Effect of chlormequat and sowing rate on yield and quality of oats.

R.J. Martin, K. Armstrong and D.R. Wilson.

Crop & Food Research Limited, Private Bag 4704, Christchurch.

Abstract

Eight field trials were conducted in Southland during four seasons to determine the effects of chlormequat application, sowing rate and nitrogen (N) fertilizer applications on growth, yield, and grain quality of tall and semi-dwarf oat cultivars. Chlormequat reduced plant height and lodging, and increased yield in two trials. However it led to higher screenings and lower hectolitre weights at some sites. Sowing rates lower than common farmer practice (150-200 kg/ha) did not reduce yields or grain quality. However, lower sowing rates resulted in less lodging in conditions where lodging was a problem. There was no advantage in using sowing rates above 100 kg/ha. At one site with higher rainfall and 70 kg N/ha applied before the trial was sown, 100 kg N/ha applied at sowing resulted in lower yields and grain quality; whereas under drier and/or lower fertility conditions, 100 kg N/ha applied at sowing resulted in higher yields, whether extra N had been applied before the trial was started or not. The results indicate that careful attention to crop management is essential if high yields of high quality oats are to be obtained in a cost effective manner.

Additional key words: *cycocel, growth regulator, nitrogen, panicle population, screenings, hectolitre weight, site, season.*

Introduction

Lodging of oat crops is a problem in Southland. It restricts grain filling, reducing yield and increasing screenings. It is worse in taller, weak strawed cultivars. Management strategies which could reduce lodging include growing short strawed cultivars (Brinkman and Rho, 1984), reducing plant population (Marshall *et al.*, 1992), applying a growth regulator (Tennenhouse and Lacroix, 1972), and using less nitrogen fertilizer (Ohm, 1976).

Shorter strawed cultivars released by Crop & Food Research are now widely grown for milling in Southland. Previous agronomic trials have shown that they lodge less than older, taller, cultivars, but, nevertheless, they can lodge badly under certain seasonal conditions combined with high soil fertility. However, under low fertility conditions, there is the risk that grain size will be reduced if the crop runs out of nitrogen before maturity.

In the 1991-92 and 1992-93 seasons, two field trials were conducted in Southland to investigate whether application of growth regulator and reduced plant population would minimize early lodging and high screenings in high yield potential crops of two tall oat cultivars, Awapuni and Enterprise. In the 1994-95 and 1995-96 seasons, further trials were carried out to evaluate the effect of growth regulator, sowing rate and nitrogen (N) fertilizer on lodging, yield and quality of a semi dwarf oat cultivar, Drummond (Anon., 1994), on three sites in Southland.

Methods

1991-92 and 1992-93

In 1991-92, cv. Awapuni and cv. Enterprise were grown in adjacent commercial oat crops on a Southland farm. In 1992-93, cv. Enterprise was grown in a commercial crop on the same farm. The trials were sown on 23 October 1991 and 1 October 1992 respectively, and were managed the same as the surrounding crop to ensure high yield potential. All three trials were laid out in a split plot design with five replicates. Main plot treatments were either sprayed with chlormequat (Cycocel) growth regulator or not sprayed. Subplot treatments were four sowing rates: 100, 150, 200 (the normal commercial sowing rate), and 250 kg/ha. The chlormequat was applied at the rate and growth stage recommended by the manufacturer (1-2 l in 200-

350 kg/ha water when the second node was just visible). Each subplot was 15 m (1991-92) or 14 m (1992-93) long and 1.35 m wide.

1994-95 and 1995-96

The trials were situated in commercial oat crops, all grown in paddocks with long cropping histories, in Southland. The cultivar used in all trials was Drummond. The 1994-95 crops were sown on 5 October (Site 3), 6 October (Site 1) and 13 October (Site 2), and the 1995-96 crops were sown on 14 October (Site 2), 25 October (Site 1) and 26 October (Site 3).

At each site, the following treatments were applied as a 2*2*2 factorial: no growth regulator or chlormequat applied at the recommended rate and growth stage (see above); 100 or 200 kg/ha of seed; and 0 or 100 kg N/ha applied as urea at sowing. The trials were otherwise managed the same as the surrounding crop to ensure high yield potential. At each site there were four replicates of each treatment arranged in a completely randomized design, and each plot was 12 m long and 1.6 m wide.

In early to mid March in each year, lodging, plant height and ear population were measured in all plots. Lodging was scored on a scale of 1 to 5, with 1 for no lodging and 5 for the whole plot being completely lodged. Plant height was taken as the mean of three measurements in each plot. Panicle population was averaged over five random 0.1 m^2 quadrats per plot.

In April of all years, the trials were machine harvested with a plot header, with the harvested area per plot ranging from 15.9 to 20.8 m^2. Yield (adjusted to 14% moisture), screening % (using a 2.4 mm screen), and hectolitre weight were measured on samples from each plot in 1991-92. In 1992-93, for screening % and hectolitre weight measurements, the replicates were bulked within sowing rates. In 1994-95, yield was measured on each plot, while screening % and hectolitre weight were measured on bulked replicates for each site. In 1991-92, a subsample of 300 grains from the bulked sample from the five replicates for each treatment was weighed and dehulled and the groats weighed to get an extraction percentage. In 1992-93, the same procedure was used for a subsample of 100 grains from each plot, and, in the last two seasons, for a subsample of 30 g of grain per plot.

All results were analysed using the Genstat statistical package. For results with individual plot data, the 1994-95 and 1995-96 trials were analysed as a combined set of three randomized block trials. Where a bulked sample from the four replicates at each site was used, data from the different sites were treated as replicate samples and only the factorial treatments were examined statistically.

Results

Yields were high in 1991-92, but there was little lodging in the trials. It was wetter in 1992-93, and more lodging occurred. The 1994-5 season was dry with reduced overall yields, although Site 1 received much more rainfall that the other sites. There was little lodging, but the crop at Site 2 grew poorly in the dry conditions. It was wet again in 1995-96, and high yields were obtained except at Site 2 where the trial was badly affected by diseases caused by *Pythium* spp., *Septoria avenae*, and *Pseudomonas coronafaciens* (Halo blight).

Application of chlormequat lowered plant height in all five trials (Tables 1-5), and it also significantly reduced lodging except for cv. Enterprise in 1991-92 (Table 2), and at Site 2 in 1995-96 (Table 5). In 1995-96, chlormequat reduced lodging more effectively in N fertilized plots at low plant populations (Table 5). In 1992-93 (Table 3) and 1995-96 (Table 5) panicle numbers were higher with chlormequat application and in 1992-93 this resulted in a higher grain yield. Grain yield was also higher with chlormequat application in 1994-95 (Table 4). Chlormequat had mixed effects on percentage screenings, increasing it in cv. Enterprise in 1991-92 (Table 2) and cv. Drummond in 1995-96 (Table 5) and reducing it in cv. Enterprise in 1992-93 (Table 3). Chlormequat had a more consistent effect on hectolitre weight, reducing it in both trials in 1991-92 (Tables 1 and 2) and in 1995-96 (Table 5). Chlormequat had little overall effect on extraction percentage (data not presented).

Increasing sowing rate from 100 to 150 or 200 kg/ha tended to result in lower plant height in four of the five trials. However, the higher sowing rates led to more lodging in cv. Enterprise in 1992-93 (Table 3) and cv. Drummond in 1995-96 (Table 5), but less lodging in cv. Awapuni in 1991-92 (Table 1). In 1995-96 lodging was increased by the combination of the higher sowing rate and N application (Table 5). Higher sowing rates produced more panicles in all trials, but had no effect on yield in four trials and led to lower yield in cv. Awapuni in 1991-92 (Table 1). In both 1994-95 (Table 4) and 1995-96 (Table 5), screenings were higher at the higher sowing rate if no N fertilizer was applied. Higher sowing rates led to sightly increased hectolitre weight in cv. Enterprise in 1991-92 (Table 1), but otherwise had no effect on grain quality. Sowing rate had little overall effect on extraction percentage (data not presented).

In 1994-95, 70 kg N/ha as urea was applied to Site 1 prior to the trial being started, and in 1995-96, 78 kg N/ha was applied at Site 1 and 40 kg N/ha was applied at Sites 2 and 3 before the trials were started. In 1994-

Table 1. Effects of growth regulator and sowing rate on plant height, lodging, panicle population, plot header yield, screenings and hectolitre weight for cv. Awapuni in 1991-92.

	Plant height (m)	Lodging score	Panicles/m²	Yield (t/ha)	Screenings (%)	Hectolitre weight (kg/hl)
Growth regulator						
no chlormequat	0.88	1.55	378	8.47	6.6	53.2
chlormequat	0.76	1.00	374	8.67	6.6	52.7
LSD (d.f. 4)[1]	0.06**[2]	0.40*	n.s.	n.s.	n.s.	0.4*
CV[3]	2.0	18.1	3.4	4.6	6.7	0.4
Sowing rate						
100	0.86	1.50	365	8.52	7.0	52.7
150	0.82	1.20	352	8.92	6.4	53.2
200	0.81	1.20	380	8.53	6.6	53.1
250	0.79	1.20	407	8.33	6.5	52.8
LSD (d.f. 24)	0.03***	0.26*	25***	0.43*	n..s.	n..s.
CV	3.4	22.1	7.1	5.4	7.5	1.3

1 Least significant difference between means at 5% level (with degrees of freedom in brackets).
2 Treatment effect: * = significant at 5%, ** at 1%, *** at 0.1%, n.s. not significant.
3 Coefficient of variation (%)

Table 2. Effects of growth regulator and sowing rate on plant height, lodging, panicle population, plot header yield, screenings and hectolitre weight for cv. Enterprise in 1991-92.

	Plant height (m)	Lodging score	Panicles/m²	Yield (t/ha)	Screenings (%)	Hectolitre weight (kg/hl)
Growth regulator						
no chlormequat	0.88	2.00	377	7.90	9.7	54.2
chlormequat	0.79	1.65	388	8.28	10.6	53.2
LSD (d.f. 4)[1]	0.06*[2]	n.s.	n.s.	n.s.	1.1*	0.7*
CV[3]	4.0	16.2	3.9	6.0	6.2	0.7
Sowing rate						
100	0.89	2.10	352	8.22	10.9	53.3
150	0.82	1.80	358	8.44	10.0	53.6
200	0.82	1.80	395	7.89	10.0	53.9
250	0.80	1.60	424	7.83	9.8	54.0
LSD (d.f. 24)	0.05**	n.s.	34***	n.s.	n.s.	0.6*
CV	6.9	31.6	9.8	7.9	13.7	1.2

1 Least significant difference between means at 5% level (with degrees of freedom in brackets).
2 Treatment effect: * = significant at 5%, ** at 1%, *** at 0.1%, n.s. not significant.
3 Coefficient of variation (%)

95, 100 kg N/ha at sowing had little effect on plant height or lodging (Table 4). In 1995-96, plant height was higher with 100 kg N/ha at sowing, except at the higher sowing rate without chlormequat (Table 5). 100 kg N/ha at sowing also led to more lodging in 1995-96 (Table 5), but less so at the lower sowing rate with application of chlormequat. 100 kg N/ha at sowing gave higher panicle populations in both years. In 1994-95 grain yield was reduced after the application of 100 kg N/ha at sowing at Site 1, but was raised by up to 1 t/ha

Table 3. Effects of growth regulator and sowing rate on plant height, lodging, panicle population, plot header yield, screenings and hectolitre weight for cv. Enterprise in 1992-93.

	Plant height (m)	Lodging score	Panicles/m^2	Yield (t/ha)	Screenings (%)	Hectolitre weight (kg/hl)
Growth regulator						
no chlormequat	1.17	3.4	383	7.69	23.7	48.6
chlormequat	0.94	1.4	425	8.43	22.5	48.5
LSD (d.f. 4)[1]	0.05***[2]	0.4***	31*	0.56*	0.77*	n.s.
CV[3]	2.8	9.7	4.4	12.7	1.5	1.6
Sowing rate						
100	1.09	2.0	330	8.30	22.1	50.5
150	1.05	1.9	369	8.03	22.6	48.1
200	1.05	2.4	434	8.00	22.4	49.0
250	1.05	3.2	484	7.90	25.3	46.5
LSD (d.f. 24)	0.04*	0.5***	38***	n.s.	-	-
CV	3.7	24.8	10.2	14.2	-	-

[1] Least significant difference between means at 5% level (with degrees of freedom in brackets).
[2] Treatment effect: * = significant at 5%, ** at 1%, *** at 0.1%, n.s. not significant.
[3] Coefficient of variation (%)

at the other two sites (Table 4). In 1995-96 100 kg N/ha at sowing led to an overall increase in yield of 0.4 t/ha (Table 5), although the increase was not uniform across sites. In 1994-95, 100 kg N/ha at sowing reduced screenings at higher sowing rates, but not at lower sowing rates and had no effect on hectolitre weight (Table 4). In 1995-96, 100 kg N/ha at sowing resulted in higher screenings and lower hectolitre weight (Table 5). 100 kg N/ha at sowing did not change extraction percentage (data not presented).

Discussion

Although chlormequat tended to reduce plant height and lodging, resulting in increased yield in two trials, it also increased screenings and/or reduced hectolitre weight in four trials. This could be a major problem with a cultivar like cv. Drummond, where screenings are inherently high and hectolitre weights inherently low. More study is required on the interactive effect of chlormequat and soil fertility on grain quality. Lodging can still be a problem with semi-dwarf oats like cv. Drummond, and so chlormequat should be applied to these cultivars where lodging is likely to occur. Reductions in plant height and lodging with the use of chlormequat have been widely reported overseas (Humphries, 1968; Linser, 1968; Tennenhouse and Lacroix, 1972), but there do not appear to be any reports on its effect on hectolitre weight.

Reducing the sowing rate reduced panicle numbers in all five trials, without affecting yield. Reducing the sowing rate also reduced lodging in three trials. Reducing sowing rate had little effect on screenings or hectolitre weight and, on occasion, improved them. Therefore, for milling oats in Southland, sowing rates over 100 kg/ha are not warranted unless conditions are conducive to poor establishment. This is similar to sowing rate recommendations in the United States (Marshall *et al.*, 1992).

There were contrasts among the sites and seasons in fertility and rainfall. At one site with higher rainfall and 70 kg N/ha applied before the trial was sown, 100 kg N/ha applied at sowing resulted in lower yields and grain quality; whereas under drier and/or lower fertility conditions, 100 kg N/ha applied at sowing resulted in higher yields, whether extra N had been applied before the trial was started or not. This indicates that there is an optimum soil fertility for maximum oat yield. This seems to be particularly so with high sowing rates when, under low fertility conditions, screenings are increased and screened yield reduced. Overseas work had also shown that increasing N fertilizer increases panicle

Table 4. **Effects of growth regulator and sowing rate on plant height, lodging, panicle population, plot header yield, screenings and hectolitre weight for cv. Drummond in 1994-95.**

	Plant height (m)	Lodging score	Panicles/m^2	Yield (t/ha)	Screenings (%)	Hectolitre weight (kg/hl)
Site						
1	0.95	2.0	445	7.26	-[1]	-[1]
2	0.71	1.0	461	6.39	-	-
3	0.73	2.0	540	5.75	-	-
LSD (d.f. 9)[2]	0.02***[3]	0.7*	46**	0.32***		
CV[4]	1.5	24.8	6.0	3.1		
Growth regulator						
no chlormequat	0.83	1.9	484	6.36	25.7	53.5
chlormequat	0.76***	1.4**	480	6.58*	25.9	53.5
Sowing rate (kg/ha)						
100	0.80	1.7	463	6.45	25.3	53.6
200	0.79	1.6	500**	6.49	26.3	53.4
Nitrogen (kg/ha)						
0	0.79	1.7	466	6.22	27.2	53.5
100	0.80	1.6	498*	6.72***	24.3*	53.5
LSD (d.f. 63)	0.025	0.3	26	0.20	2.5	n.s
CV	7.5	44.8	13.2	7.4	10.9	1.9
Significant interactions[5]	None	None	None	Site*N	SowRate*N	None

1 Samples bulked according to treatments (sites treated as replicates).
2 Least significant difference between means at 5% level (with degrees of freedom in brackets).
3 Treatment effect: * = significant at 5%, ** at 1%, *** at 0.1%, n.s not significant. For subplots, asterisks placed next to the factorial comparison which is significantly different at the two levels.
4 Coefficient of variation (%)
5 Described in text if inconsistent with main effects.

number and reduces grain size and hectolitre weight, with an optimum N fertilizer rate for grains per panicle (Brinkman and Rho, 1984)

These results, together with the results of other oat agronomy trials in Southland over the past four years, indicate that careful attention to crop management is essential to obtain high yields and high quality oats in a cost effective manner. In particular, the balance between sowing rate, soil fertility and chlormequat must be such that grain size is maximized without decreasing yield and increasing lodging. This is likely to vary between seasons, but we currently know little about how the oat crop responds to water and temperature.

Similar problems have been encountered in the past with barley and wheat, but careful experimentation and interpretation of previous trial results have enabled scientists at Crop & Food Research to develop models of how these crops grow and respond to environmental and management factors (de Ruiter, 1997; Jamieson *et al.*, 1998). These models have now been developed to a stage where they can be used as decision support tools for farmers. There is potential to do the same for the oat crop.

Acknowledgements

Thanks to Mr. Robert Saunders, Mr Peter McLeish and the Gardyne Family Trust for allowing us to conduct the trials on their properties, and to Fleming and Company Ltd., Gore for financial assistance in the first year. Bob Telfer, Nathan Cruikshank and casual staff at Crop & Food Research managed the trials and carried out the machine harvesting. Myles Rea and Sarah Sinton assisted with crop sampling.

Table 5. Effects of growth regulator and sowing rate on plant height, lodging, panicle population, plot header yield, screenings and hectolitre weight for cv. Drummond in 1995-96.

	Plant height (m)	Lodging score	Panicles/m^2	Yield (t/ha)	Screenings (%)	Hectolitre weight (kg/hl)
Site						
1	0.97	2.0	372	6.89	18.2	48.6
2	0.84	1.7	526	4.49	24.6	48.0
3	0.89	2.0	471	6.48	13.5	49.7
LSD (d.f. 9)[2]	0.03***[2]	n.s	41***	0.21***	1.7***	0.6***
CV[4]	1.8	13.8	5.6	3.3	5.5	0.7
Growth regulator (GR)						
no chlormequat	0.97	2.3	441	6.01	17.6	49.4
chlormequat	0.83***	1.6***	471**	5.89	19.9***	48.1***
Sowing rate (SR) (kg/ha)						
100	0.92	1.6	409	5.90	18.0	48.8
200	0.88***	2.2***	503***	6.00	19.6***	48.7
Nitrogen (N) (kg/ha)						
0	0.87	1.3	433	5.76	16.9	49.3
100	0.93***	2.2***	480***	6.14***	20.7***	48.2***
LSD (d.f. 63)	0.015	0.2	19	0.13	0.9	0.3.
CV	4.1	22.1	10.2	5.5	12.1	1.5
Significant interactions[5]	Site*GR Site*N Site*GR*N Site*SR*N GR*SR*N	SR*N Site*GR Site*GR*N Site*SR*N GR*SR*N	Site*SR	Site*N	Site*N	none

[1] Least significant difference between means at 5% level (with degrees of freedom in brackets).
[2] Treatment effect: * = significant at 5%, ** at 1%, *** at 0.1%, n.s not significant. For subplots, asterisks placed next to the factorial comparison which is significantly different at the two levels.
[3] Coefficient of variation (%)
[4] Described in text if inconsistent with main effects.

References

Anonymous. 1994. Drummond - a Southland oat. Crop & Food Research Broadsheet 51. 2p. Crop & Food Research, Lincoln.

Brinkman, M.A. and Rho, Y.D. 1984. Responses of three oat cultivars to N fertilizer. *Crop Science* ***24***, 973-977.

De Ruiter, J.M. 1997. Prediction of the effect of nitrogen management on barley quality for malting. *Proceedings Agronomy Society of New Zealand* ***27***, 67-72.

Humphries, E.C. 1968. CCC and cereals. *Field Crops Abstracts* ***21***, 91-99.

Jamieson, P.D., Semenov, M.A., Brooking, I.R. and Francis, G.S. 1998. *Sirius*, a mechanistic model of wheat response to environmental variation. *European Journal of Agronomy* ***8***, 161-179.

Linser, H. 1968. Influence of CCC on lodging and behaviour of cereal plants. *Euphytica 17 Supplement* ***1***, 215-238.

Marshall, H.G., McDaniel, M.E. and Cregger, L.M. 1992. Cultural practices for growing oat in the United States. *In* Oat Science and Technology. Monograph 33 Agronomy Series (eds., H.G. Marshall and M.E. Sorrells), 191-221. American Society of Agronomy and Crop Science Society of America, Madison.

Ohm, W.M. 1976. Response of 21 oat cultivars to nitrogen fertilization. *Agronomy Journal* ***68***, 773-775.

Tennenhouse, A.N. and Lacroix, L.R. 1972. Effects of (2-chloroethyl) trimethylammonium chloride (CCC) on certain agronomic traits of oats and triticale. *Canadian Journal of Plant Science* ***52***, 559-567.