ear and tiller density was that most of the plant densities were found to be in a relatively narrow range (Fig. 1). It would have been preferable to have had a wider spread of plant numbers. Also the plant density may have been close to, or exceeded, the optimum number (Hampton, 1981). It should be pointed out however, that, over the range of plant numbers measured, a wide variation in tiller, ear and grain production was measured, again indicating that another variable was the dominant influence on plant development. This variability emphasises the difficulty of recommending a single plant density on a district basis because of its possible low general association with yield in some seasons. Perhaps more attention should be given to the conditions which influence tiller development with a view to introducing inputs, such as the application of nitrogen at a critical time, to ensure that an adequate ear density is achieved. Farmers should perhaps be encouraged to monitor tiller density rather than plant density or be encouraged to have a flexible nitrogen policy depending on weather conditions during early growth and on the condition of the seedbed.

It is of interest that, although the herbage nutrient samples were taken early in growth and were not taken directly from the quadrat areas, the levels of N and P in the herbage were useful in accounting for variability in grain yield and ear number.However it should be noted that for herbage N and yield response to N, the relationship was positive (i.e. nitrogen response was greatest when herbage N levels were higher) when a negative relationship was expected. This may indicate that the N response was being limited by P levels as N and P were highly correlated, and, when additional nitrogen was being added, herbage P became more strongly associated with yield and ear number. The mean value and lower end of the range for herbage P (Table 2) were lower than the optimal level suggested by Tserling (1975). Another possibility is that the high herbage N and P levels were indicating situations where nutrients were capable of being utilised and thus plants were more responsive to additional nutrients.

Potential of a "Surviment"

The characteristic of a survey is that information on a large number of variables can be collected over a range of conditions. Relationships among variables can be determined from survey data but the cause-and-effect mechanisms are difficult to isolate. Traditional experiments, on the other hand, study only a few variables under a limited range of conditions. The problem which farm advisors face is that of attempting to extrapolate results from experiments to the range of farming conditions present among their clients. This problem is partially solved by repeating trials over a number sites. These can range from the traditional multiple-site experiments which we light-heartedly called an "Experivey" through a range of modifications to a 'Surviment" which is a survey but which also involves a simple experiment at each site.

An advantage of the "surviment" is that it provides both experimental and survey information which allows the experimental information to be assessed over a range of farming conditions to test its applicability. It may therefore by a useful tool to help bridge the "gap" between research and the farmer by testing selected treatments indicated by a research programme under a range of farming conditions. The survey data could be used to indicate situations where the research recommendations may need to be modified. The "Surviment" may also be useful in indicating directions of possible research.

CONCLUSIONS

1. In the 1980/81 season, the yield of wheat was apparently closely associated with the density of ears and the cultivar used.
2. The association between ear or tiller density and plant density was low. It seemed that environmental factors, possibly the amount of excessive soil water present, had a dominant effect on the number of tillers produced.
3. The grain response to an additional 50 kgN/ha was variable so that, if higher rates of N are to be used, a method of identifying responsive paddocks is essential. Herbage N and P levels were associated with the nitrogen response but the nature of the relationship needs further investigation.
4. Further attention is required on factors which influence growth onset of tillering and ear emergence.
5. The "Surviment" technique has potential to assist in the evaluation of new techniques in the farming situation and for determing the relative importance of managerial inputs.

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