PLANT POPULATION AND NITROGEN EFFECTS ON IRRIGATED WINTER WHEAT

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ABSTRACT

Field experiments were carried out in three consecutive years to examine the relationship between plant population and nitrogen fertiliser in winter-sown wheat. Kopara and Rongotea were grown in all three years and Arawa in two years. Seed rates were calculated to establish 150, 275 and 400 plants/m^2. At tillering and at booting, 25 and 50 kg N/ha were applied.

Mean cultivar yields were 5300, 6580 and 3640 kg/ha in 1979-80, 1980-81 and 1981-82 respectively, reflecting variability in climate and soil fertility.

Plant population had little influence on the yield of Arawa and Rongotea; Kopara yield increased with increasing population only in the high-yielding second year. Compensatory growth by the yield components contributed towards yield stability within the plant population range.

In the second and third year there was a significant response to 25 kg N/ha and a further response to 50 kg N/ha. Nitrogen x cultivar interactions occurred in all years; cultivars differed in their response to nitrogen timing in the first year, to nitrogen rate in the second year, and to both time and rate of nitrogen in the third year. Interactions between nitrogen and plant population were highly significant in the high-yielding experiment.

Additional Key Words: cultivars, Lismore soils, yield components, nitrogen rate, nitrogen application timing.

INTRODUCTION

Many wheat experiments in the past have shown there is a wide range of seed rates over which the yield does not differ significantly because of compensatory growth amongst the yield components (Scott *et al.*, 1973, 1977; Clements *et al.*, 1974; Scott, 1978; McLeod, 1979). Ear population increases with increasing plant population but the number of grains per ear decreases leading to yield stability.

The effects of rates of nitrogen fertiliser, applied at one growth stage, to different plant densities have been measured in a number of experiments. For example, on heavy soil at Lincoln, Scott (1978) measured increasing yield with increasing rates of nitrogen applied at tillering but no difference between 250 and 500 viable seeds/m^2 and there was no interaction. Single rates of nitrogen applied in two dressings either increased the yield (Scott *et al.*, 1977) or had no effect (Dougherty *et al.*, 1975) and again there were no interactions between nitrogen and the two seed rates employed. In other experiments by Fraser and Dougherty (1977) and Martin and Drewitt (1982) on a medium soil, the response to nitrogen applied at the tillering stage was not dependent on seed rate. There have however, been few experiments where rate and time of nitrogen fertiliser application have been adjusted to exploit the advantages of different plant populations. Dougherty *et al.* (1978) found that nitrogen applied at tillering was more effective than nitrogen applied at spikelet growth and that the later application tended to depress yields of lower seed rates and increase yields of higher seed rates but seed rate generally had very little influence on yield.

On the less fertile light soils in Canterbury yield responses to nitrogen fertiliser, depend on previous cropping history and the level of irrigation applied (Drewitt, 1979). The soil nitrogen supply frequently becomes depleted before plant growth is complete and timing of nitrogen application becomes more critical. Under conventional seed rates, nitrogen at tillering is as effective as nitrogen applied earlier in raising the yield (Drewitt, 1980) and, in unpublished work at Winchmore, nitrogen applied as late as booting also equalled earlier applications as well as improving grain quality, an important consideration on the light soils under irrigation (Drewitt, 1980). Grain nitrogen content was found to be closely related to grain yield and grain size (Drewitt, 1979b) and both plant density and nitrogen fertilisation may effect grain size (Dougherty *et al.*, 1975; 1978; Scott, 1978; Drewitt, 1979).

The nitrogen fertiliser requirements for different seed rates of a range of cultivars have not previously been investigated. The relationship between seed rate and nitrogen could be expected to differ with cultivar because of variable tillering capacity, ear conformation and growth habit. Determination of these relationships could lead to economy in seed wheat use and more efficient use of nitrogen fertiliser.

Yield and quality responses to rates and times of nitrogen applied to three winter-wheat cultivars sown at three seed rates were examined in three experiments from 1979-80 to 1981-82. In accord with modern practice, seed rates were calculated to establish specific plant populations. Detailed results of grain yield and grain nitrogen content are presented in this report. A full yield component analysis was carried out in two of the experiments.

MATERIALS AND METHODS

The experiments were carried out on Lismore stony silt loam at Winchmore Irrigation Research Station in three consecutive years 1979-80 to 1981-82. Site history and soil test data are given in Table 1.

TABLE 1: Experimental site history and soil test, 0-15 cm depth.

Year of experiment	Previous crop	pH	Ca	K	P
1979-80	Lucerne 9 yrs	6.1	10	6	13
1980-81	Pasture 3½ yrs	6.1	10	8	13
1981-82	Pasture 3½ yrs	6.3	10	5	10

Two replicates of a split plot design were laid down with the treatments arranged as follows:

Main Plots:
  Cultivars
  1. Arawa
  2. Kopara
  3. Rongotea
Sub plots:
  Plant population
  1. 150 plants/m^2
  2. 275 plants/m^2
  3. 400 plants/m^2
Sub sub plots:
  Nitrogen
  1. 25 kg N/ha at tillering
  2. 50 kg N/ha at tillering
  3. 25 kg N/ha at booting
  4. 50 kg N/ha at booting
  5. 25 kg N/ha at tillering + 25 kg N/ha at booting
  6. No nitrogen

Each main plot occupied three adjacent border strips, sub plots were single borders 30-39m x 4.8m and sub sub plots 10-13m x 2.4m.

Cultivars Kopara and Rongotea were grown in all three years. In the first year a third cultivar, Pahau, was used but, following its withdrawal from the acceptable cultivar list, it was replaced by Arawa in the second and third year and is not included in these results. Kopara, a medium-short, tip-awned cultivar occupied the highest percentage of the wheat area in Canterbury in 1979, while Rongotea, a standard height x Mexican semi-dwarf cross, fully awned cultivar was increasing in popularity. Both cultivars are good bread wheats. Arawa is a medium-short, awnless cultivar with good baking quality, but low flour extraction.

Plant population Seed rates were calculated to provide specific plant populations in the pre-tiller phase for each cultivar. Sowing dates are shown in Table 2.

Nitrogen The first application of ammonium sulphate was carried out at early tillering and the second was made at the booting stage or sooner if soil nitrate in the 0-15cm zone fell to 2ppm, (Table 2).

TABLE 2: Sowing dates and dates of nitrogen application with growth stages (Feekes scale) in parentheses.

Sowing date	N at tillering	N at booting
22 June 1979	10 September (2)	15 October (7)
1 July 1980	17 September (2)	31 October (8)
2 July 1981	18 September (2)	2 November (8)

A basal application of 20kg N/ha was drilled with the seed in 1979-80 to compensate for probable soil nitrogen losses during unusually heavy soil movement in the construction of border strips. No basal nitrogen was applied in the next two years. All three experiments received 200-240kg/ha of superphosphate at drilling.

Irrigation was applied by the border-strip method when soil moisture in the top 15cm fell to approximately 25% available.

Plant counts were carried out at the two or three leaf stage on two quadrats (66.6 x 30cm) in each sub sub plot. In 1980-81 and 1981-82 the same quadrats were used at harvest time for yield component analysis. Only plant population and mean grain weight were measured in 1979-80. The number of grain-bearing spikelets per ear was counted on 25 ears drawn from these samples and the number of grains per spikelet was calculated from the number of grains in the 25 ears. Mean grain weight was measured on one thousand grains. Grain nitrogen was determined by the Kjeldahl method and expressed as a percentage of the dry weight. For the main yield analysis one header strip 1.2m wide was taken from the centre of each plot. The yields given are of grain retained on A5½ (12.7 x 2.2mm) screen and corrected to 12% moisture.

RESULTS

Some variation in the seeding rates achieved and in field establishment caused plant population to be higher than predicted in the first two years and lower in the third year. In the latter, field establishment decreased with increasing seed rate and was particularly poor in Rongotea (Table 3).

The growing season in 1979-80 was wetter than normal with heavy rainfall in August, October and January. The next two seasons were comparatively dry; only November rainfall was high in 1980-81 while in 1981-82 heavy rainfall in July and August was followed by a dry, frosty September, and the season concluded with very warm dry conditions which shortened the grain ripening period. One irrigation was required in 1979-80 and three in each of the next two years.

Development was approximately equal in all three cultivars; small differences of not more than two or three days were not carried forward to succeeding stages and all cultivars matured at the same time. In 1979-80 harvesting was delayed until 19 February by wet weather but was carried out on 28-29 January in the next two seasons.

TABLE 3: Plant population (/m^2) and field establishment (F.E.)%.

Treatments (plants/m^2)	1979-80 Plant population	1979-80 F.E. %	1980-81 Plant population	1980-81 F.E. %	1981-82 Plant population	1981-82 F.E. %
Arawa						
150	—		200	88	173	85
275	—		325	84	262	78
400	—		505	91	396	75
Kopara						
150	170	77	170	79	161	80
275	322	80	330	82	287	78
400	429	73	480	80	345	66
Rongotea						
150	162	81	175	83	130	66
275	297	76	305	79	205	61
400	453	81	450	80	319	61

TABLE 4: Main effects of cultivar, plant population and nitrogen for grain yield (kg/ha) in three seasons.

	1979-80	1980-81	1981-82
Cultivar			
Arawa	—	6070	3550
Kopara	4860	6650	3360
Rongotea	5750	7050	4020
S.E. (mean)	102	342	264
Plant population			
150 plants/m^2	5240	6470	3660
275 plants/m^2	5170	6680	3720
400 plants/m^2	5510	6610	3540
Linear contrast	ns	ns	ns
Quadratic contrast	ns	ns	ns
S.E. (mean)	126	75	189
Nitrogen			
25 kg N/ha at tillering	5190	6540	3470
50 kg N/ha at tillering	5270	7110	3910
25 kg N/ha at booting	5220	6380	3400
50 kg N/ha at booting	5590	7030	4010
25 at tillering + 25 at booting	5540	6790	4180
No N	5040	5670	2870
Rate contrast	ns	1%	1%
Time contrast	ns	ns	ns
Rate x time interaction	ns	ns	ns
S.E. (mean)	144	96	110

Grain Yield

In 1979-80, grain yield was slightly above the long term average for Kopara on Lismore stony silt loam. Yields were exceptionally high in 1980-81 and very low in 1981-82 (Table 4).

Main effects of cultivar and plant population

Cultivars Although differences between cultivars were not statistically significant in any of the experiments, Rongotea was the highest yielding cultivar in all three seasons (Table 4).

TABLE 5: Yield components for 1980-81 and 1981-82.

	1980-81				1981-82			
	Ears/ m^2	Spkt/ ear	Grains/ spkt.	Grain/ wt. mg.	Ears/ m^2	Spkt/ ear	Grains/ spkt.	Grain wt. mg.
Cultivar								
Arawa	451	11.9	2.50	48.5	349	11.8	2.35	47.3
Kopara	472	14.6	2.25	42.7	333	14.1	2.16	43.1
Rongotea	567	13.1	1.97	49.6	360	13.2	1.94	50.3
S.E. (mean)	11.1	0.40	0.027	0.60	2.54	0.33	0.37	0.24
Plant population								
150 plants/m^2	434	14.7	2.24	46.1	305	14.2	2.24	47.4
275 plants/m^2	499	12.9	2.28	47.5	347	13.0	2.17	47.0
400 plants/m^2	557	12.0	2.20	47.2	389	11.9	2.04	46.4
Linear contrast	1%	1%	ns	5%	1%	1%	1%	5%
Quadratic contrast	ns	1%	ns	5%	ns	ns	ns	ns
S.E. (mean)	5.7	0.09	0.024	0.22	12.8	0.19	0.028	0.26
Nitrogen								
25N at tillering	484	13.2	2.25	47.0	354	12.9	2.11	46.3
50N at tillering	522	13.5	2.28	46.9	360	12.9	2.16	46.4
25N at booting	489	13.0	2.20	46.7	328	13.1	2.15	47.2
50N at booting	502	13.6	2.26	47.1	354	13.4	2.25	47.9
25N at t. + 25 at b.	525	13.2	2.25	46.8	348	13.5	2.19	47.0
No N	458	12.7	2.20	47.3	339	12.4	2.04	46.7
Rate contrast	5%	1%	ns	ns	ns	ns	1%	5%
Time contrast	ns	ns	ns	ns	ns	1%	1%	1%
Rate x time int.	ns	ns	ns	ns	ns	ns	ns	ns
S.E. (mean)	9.0	0.13	0.027	0.26	9.3	0.13	0.021	0.18

Plant population Grain yields did not differ significantly with plant population in any year (Table 4). In the two years in which yield components were measured ear density at harvest increased and the number of spikelets per ear decreased with increasing plant population (Table 5). The number of grains per spikelet also decreased with increasing plant population in 1981-82. Mean grain weight was comparatively low with the low plant population in 1980-81 and with the high plant population in 1981-82.

Interaction of cultivar and plant population The only two factor interaction between cultivar and plant population occured in 1980-81, the high-yielding year. The yield of Arawa and Rongotea did not vary with plant population while that of Kopara increased with increasing plant population (Table 6). The increase in Kopara yield with increasing plant population was mainly due to the number of grains per spikelet; this component increased slightly with plant density in Kopara but decreased in Arawa and Rongotea. In all three cultivars, ear density and mean grain weight increased and spikelets per ear decreased in equal magnitude as plant population increased.

Nitrogen effects

There were responses to nitrogen fertiliser in all three experiments and nitrogen effects featured in all the remaining two and three factor interactions in the grain yield analysis. Only those interactions considered important are present in this report.

TABLE 6: Interaction of cultivar and plant population (linear) for grain yield, kg/ha, 1980-81 (5% sig.)

Treatment (plant/m^2)	Arawa	Kopara	Rongotea
150	6030	6290	7100
275	6230	6640	7170
400	5950	7000	6880

1979-80 The response to nitrogen was comparatively small and there were no significant main effects although both the heavy rate at booting and the split application increased yield (Table 4). There were however interactions between cultivar and nitrogen and between plant population and nitrogen. Kopara did not respond to nitrogen at either tillering or booting, while Rongotea responded to nitrogen at booting only (Table 7).

Both single applications of 25 kg N/ha were more effective with the heavy plant population than with the low plant population but, when 25 kg N/ha at booting followed 25 kg N/ha at tillering, there was no difference between the populations (Table 8). That is, the low plant population required two applications of 25 kg N/ha to equal the yield from the high plant population receiving only one

TABLE 7: Interaction between cultivar and time of nitrogen application for grain yield, 1979-80 (kg/ha, 1% sig.)

Cultivar	N at tillering	N at booting
Kopara	5020	4730
Rongotea	5430	6080

TABLE 8: Interaction between plant population (linear) and nitrogen (tiller x boot) for grain yield, 1979-80 (kg/ha, 5% sig.).

Treatment (plants/m²)	No N	N at tillering	N at booting	N at tillering + N at booting
150	5360	4790	4980	5600
400	5080	5600	5460	5610

application of 25 kg N/ha at either tillering or booting. The yield from these two treatments was equal to that from 50 kg N/ha at booting on both low and high plant populations.

Mean grain weight was the only yield component measured in this year. Rongotea (49.0 mg) was significantly higher than Kopara (43.6 mg); small variations due to the rate and time of nitrogen were insufficient to influence the yield.

1980-81 This was a particularly favourable year for wheat and yields were well above average throughout the district. There was a large response to nitrogen, with 50 kg N/ha more effective than 25 kg N/ha (Table 4) and, although there was no significant main effect with time of nitrogen, there were significant interactions involving nitrogen rate and time of application. At the low plant density, 50 kg N/ha was only slightly higher yielding than 25 kg N/ha applied at tillering but was much higher yielding when applied at booting (Fig. 1). At the high plant density, 50 kg N/ha was much higher yielding than 25 kg N/ha applied at tillering and only slightly higher with the booting application. Thus, at the more effective 50 kg N/ha level, the booting application was slightly higher yielding on the low plant population and the tillering application higher on the high plant population. When no nitrogen was applied, the high plant population gave a higher yield than the low population. Amongst the cultivars, time of nitrogen application was important only in Kopara where the tillering application was much more effective than the booting application on the low plant population (Fig. 2). In the cultivar x plant population interaction previously described (Table 6), Arawa and Rongotea did not vary with plant population but Kopara yield increased with increasing plant population. Arawa was less responsive than Kopara and Rongotea to the heavier nitrogen rate (Fig. 3). With Rongotea, the additional response to the heavier N rate occurred on the low and high plant populations only, whereas Kopara responded to the heavier N rate on all three plant populations.

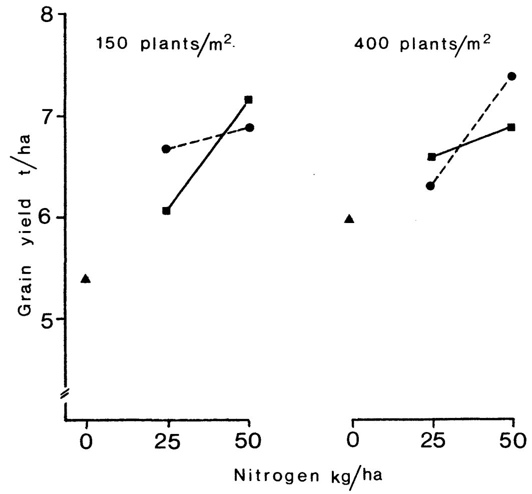

Figure 1: **1980-81, grain yield (seed rate (linear) x N (rate x time) interaction**). ● N at tiller; ■ N at boot.**

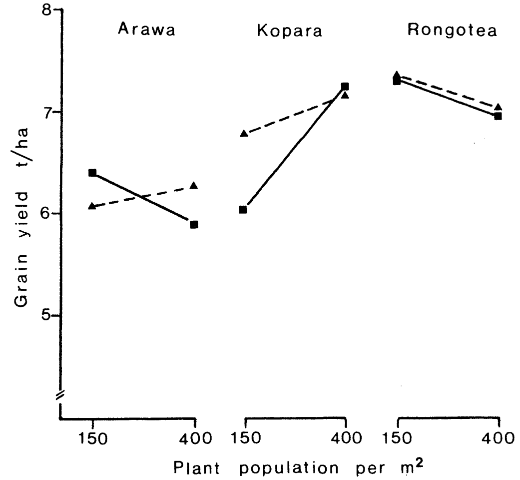

Figure 2: **1980-81, grain yield (cultivar x seed rate (linear) x N (time) interaction*). ▲ N at tiller; ■ N at boot.**

Of the three cultivars, Rongotea had the highest number of ears/m² and the lowest number of grains/spikelet (Table 5). Arawa and Kopara had similar ear density but the number of spikelets/ear was higher and mean grain weight lower on Kopara. An increase in ear density with increasing plant population was accompanied by a decrease in the number of spikelets/ear. Nitrogen responses and the higher yield from the heavier nitrogen rate were mainly due to increases in ear number and the number of spikelets/ear.

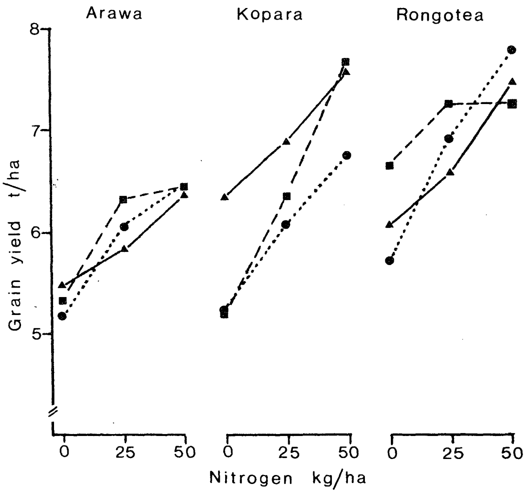

Figure 3: **1980-81, grain yield (cultivar x seed rate (quadratic) x N (rate) interaction*). ● low, ■ medium, ▲ high seed rate.**

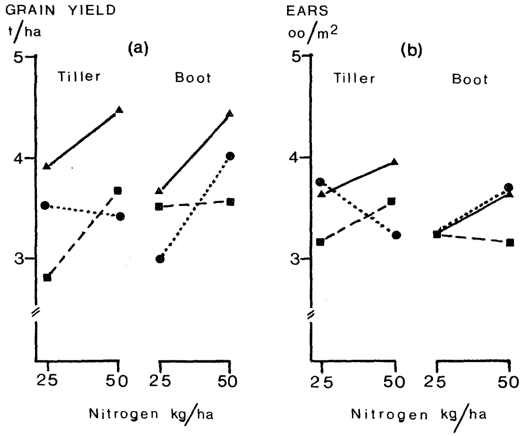

Figure 4: **1981-82, (a) grain yield (cultivar x N (rate x time) interaction**). (b) ear population (cultivar x N (rate x time) interaction*). ●Arawa; ■Kopara; ▲Rongotea.**

TABLE 9: **Grain N% for 1979-80, 1980-81 and 1981-82.**

	1979-80	1980-81	1981-82
Cultivar			
Arawa	—	2.12	2.39
Kopara	1.80	1.84	2.05
Rongotea	1.70	1.96	1.95
S.E. (mean)	0.055	0.088	0.023
Plant population			
150 plants/m^2	1.75	1.96	2.06
275 plants/m^2	1.77	1.94	2.15
400 plants/m^2	1.73	2.02	2.19
Linear contrast	ns	5%	1%
Quadratic contrast	ns	5%	ns
S.E. (mean)	0.032	0.013	0.014
Nitrogen			
25 kg N/ha at tillering	1.70	1.90	2.02
50 kg N/ha at tillering	1.77	2.03	2.05
25 kg N/ha at booting	1.72	1.96	2.15
50 kg N/ha at booting	1.81	2.04	2.30
25 at tillering + 25 at booting	1.84	2.01	2.18
No N	1.68	1.90	2.10
Rate contrast	1%	1%	1%
Time contrast	ns	ns	1%
Rate x time interaction	ns	ns	1%
S.E. (mean)	0.024	0.018	0.017

1981-82 In contrast to 1980-81, grain yields in 1981-82 were very low. There was again a large response to nitrogen and the level of response to rates and time of N application varied with cultivar (Fig. 4a). Arawa was equally responsive to both rates of N applied at tillering but much more responsive to the heavier N rate at booting while Kopara responded more to the heavier N rate at tillering and equally to both rates at booting. Rongotea was more responsive to the heavier N rate at both times.

These differences with N rate and timing were closely related to differences in ear number (Fig. 4b). The number of ears/m^2 of Arawa decreased with the heavier N rate at tillering but increased with the heavier N rate at booting. Kopara ears/m^2 were higher with the heavier N rate at tillering but no different with N rate at booting. Rongotea ear population increased with the heavier N rate at both times. Small differences amongst the other yield components were insufficient to have had any significant effect on the yield.

Grain nitrogen content

Grain N% was lowest in 1979-80 and highest in 1981-82 (Table 9). Arawa had the highest grain N% in the two years it was included in the study, though not significantly in 1980-81. There was a difference of only 0.1% grain N between Kopara and Rongotea in all three seasons.

Plant population had little effect on grain N% in 1979-80 and 1980-81 but in 1981-82 grain N% increased slightly with increasing plant population.

In all three seasons, grain N% was higher with the heavier nitrogen rate at the 1% significance level. Nitrogen applied at booting gave higher grain N% than nitrogen at tillering in all years although the main effect was not significant in 1979-80 and 1980-81.

The nitrogen rate x time interaction was significant in 1981-82 when the difference between the two rates was much greater at booting than at tillering.

DISCUSSION

The results of the three experiments differed widely from year to year making interpretation difficult. In the first experiment, the effectiveness of the nitrogen treatments was probably reduced by the application of 20 kg N/ha at drilling considered necessary to provide sufficient nitrogen to enable the crop to establish following heavy scraping and frequent cultivations in the preparation of border strips and a satisfactory seed-bed. There was however, a response to nitrogen applied at tillering at the high plant population, reflecting the greater demand for nitrogen in the higher plant densities.

Results of 1980-81 and 1981-82 differed considerably and they illustrate the importance of growing conditions in determining the level of yield and the relationships between plant population and nitrogen fertiliser. Both experiments followed 3½ years of irrigated pasture preceded by two cycles of a 4 year pasture/2 year crop rotation. Nitrogen responses were quite large in both seasons and, although there were significant interactions between plant population and nitrogen in 1980-81, there was no particular pattern and they were overshadowed by the greater effectiveness of the heavier nitrogen treatment which itself may have been less than the total nitrogen requirement (Fig's 1, 3 and 4).

The mean harvested yield was 6590 kg/ha in 1980-81 and 3640 kg/ha in 1981-82. Seasonal climatic conditions, especially early in the season, were mainly responsible for the large difference in yield in these two years. In 1980-81 rainfall in July and August was below average, though adequate, and field establishment was above expectation for all three cultivars. In contrast, in 1981-82, rainfall in July and August was double that in 1980-81 and would have caused higher nitrate losses through leaching (Ludecke and Tham, 1971). Consequently, the higher inter-plant competition for nitrogen in the higher plant densities resulted in a decrease in field establishment with increasing seed rate (Puckeridge and Donald, 1967). Lismore soils are free draining and any adverse effect of waterlogging (Trought and Drew, 1980a, 1980b; Watson *et al.,* 1976) would have been of short duration. The poor field establishment of Rongotea in 1981-82 may have been the result of low seed vigour (Hampton, 1981).

Weather conditions at the tillering stage were also much less favourable in 1981-82 when mean air and ground temperatures in September and October were considerably lower. No tiller counts were taken in these experiments but the number of ears at harvest in 1981-82 was much lower than in the previous year; individual ear components for each treatment did not differ greatly between years (Table 5). However, when equivalent plant densities in the two seasons are compared, the number of ears per plant are also found to be much lower in 1981-82. For example, with Rongotea, the medium plant population in 1980-81 and the high plant population in 1981-82 were similar (Table 3) but the number of ears/plant (N mean) was 1.96 in 1980-81 and 1.22 in 1981-82. The yield per ear was also lower in 1981-82 (11.42g compared with 12.27g in 1980-81). McLaren (1981) also found variation in plant densities resulting from differences in establishment and plant losses in winter between years, lower yield in the low establishment year and a poor relationship between grain yield and plant density.

The time interval of 5 to 6 weeks between nitrogen treatments had no significant main effect on the yield in any of the experiments and there was no advantage in splitting the 50 N kg/ha rate between tillering and booting. However, the later applications tended to increase grain nitrogen content in all years.

With Arawa and Rongotea, the low plant population was adequate in all experiments, indicating a capacity to increase and/or maintain tillers at wider plant spacing. Kopara tended to respond to increasing plant population particularly in the high-yielding year. With all three cultivars, grain nitrogen content was increased by higher plant populations.

With Kopara, the nitrogen was more effective applied at tillering. Rongotea and Arawa appeared to respond more to a later nitrogen application. Grain nitrogen content was increased by delaying the nitrogen application regardless of cultivar.

The large variation in grain yield and in the relationship between plant population and nitrogen caused by climatic conditions in this three year study shows that optimum plant population and nitrogen combinations are difficult to predict prior to drilling and in any event should not be based on the results of one years experimentation. The appropriate seed rate for the chosen cultivar should be used and the time and rate of nitrogen fertilisation should preferably be determined by the availability of soil nitrogen (Ludecke, 1974; Quin *et al.,* 1982) rather than according to growth stage.

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