YIELD COMPONENTS OF KOPARA WHEAT IN RESPONSE TO SEEDING RATES, RATES AND TIMES OF APPLICATION OF NITROGEN FERTILIZER

M. M. Nourafza and R. H. M. Langer
Department of Plant Science
Lincoln College
Canterbury

ABSTRACT

In a field experiment, Kopara wheat was autumn sown at 5 densities (170 to 580 seeds/m^2), and varying levels (0 to 180 kg/ha) of nitrogen fertilizer were applied in August and November, giving different ratios between these two dates. The components of yield were determined.

A sowing rate of 375 seeds/m^2 was found to be the optimum for grain yield. At higher rates the increase in spike populations was offset by reduced grain set. Nitrogen fertilizer increased tillers/m^2 at the final harvest but this was attended by a decrease in mean grain weight. Grain set was increased by late-applied nitrogen at low populations but not enough to improve yield. A yield of 730g grain dry weight/m^2 was recorded at a sowing rate of 375 seeds/m^2 with 90 kg N/ha split equally between the tillering and floret growth stages.

The results emphasise the flexibility of the yield components of wheat.

INTRODUCTION

The standard height cultivar Kopara was released in 1971 as wheat suitable for autumn sowing in South Island conditions. The tillering pattern (Fraser and Dougherty, 1977), growth and yield (Scott, 1978), grain yield and N content (Dougherty *et al.*, 1979) of Kopara have been compared with those of Karamu as a part of a wheat research programme in the Department of Plant Science, Lincoln College.

To continue these studies a series of experiments was designed to determine the relationship between carbohydrate and nitrogen content of Kopara wheat at various stages of growth in response to different agronomic treatments. This paper presents part of these studies, mainly those concerned with the components of grain yield.

MATERIALS AND METHODS

Kopara wheat (*Triticum aestivum* L.) was sown by combine drill on 15 June 1977 in a three factor central composite design with incomplete blocks (Cochran and Cox 1957; Plant 8A.4), each plot being 50 x 1.65 metres with 10 rows at 15 cm spacing. The levels and codes of the factors studied in this experiment are shown in Table 1 while the importance of design and data processing have been explained by Dougherty *et al.* (1978). The experiment was carried out on a Templeton silt loam at the Lincoln College Research Farm. The previous crop on the experimental site was mature lucerne. Super-phosphate at 250 kg/ha was applied as a basal dressing. Ammonium sulphate (21% N, 24% S) was applied on 23 August 1977 to influence tiller production and on 3 November 1977 to affect floral development, according to the design of the experiment which provided for different total amounts distributed over the two dates to give varying ratio.

TABLE 1: Levels and codes of the three factors in response surface.

Levels	-1.633	-1.0	0.0	+1.0	+1.633
X_1 Seeding rate (Viable seeds/m^2)	170	250*	375	500	580
X_2 Nitrogen (kg/ha)	0	35	90*	145	180
X_3 Early/late (ratio)	0:1	2:8	1:1*	8:2	1:0

*Most common in practice.

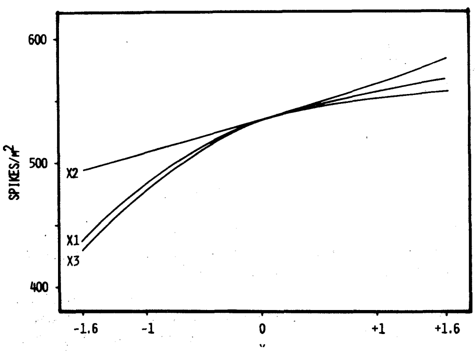
At fortnightly intervals commencing 2 weeks after anthesis, wheat plants from a 0.1 m^2 quadrat were cut at ground level from each plot, and a total of 4 quadrats were sampled. At each harvest a subsample of ears from 20 tillers was removed. The number of spikelets was counted, the ears were oven dried at 80°C, threshed by hand, and the grains were cleaned and counted. The mean number of spikelets per ear (S/E), grains per spikelet (G/S) and grains per ear (G/E) are based on the mean of these 4 quadrats. At the final grain harvest (25 January 1978) 10 quadrats from each plot were taken, the ears were counted, the grains were mechanically separated, dried and weighed. The number of tillers per m^2 (T/m^2) and the mean individual grain weight are from this final 1 m^2 harvest. The calculated grain yield is derived from the product of its components. (Grain yield per m^2 = T/m^2 x S/E x G/S x grain weight) and the obtained grain yield is based on 1 m^2 harvested at maturity.

RESULTS

Spike Populations

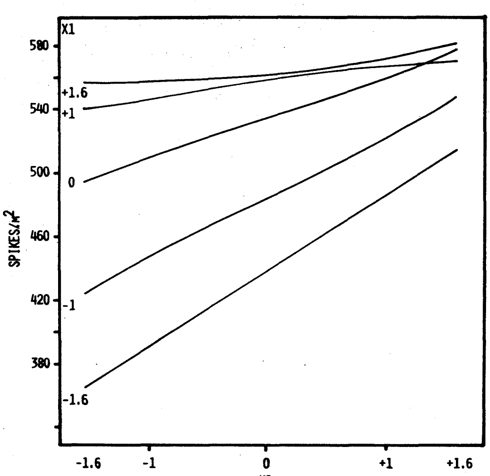
At the central level of the factors (X = O) 533 T/m^2 were present at maturity. The significant coefficient for sowing rate (X1) and early/late ratio of N application (X3) revealed that a denser crop and early application of N increased the number of ear-bearing tillers at maturity (Table 2). Fig. 1 shows the effect of seeding rates, rates and times of N application on the number of ears/m^2. When N was

Figure 1: The response surface for mean number of spikes/m^2 for seeding rates (X1), rates (X2) and times of N application (X3) at medium levels of the other factors (X=0).



equally divided between tillering and flowering, the more widely spaced plants showed better response in producing ears/m^2 than those in dense populations (Fig. 2).

Figure 2: The response surface for mean number of spikes/m^2 when seeding rates (X1) and rates of N application (X2) vary at the median level of times of N application (X3=0).



Spikelets Per Ear

The mean number of spikelets per ear decreased as plant population (seeding rate) increased, and it tended to increase in response to early N application (Fig. 3). The very low coefficient for interaction between sowing rate (X1) and nitrogen fertilization (X2) shows that the effects of these factors on the mean number of spikelets per ear are additive (Table 2).

Grains Per Spikelet

The mean number of grains per spikelet was affected by plant population and time of N application, both showing significant interaction (Table 2). N applied at the rate of 90 kg/ha (X2 = 0) at tillering (X3 = +1.6) in high-density plants, and at flowering (X3 = -1.6) in low-density plants increased the mean number of grains per spikelet (Fig. 4). The mean number of grains per ear showed the same response (Fig. 5).

Figure 3: The response surface for mean number of spikelets per spike for seeding rates (X1), rates (X2) and times of N application (X3) at median levels of the other factors (X=0).

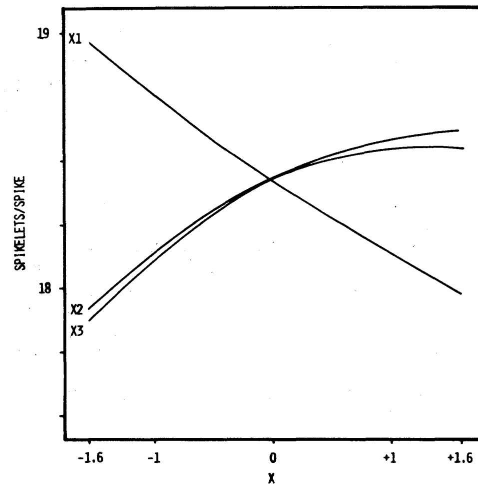
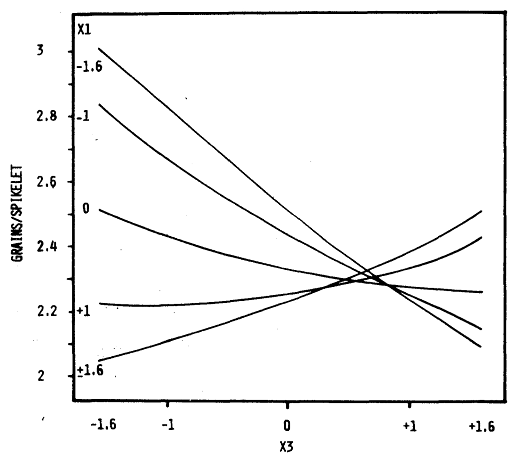


Figure 4: The response surface for mean number of grains per spikelet when seeding rates (X1) and times of N application (X3) vary at the median level of rates of N application (X2=0).



Grain Dry Weight

N fertilizer showed a significant effect on mean grain weight (Table 2). Increasing rates of N when equally split between tillering and flowering (X3 = 0) decreased grain size (Fig. 6).

Grain Yield

The changes in calculated and obtained grain yield did not reach statistically significant levels in response to the factors studied in this experiment, and at the central level of the factors the amounts were 843 and 730 g of grain dry weight per m^2 respectively (Table 2). However there was a trend for grain yield to be

TABLE 2: Constants and coefficients of response surfaces of grain yield and its components.

Term	Tillers/m^2	Spikelets/ear	Grains/spikelet	Grains/ear	Mean grain weight (mg)	Grain Yield (g/m^2) Obtained	Grain Yield (g/m^2) Calculated
Constant	533.54	18.421	2.330	42.91	36.97	730.74	848.13
X1	37.74*	- 0.304**	- 0.089**	- 2.349**	- 0.24	- 19.15	14.48
X2	25.04	0.223	0.004	0.60	- 1.47*	29.34	21.96
X3	37.39*	0.194	- 0.077*	- 0.98*	- 0.63	- 0.57	31.53
x_1^2	- 12.53	0.023	0.014	0.34	0.77	- 25.83	0.80
X_2^2	0.59	0.060	- 0.002	- 0.17	0.28	- 19.92	2.68
X_3^2	- 13.47	- 0.080	0.021	0.19	0.90	- 28.14	- 3.69
X1.X2	- 12.62	- 0.003	0.013	0.21	0.34	8.07	- 13.87
X1.X3	- 6.12	- 0.026	0.133**	2.36**	0.46	4.25	42.62
X2.X3	4.37	0.066	- 0.031	- 0.41	- 0.14	- 24.17	- 5.87
* S.E. Constant	22.76	0.081	0.035	0.59	0.71	29.32	49.13
Linear	15.35	0.055	0.023	0.40	0.48	19.78	33.14
Quadratic	15.43	0.055	0.024	0.40	0.48	19.87	33.30
Cross product	19.82	0.071	0.030	0.50	0.62	25.53	42.79
C. V. (%)	11	1	4	3	5	10	14
R^2 (%)	67	89	85	89	69	51	25

* Least Significant Coefficient = S.E. * t (8 d.f.)
R^2 Percentage of variation explained by the model.

Figure 5: The response surface for mean number of grains per spike when seeding rates (X1) and times of N application (X3) vary at the median level of rates of N application (X2=0).

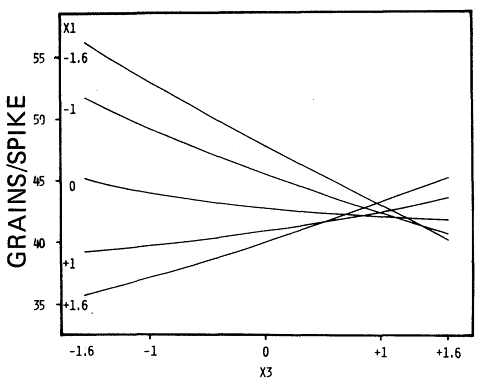
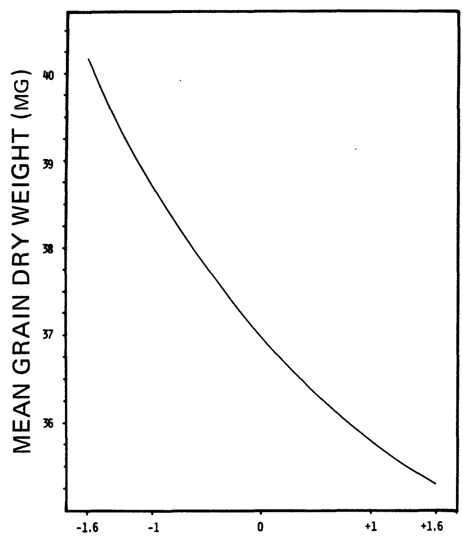


Figure 6: The effect of rates of N application (X2) on mean grain weight at the median level of seeding rates and times of N application (X1, X3=0).



increased at sowing rates of up to 375 seeds/m^2 (X1 = 0) and in response to application of 90 kg N/ha (X2 = 0) when equally divided between tillering and flowering (Fig. 7).

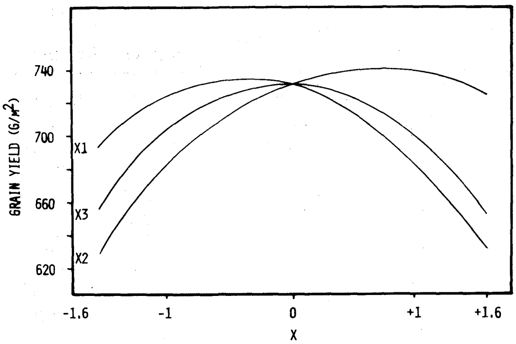
Relation Between Components of Calculated Grain Yield

Simple linear correlation between calculated grain yield and its components showed strong positive correlation between T/m^2 and grain yield and negative relation between T/m^2 and G/S (Table 3).

TABLE 3: Simple correlation matrix between calculated grain yield and its components.

Component		S/E	G/S	G wt.	T/m^2	Y/m^2
Spikelets/ear	(S/E)	1.000	0.080	- 0.311	- 0.013	0.064
Grains/spikelet	(G/S)		1.000	0.326	- 0.536*	0.095
Grain weight	(G wt.)			1.000	- 0.352	0.222
Tillers/m^2	(T/m^2)				1.000	0.696**
Grain yield	(Y/m^2)					1.000

Figure 7: The response surface for grain yield (dry weight) for seeding rates (X1) rates (X2) and times of N application (X3) at the median levels of the other factors (X=0).



When fitted against stepwise linear regression (Table 4), T/m^2 was the main component which caused 48% of variation in grain yield, with G/S being the second component. Both together caused 79% of variation, but when grain weight and S/E were added, this figure was increased to 95% and 99% respectively.

DISCUSSION

At the central level of the factors 730 g grain dry weight/m^2 was obtained which was two times more than the average yield recorded for Canterbury in the same season (Davey *et al.*, 1978). The changes in grain yield in response to the treatments imposed failed to reach statistical significance, but there was a trend to show an increase in grain yield in response to treatments up to the central level (Fig. 7). The number of ears at maturity was the main component of grain yield (Table 4) and this was determined by

TABLE 4: Stepwise multiple regression of components of calculated grain yield.

Variable	Coefficient	SE of coefficient
Constant	- 2485.848	
Tillers/m^2	1.673	0.038
Grains/spikelet	333.296	16.533
Grain weight	21.733	1.057
Spikelets/ear	46.555	5.508

the effects of plant population (seeding rate) and N fertilization. N application at tillering stimulated tiller production at low plant density more than at high density. This might have been due to more light intensity in widely spaced plants (Puckridge 1968) or relief of some other limiting factors. N fertilization improved tiller survival at flowering in low density plants probably by promoting the availability of total nonstructural carbohydrates as shown by results not presented here. N application has been reported to intensify competition between vegetative and reproductive organs (Dougherty and Langer, 1974) and this may have been the case in the denser crop. As a result, the low density crop produced more ears/plant in response to N but this was not enough to compensate for the initial low plant population (Fig. 2).

The reduction in spikelets per ear in closely spaced plants could be attributed to competition for light (Willey and Holliday, 1971). The response of the same component to N fertilization could have been due to the effect of N on spikelet differentiation or delay in the determination of the terminal spikelet (Single, 1964; Rawson, 1970) and according to previous work the latter has been suggested to be the more important (Dougherty *et al.*, 1978).

The fertility of spikelets is determined after their number has been established, and it may be increased by N application before flag leaf emergence (Single, 1964). Thus in this experiment the number of grains per spikelet and grains per spike was increased in a low density crop when N was applied 2 days before flag leaf emergence, and this was associated with high level of total nonstructural carbohydrates in plants.

Grain size was affected by N fertilization, probably through the effect of N on availability of assimilate which could regulate floret development (Bingham, 1972) or cell division in the endosperm (Brocklehurst, 1977). Kirby (1974) stated that the events in pre-anthesis floret growth may determine the potential grain size and Fischer and Hille Res Lambers (1978) also reported a positive relation between floral weight (spike tissue/floret) at anthesis and potential grain weight. Our data (not presented) showed that those conditions which caused ample carbohydrate to be present in the plant at the time of pre-anthesis also produced heavier grains.

The number of spikes/m^2 was positively correlated with grain yield ($r = 0.696^{**}$) and negatively with the grain number/spikelet ($r = -0.536^{*}$) and other components of yield (Table 3). The presence of negative correlation between components of yield could imply that the supply of assimilates limits grain yield (Evans and Wardlaw, 1976). This source limitation may have been operating at pre-anthesis in these experimental conditions, as the positive, although not significant, correlation between grain number/ear and individual mean grain weight ($r = +0.22$) shows the lack of intra-ear competition during the grain filling period which should have occurred in the presence of enough assimilates supply. The results support the conclusion drawn by Langer and Dougherty (1976) that under our environmental conditions with a high level of incident radiation during normal grain filling period grain yield could be sink limited.

Grain yield increases with increments of seeding rates to a maximum value at an optimum density but then decreases again (Donald and Hamblin, 1976). The results of this experiment and previous work (Dougherty *et al.*, 1979) indicated that the optimum density for Kopara is at or near to 375 seeds/m^2 in this Templeton silt loam. Increase in spike population at higher plant populations than the optimum is offset by a drastic reduction in grain set (Table 2). As the competition for light intensity among high density crops is more severe and occurs earlier than in low density crops, as shown by massive leaf and tiller senescence (Puckridge and Donald, 1967; Fischer *et al* ., 1976). crop growth rate (Puckridge and Donald, 1967) and net assimilation rate during the critical period of floret growth (Scott *et al.*, 1973) are slowed down. As a result the supply of assimilates to developing ear is limited (e.g. Scott *et al.*, 1973;

Dougherty and Langer, 1974; Fischer and Laing, 1976; Dougherty *et al.*, 1978) and this probably is the cause of failure of florets to set grain (Bingham, 1972).

Grain yield was increased by 14% in response to 90 kg of N mainly because of its positive effect on number of spikes at maturity (Fig. 1). The negligible response of grain yield to N fertilizer at a rate greater than 90 kg N/ha is probably explained by better response of vegetative growth to N application at the expense of reproductive development (Dougherty and Langer, 1974) which was presumably associated with dilution of total nonstructural carbohydrates in plants during the pre-anthesis period and thus reduction in mean grain weight (Fig. 6).

The obtained grain yield at the central level of the factors studied was 14% less than the calculated grain yield but this was not unexpected and could be related to grain shedding and bird damage.

ACKNOWLEGEMENTS

We wish to express our appreciation to Dr C. T. Dougherty, Mr N. S. Mountier and Mr B. G. Love for their assistance.

REFERENCES

Bingham, J. 1972. Physiological objectives in breeding for grain yield in wheat. *Proceedings of the Sixth Congress of Eucarpia* 1971: 15-29.

Brocklehurst, P.A. 1977. Factors controlling grain weight in wheat. *Nature 266:* 348-49.

Cochran, W. G., Cox, G. M. 1957. "Experimental Designs". John Willey & Sons Inc.

Davey, L. E., Lough, R. D., Lines, S. A., Maclean, R. M., Moffitt, R. G. 1978. An Economic Survey of New Zealand Wheatgrowers. Survey No. 2, 1977-78, Lincoln College Agricultural Economics Research Unit, Research Report 92: 64p.

Donald, C. M., Hamblin, J. 1976. The biological yield and harvest index of cereals as agronomic and plant breeding criteria. *Advances in Agronomy 28:* 361-405.

Dougherty, C. T., Langer, R. H. M. 1974. An analysis of a nitrogen-induced depression in yield in irrigated Kopara wheat. *N.Z. Journal of Agricultural Research 17:* 325-31.

Dougherty, C. T., Love, B. G., Mountier, N. S. 1978. Response surfaces of semi-dwarf wheat for seeding rate, and levels and times of application of nitrogen fertilis r. *N.Z. Journal of Agricultural Research 22:* 47-54.

Dougherty, C. T., Love, B. G., Mountier, N. S. 1979. Response surface of 'Kopara' wheat for seeding rate, and levels and times of application of nitrogen fertiliser. *N.Z. Journal of Agricultural Research 22:* 47-54.

Evans, L. T., Wardlaw, I. F. 1976. Aspects of comparative physiology of grain yield in cereals. *Advances in Agronomy 28:* 301-59.

Fischer, R. A., Aguilar, I. M., Maurer, R. O., Rivas, S. A. 1976. Density and row spacing effects on irrigated short wheats at low latitude. *Journal of Agricultural Science, Cambridge 87:* 137-146.

Fischer, R. A., Laing, D. R. 1976. Yield potential in a dwarf spring wheat and response to crop thinning. *Journal of Agricultural Science, Cambridge 87:* 133-22.

Fischer, R. A., Hille Ris Lambers, D. 1978. Effect of Environment and Cultivar on Source Limitation to Grain Weight in Wheat. *Australian Journal of Agricultural Research 29:* 443-58.

Fraser, J., Dougherty, C. T. 1977. Effects of sowing rate and nitrogen fertilization on tillering in Kopara and Karamu wheats. *Proceedings Agronomy Society of New Zealand 7:* 81-7.

Kirby, E. J. M. 1974. Ear development in spring wheat. *Journal of Agricultural Science, Cambridge 82:* 437-447.

Langer, R. H. M., Dougherty, C. T. 1976. Physiology of grain yield in wheat. *Perspectives in Experimental Biology 2:* 59-67.

Puckridge, D. W. 1968. Competition for light and its effect on leaf and spikelet development of wheat plants. *Australian Journal of Agricultural Research 19:* 191-201.

Puckridge, D. W., Donald, C. M. 1967. Competition among wheat plants sown at a wide range of densities. *Australian Journal of Agricultural Research 18:* 193-211.

Rawson, H. M. 1970. Spikelet number, its control and relation to yield per ear in wheat. *Australian Journal of Biological Science 23:* 1-15.

Scott, W. R. 1978. Development and yield of 'Kopara' and 'Karamu' wheat under different rates of nitrogen. *N.Z. Journal of Agricultural Research 21:* 463-6.

Scott, W. R., Dougherty, C. T., Langer, R. H. M. and Meijer, G. 1973. Wheat yield as affected by sowing rate, irrigation and time of white clover introduction. *N.Z. Journal of Experimental Agriculture 1:* 369-76.

Single, W. V. 1964. The influence of nitrogen supply on fertility of the winter wheat ear. *Australian Journal of Experimental Agriculture and Animal Husbandry 4:* 165-68.

Willey, R. W., Holliday, R. 1971. Plant population, shading and thinning studies in wheat. *Journal of Agricultural Science, Cambridge 77:* 453-61.