Establishment, sowing time and plant population effects on CRD Otane wheat

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Abstract

Three trials were conducted in the 1988/89 season in Canterbury to obtain information on the response of CRD Otane to a range of sowing times, plant populations and plant establishment treatments. Yields were generally higher from late winter-early spring sowings than from October or later. The risk of frost damage at anthesis was considered low from sowings as early as 1 June, even though CRD Otane had previously only been recommended for spring sowing.

There was no effect of plant population on grain yield provided there was a minimum of 200 plants/m^2 established. Although it often produces lower ear numbers than many other cultivars, CRD Otane seems able to compensate for low plant numbers by producing more ears per plant and grains per ear.

Plant establishment was reduced by inadequate cultivation, sowing too deep, seed treatment with fungicide and, especially, poor seed quality. The largest yield reduction occurred with a badly sprouted, low germination seedline. There was no evidence of a plant establishment problem unique to CRD Otane.

Additional key words: Triticum aestivum, *sowing rate, wheat yield, autumn sowing, spring sowing, yield components, cultivation, seed quality*

Introduction

CRD Otane is a short-strawed early maturing red wheat with good disease resistance and excellent milling and breadmaking qualities. It was selected from material introduced to New Zealand in 1973 from the CIMMYT international wheat breeding programme in Mexico (McEwan, 1982). Seed of the new cultivar was first available commercially in 1986 and by the 1988/89 season CRD Otane occupied about 70% of the New Zealand wheat area. This paper reports on three trials which were conducted in Canterbury in the 1988/89 season to obtain improved information on three aspects of CRD Otane management.

When it was released in 1985, CRD Otane was recommended for spring sowing only (G.E. Ovenden, pers. comm.). It was thought to develop too rapidly in spring if sown before about 1 August because it has low photoperiod sensitivity and no vernalisation requirement and the risk of frost damage at flowering was judged to be too high. Despite the recommendation, some growers sowed CRD Otane earlier because its agronomic characteristics and grain quality were much better than alternative autumn-winter cultivars. This was of some concern because the risk of frost damage had not been quantified and little was known about how CRD Otane would perform under winter sowing. Therefore the first objective of this paper is to present the results of two trials conducted to study the performance of CRD Otane sown at several times in winter and spring in Canterbury and to define the risk of frost damage at flowering.

There was also uncertainty about the best seeding rates for CRD Otane crops. Recommended populations for most wheat cultivars are 200-250 plants/m^2 for autumn sown crops and 350-400 plants/m^2 for spring sown crops (Wilson, 1985). The aim then is to establish ear populations of 600/m^2 at maturity to produce grain yields of 6 t/ha or more in Canterbury (Scott, 1978). However, relationships among plant population, tiller production and survival, and final ear population are very complex, and as well as cultivar differences there is a strong environmental influence on the association between plant and final ear numbers (Withers and Pringle, 1981). Early experience with CRD Otane indicated that it produced fewer tillers and lower ear populations than other cultivars. Higher seeding rates were sometimes recommended, but the benefits were unclear. Therefore the second objective of two of the trials reported in this paper was to determine the effects of varying plant populations at different sowing times on the performance of CRD Otane wheat.

The third objective was to identify the causes of poor plant establishment which occurred in some crops despite the use of recommended seeding rates. It was unclear whether the problem was unique to CRD Otane or whether it was caused by factors such as poor seed quality or seed-bed preparation. These possibilities were investigated in a trial at Methven in which the effects were measured of cultivation, seeding depth and fungicide seed treatment on the establishment and yield of CRD Otane and CRD Oroua seed-lines of varying quality.

Methods

All trials were grown in the 1988/89 season which was warmer than average in Canterbury with fewer frosts, although slightly more than usual were recorded in September. Temperatures in the spring were very high (Table 1).

Trial 1

Trial 1 was conducted on a Templeton silt loam on the DSIR Crop Research experiment station at Lincoln. It was a split plot design with five sowing dates (3 June, 22 July, 30 August, 27 September and 21 October) as the main plots, four target populations (200, 300, 400 & 500 plants/m^2) as the sub-plots and three replicates. Seeding rates were calculated taking account of the germination percentages, mean seed weights and expected field emergences. Plots were 19m long and 1.35m wide of which the final harvested area was 15.4m^2.

All plots received 125 kg/ha di-ammonium phosphate (N:P:K:S = 18:20:0:0) at sowing and the first four sowings also received 475 kg/ha ammonium sulphate (N:P:K:S = 21:0:0:24) during tillering. The first three sowings were sprayed for weed control with a mixture of chlorsulfuron (Glean, 20 g/ha) and clopyralid (Versatill, 0.5 l/ha) on 26 September. The fourth sowing was sprayed on 1 November with a mixture of chlorsulfuron and bromoxynil/ioxynil (Combine).

To protect them from rust diseases the first three sowings were sprayed on 4 November with propiconazole (Tilt) plus prochloraz (Sportak) at half label rates. The fourth and fifth sowings received prochloraz and triadimenol (Cereous) at half label rates on 9 December.

The trial was irrigated according to a water budget and 320mm was applied in 7 applications. It was not possible to irrigate later sowings while earlier ones were approaching harvest maturity and this practical difficulty may have affected final yield results.

The first sowing was not harvested because of severe bird damage, but the later sowings were protected by nets. The 2nd to 5th sowings were harvested on 11, 13 and 23 January and 10 February respectively.

Trial 2

Trial 2 was a split pot design with four replicates. Main plots were five sowing dates (28 June, 26 July, 24 August, 20 September and 27 October) and the sub plots were two sowing rates (aimed at establishing 300 and 450 plants/m^2). It was conducted on a Wakanui

TABLE 1: Weather data at Lincoln during the growing season of 1988 and in the preceding years.

Month	Mean Daily Temperature (°C)					Number of Days of Screen Frosts				
	'88	'87	'86	'85	'84	'88	'87	'86	'85	'84
May	9.3	8.1	8.6	8.8	7.4	4	4	8	6	8
June	6.9	6.6	6.4	7.1	7.2	6	8	16	7	12
July	7.6	6.1	5.5	6.9	6.6	5	10	14	9	8
Aug	8.1	9.0	5.6	7.4	8.9	7	3	11	7	4
Sept	11.2	10.0	8.4	9.8	9.4	4	2	3	0	3
Oct	14.0	11.8	11.6	10.3	11.5	0	1	0	2	0
Nov	15.1	13.7	13.0	13.0	14.5	0	0	0	0	0
Dec	18.6	15.6	15.8	14.4	15.9	0	0	0	0	0

silt loam on the MAF Technology research farm at Lincoln. Plots received basal superphosphate at 125 kg/ha and nitrogen fertiliser (as ammonium sulphate) at late tillering at an average rate of 80 kg N/ha. Plots were 14m x 1.65m.

The herbicides chlorsulfuron (Glean, 20 g/ha), diclofop-methyl (Hoegrass, 2.5 l/ha) and clopyralid (Versatill, 1 l/ha) plus the fungicide triadimenol (Cereous, 0.5 l/ha) and insecticide pirimicarb (Pirimor, 250 g/ha) were applied to each sowing at late tillering. Half label rates of propiconazole (Tilt) and prochloraz (Sportak) were applied to each sowing for rust protection at anthesis. The trial area received 400 mm water in 11 irrigations during the season. The plots were harvested in order of sowing on 13, 13, 17 and 31 January and 20 February.

Trial 3

Trial 3 was conducted on a Ruapuna silt loam at Methven by Crop Marketing NZ Society Ltd and DSIR Crop Research. It was sown in a split-split plot design on 2 September with main plots of two cultivation treatments, fine or coarse seedbeds; sub-plots of two sowing depths, 3-4cm and 6-8cm; and sub-sub-plots of four seed lines of CRD Otane and one of CRD Oroua, each treated with Baytan IM or untreated. There were three replicates. Plot size was 10m x 1.5m.

The seed lines were selected with a range of germination percentages, falling numbers (FN, a measure of enzyme activity, below 250 being considered undesirable for baking) and sprouting scores (S0 = nil sprout, S1 = bread is 'slightly doughy', S3 = 'bread is doughy'; S3 flour has approximately three times the enzyme activity of S1 flour) as follows: CRD Otane Line 1 had 75% germination, 62 FN, S3; Line 2 had 93%, 62 FN, S1; Line 3 had 94%, 150 FN, S0; Line 4 had 96%, 250 FN, S0; CRD Oroua had 95%, 350 FN, S0.

Sowing rates were then calculated using germination percentages, seed weight and expected field emergence to achieve the target population of 350 plants/m^2. The trial was sown with 100 kg/ha di-ammonium phosphate and all plots received an application of 180 kg/ha of urea at tillering. The trial area was sprayed with propiconazole for stripe rust at the 3-leaf stage and again at ear emergence. The trial was irrigated three times. It was harvested on 30 January.

In all trials plant populations were recorded after plots were fully established and ear populations were counted just before final harvest. All trials were machine harvested, and header yields analysed and reported. Grain weights were measured on machine-dressed samples and the results were used to estimate grain numbers per ear.

Results

Trial 1

There were large differences in yield between the July/August and September/October sowings in Trial 1, but they were not significant at the 5% level (Table 2). The large LSD results from the large differences between replicates in each sowing date but they were not consistent over the trial area. The combined effect of differing ear populations and grain weights contributed to the high variation. Plant establishment for the July and August sowings was slightly above the target population but was about 75% below for the September and October sowings (Table 2). Ear populations in the later sowings were also slightly lower than the earlier sowings while the August sown plots produced more ears/m^2 than the July sown ones.

Yield tended to increase with plant population. At a population of around 350/m^2 it was higher ($P<0.05$) than at 190 or 270 plants/m^2 (Table 2) but the yield at 425/m^2 was not significantly different from any of the lower populations. A significant interaction between sowing time and population occurred due to a relatively high population for the July sowing at 300 plants/m^2. Sowing times did not affect grain quality as

TABLE 2: Yields and yield components from Trial 1 (Lincoln DSIR).

	Plants per m^2	Ears per Plant	Grains per Ear	TGW (g)	Yield (t/ha @14%MC)
Sowing Date					
July	375	1.39	31.1	48.8	7.49
August	367	1.56	34.9	39.7	7.28
September	240	2.01	33.9	36.8	5.65
October	262	1.58	31.3	45.9	5.50
$LSD_{0.05}$	43	0.23	9.7	7.0	2.10
Target Population					
200	193	2.20	34.9	42.7	6.27
300	272	1.69	33.7	43.1	6.40
400	354	1.43	32.1	43.2	6.78
500	425	1.22	30.5	42.1	6.46
$LSD_{0.05}$	24	0.16	2.8	1.4	0.34
Interaction	*	n.s.	n.s.	n.s.	n.s.
CV%	9.3	11.3	7.3	3.9	6.2

measured by bake scores and protein levels. MDD bake scores averaged 28 and grain protein content averaged 12.8%, these values being very good for a bread wheat.

Trial 2

Yields were similar for the June, July and September sowings but lower in the August and October ones (Table 3). This was a consequence of varying combinations of ear populations and grain weights. Mean grain weight declined with progressively later sowings. The ear numbers per plant were highest in the September sowing, resulting in high grain numbers per m^2. This led to a higher yield despite low grain weights. There was no significant effect of plant population on yield because the plots with lower plant establishment produced more ears per plant and more grains per ear.

There was a significant interaction between sowing date and population for both plant population and ears/plant. This resulted from the low sowing rate in June having lower plant establishment and a higher number of tillers/plant than at other sowing times. There was no consistent effect of time of sowing on grain quality as determined by nitrogen content.

Trial 3

Cultivation had no effect on yields even though plant establishment was higher with fine cultivation (Table 4). Deep seeding reduced plant establishment but ear number per plant was higher so yield was not affected. Seed treatment, however, significantly reduced plant numbers and numbers of grain per m^2 and resulted in a reduction in final yield.

Line 1 of CRD Otane produced very low plant numbers despite increased seeding rates to compensate for its poor germination. It is probable that the germination percentage decreased between measurement and sowing. Each plant produced more tillers than in the other lines but this was insufficient to produce enough grains to bring the yield to the same level as the other CRD Otane lines. Despite a higher ear population than the CRD Otane lines, CRD Oroua produced no more grains/m^2 than the CRD Otane lines 2, 3 or 4 and, with a lower grain weight, produced the lowest yield of all lines, including CRD Otane line 1.

TABLE 3: Yields and yield components from Trial 2 (Lincoln MAF).

	Plants per m^2	Ears per Plant	Grains per Ear	TGW (g)	Yield (t/ha @14%MC)
Sowing Date					
June	278	1.49	29.4	52.1	6.15
July	275	1.29	34.7	50.8	6.16
August	282	1.43	28.9	45.0	5.00
September	280	1.72	32.6	40.1	6.16
October	306	1.38	35.6	39.4	5.50
$LSD_{0.05}$	23	0.21	5.7	12.4	0.76
Target Populations					
300	229	1.68	33.9	45.6	5.78
450	340	1.24	30.6	45.4	5.81
$LSD_{0.05}$	16	0.10	1.9	0.7	0.11
Interaction	**	**	n.s.	n.s.	n.s.
CV%	15.9	18.5	11.4	4.1	5.3

TABLE 4: Yields and yield components from Trial 3 (Methven).

	Plants per m^2	Ears per Plant	Grains per Ear	TGW (g)	Yield (t/ha @14%MC)
Cultivation (C)					
Fine	238	2.04	30.0	42.6	5.57
Coarse	208	2.15	30.3	42.6	5.31
$LSD_{0.05}$	27	0.56	1.4	2.1	0.41
Depth (D)					
Shallow	259	1.81	29.3	42.8	5.48
Deep	187	2.38	30.9	42.4	5.39
$LSD_{0.05}$	14	0.18	1.9	2.6	0.26
Seed Treatment (T)					
Yes	200	2.25	30.9	42.6	5.31
No	246	1.94	29.3	42.6	5.57
$LSD_{0.05}$	10	0.11	1.0	0.5	0.08
Seed Line (L)					
CRD Otane 1	152	2.59	33.3	43.6	5.33
CRD Otane 2	249	1.78	30.6	44.4	5.73
CRD Otane 3	237	1.81	31.6	44.0	5.65
CRD Otane 4	237	1.79	32.5	43.8	5.79
CRD Oroua	241	2.50	22.6	37.2	4.70
$LSD_{0.05}$	16	0.17	1.6	0.8	0.13
Interactions					
CxD	n.s.	n.s.	n.s.	n.s.	n.s.
CxT	n.s.	n.s.	*	n.s.	n.s.
CxL	n.s.	*	n.s.	n.s.	**
DxT	n.s.	*	n.s.	*	*
DxL	*	n.s.	n.s.	n.s.	n.s.
TxL	*	**	n.s.	n.s.	n.s.
CV%	12.2	14.1	9.5	3.4	4.2

Significant interactions occurred between cultivation and seed line in both grains/m^2 and yield. CRD Otane had higher grain weights under fine cultivation, with line 1 yielding 0.6 t/ha more than under coarse cultivation while lines 2, 3 and 4 yielded 0.2 t/ha more. CRD Oroua had higher grain weights under coarse cultivation, with no yield differences between cultivation treatments.

Time to flowering

A regression of development rate (reciprocal of duration from sowing to anthesis) against temperature for the period from sowing to anthesis in Trials 1 and 2 gave an intercept of 5°C. Hence thermal duration was calculated using a base temperature of 5°C. Although the chronological duration fell rapidly with later sowings, the thermal duration was consistent (Table 5).

TABLE 5: Thermal time (base 5°C) from sowing to anthesis for CRD Otane derived from Trials 1 and 2.

Sowing Date	Anthesis Date	Days from Sowing to Anthesis	Thermal Time (base 5°C) Sowing to Anthesis
3/6	4/11	154	748
28/6	7/11	132	712
22/7	11/11	112	702
26/7	12/11	109	687
24/8	24/11	92	719
30/8	27/11	89	733
20/9	10/12	81	770
27/9	12/12	76	755
21/10	25/12	65	723
27/10	28/12	62	707
			mean = 726

Discussion

Time of sowing

Although yield differences between sowing dates appeared to be related to plant establishment in Trial 1, examination of grain numbers shows that the September sowing produced more grains/m^2 than the July sowing, indicating that a high degree of compensation for the lower population had occurred. The difference between September and July sowings was therefore mainly due to low grain weights in the later sowings, which were probably caused by water stress inhibiting grain fill.

Yield is a function of grain number and grain weight, with grain numbers indicating the yield potential of each sowing date. In the October sowing of both Trials 1 and 2 compensation for lower plant populations, by increasing ear numbers per plant, did not occur as much as in September sowings. This observation is supported by Sheath and Galletly (1980) who found that, in spring sowings, tiller population may be limited by the shorter tillering phase.

A small sowing date trial conducted in Southland in 1988/89 (K.M. Paterson, pers. comm.) found that November sowings of CRD Otane produced higher yields than October or December sowings. Ear populations increased with later sowings but grain numbers or weights must have been highest in the November sowing. This shows that optimum sowing times for CRD Otane differ greatly with environment, Canterbury recommendations being very different to those for Southland.

The calculation of the thermal duration from sowing to anthesis shown in Table 5 suggests that CRD Otane has, at most, a minimal photoperiod response. This makes CRD Otane more likely than photoperiod responsive cultivars to be susceptible to frost damage if sown too early. However, in these trials, when sown on 3 June CRD Otane did not reach anthesis until 4 November. In a cooler, more average season, anthesis would be delayed thus reducing the frost risk still further (Table 1). In the period from 1975 to 1989 inclusive, there were only two air frosts recorded in November at Lincoln, and both were of less than 1°C. In inland areas of Canterbury, frost risks would be slightly greater but cooler temperatures would delay anthesis.

The older wheat cultivars CRD Oroua and CRD Karamu develop to anthesis at a similar rate to CRD Otane and both of these cultivars have been winter sown commercially without any major problems. We therefore conclude that there is a low risk of frost damage at flowering in winter sown CRD Otane crops.

Plant populations

Plant establishment was lower than expected in both Trials 1 and 2, possibly due to high estimates of field emergence when calculating sowing rates. Low populations, however, were compensated by increased ear numbers and grains per ear. This indicated that the lower yields in the September and October sowings of Trial 1 could not have resulted solely from the lower plant establishment at these times.

CRD Otane appears able to compensate for a wide range of plant populations. The higher sowing rates had higher ear numbers but fewer grains per ear, resulting in no effect on overall yield. This finding contrasts with studies by Hampton et al. (1981) on the older wheat cultivars Arawa, Kopara, Rongotea and Karamu which showed a significant positive relationship between yield and ear number.

The 'optimum' ear population of $600/m^2$ was not reached in any treatment. Ear numbers were highest in Trial 1, averaging $465/m^2$. This indicates that CRD Otane may be unable to support high ear populations, perhaps because it has larger ears than most other cultivars. In Trial 3 (Table 4), CRD Oroua produced 563 ears/m^2 at a similar plant population to the CRD Otane lines 2, 3 and 4, which produced, on average, 416 ears/m^2. All CRD Otane lines, however, yielded significantly more than the CRD Oroua.

Cultivars are known to respond differently to variations in plant and ear populations. In a study of spring sown Kopara wheat, Fraser and Dougherty (1978) found that at a plant population of $520/m^2$ grain yield was 11% greater than at 250 plants/m^2 due in part to ear densities being 29% higher at the higher sowing rate in their study. Main-stem tillers made a greater contribution to yield at higher sowing rates but the numbers of ears per plant were greatly reduced, accounting for the significantly lower yield per plant which resulted. This difference was not apparent in CRD Otane, which compensated for lower plant populations more successfully. CRD Otane has larger ears and the capacity for larger seed than Kopara, another feature aiding its compensatory ability.

Sheath and Galletly (1980) found that in Aotea and Takahe wheats, increased grain numbers partially compensated for reductions in ear numbers associated with spring sowings compared with winter sowings, while in the cultivar Karamu numbers of grains per ear were significantly reduced by spring sowing. Again, CRD Otane appears able to adjust more successfully than these cultivars under a range of plant populations.

Plant establishment

Sowing too deep, inadequate cultivation, seed treatment with fungicide and using seed with low germination and vigour scores all reduced plant establishment of both cultivars in Trial 3. There were no yield reductions, however, except for the badly sprouted, low germination seedline 1 of CRD Otane. All the CRD Otane lines outyielded CRD Oroua showing that, although the former usually produces fewer ears per plant and per unit area than other cultivars, it compensates by producing more grains per ear and larger grains. The treatments affected both cultivars in the trial equally.

Conclusions

The possible yield advantage of sowing CRD Otane during winter must be weighed against the risk of frost damage at anthesis. The results from these trials suggest that in Canterbury CRD Otane will usually reach anthesis during a period of relatively low frost risk if sown as early as 1 June. Although not conclusive, the results also suggest the higher yields are likely from earlier sowing. We therefore recommend that CRD Otane is suitable for either winter or spring sowing.

The results also showed that there is no need to sow CRD Otane at higher plant populations than other cultivars. No consistent relationship was found between yield and plant population over the range tested. Although it may produce lower ear populations than other cultivars, it is clearly able to compensate to a large extent for low plant numbers by producing more ears per plant and grains per ear. In this respect, it behaves in the same manner as most other wheat cultivars.

There was no evidence of a plant establishment problem unique to CRD Otane. The results of Trial 3 showed that it is important to use seed with high germination and vigour, whatever the cultivar. The best plant establishment is achieved by not sowing too deep into a well-cultivated, fine seed-bed. Fungicide seed treatment decreased both plant establishment and grain yield but this must be weighed against possible damage caused by diseases. In this trial fungicide applications during crop growth prevented disease problems.

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