THE EFFECT OF IRRIGATION AND NITROGEN FERTILISER ON THE YIELD AND MALTING QUALITY OF BARLEY

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ABSTRACT

In four experiments conducted during three seasons, the responses of Zephyr barley to irrigation and nitrogen fertiliser were examined. All experiments were carried out on stony silt loam soil; two followed pasture and two followed a nitrogen-depleting cash crop. Irrigation increased grain yields and improved malting quality in all experiments. The improvement in malting qualtiy was due to reduced grain nitrogen content and screenings, and increased malt extract. Barley grain screenings were generally reduced by irrigation but they varied with different levels of irrigation in three of the experiments.

Yield responses to nitrogen fertiliser varied from little or no response in the absence of irrigation or when the barley followed pasture, to highly significant when it followed a nitrogen-depleting cash crop and when irrigation was applied. In all experiments nitrogen fertiliser decreased malting quality through an increase in the screenings and grain nitrogen content, and a reduction in malt extract. The extent of this depression of quality depended on the amount of irrigation, previous crop and the season, and varied more with rate than with time of nitrogen application.

INTRODUCTION

Nitrogen fertiliser is not generally recommended for barley crops destined for malting because it raises the nitrogen content of the grain, thus reducing malting quality (Russell and Bishop, 1933). However, there are no recent detailed accounts of the effects of nitrogen fertiliser on the yield and malting quality of barley in New Zealand. Malcolm and Thompson (1968) stated that nitrogen fertilisers do not significantly affect yield or grain nitrogen content of barley, and one of the reasons for the lack of response was thought to be low soil moisture limiting the uptake of nutrients. The same authors also reported considerable variation in grain nitrogen content resulting from previous land use. Subsequently, Thompson (pers. comm.) found that nitrogen fertiliser depressed yield and increased grain nitrogen content in unirrigated barley.

In a series of irrigation experiments using Zephyr barley on the light stony soil in the Winchmore district of Canterbury, irrigation greatly increased the yield and improved malting quality (Thompson *et al.*, 1974). The quality improvement was in lower grain nitrogen content and higher malt extract and a reduction in the screenings percentage by irrigation applied after ear emergence. There were no nitrogen fertiliser treatments in those experiments.

Experiments with irrigation and nitrogen fertiliser on wheat at Winchmore have shown that grain yield and grain nitrogen content responses to nitrogen depend on the time and rate of application and available soil moisture (Drewitt and Rickard, 1971, 1973), and on previous cropping history (Drewitt, 1979a). Wheat grain nitrogen content was significantly negatively correlated with the total amount of water applied (Drewitt and Rickard, 1971) and with grain yield and mean grain weight (Drewitt, 1979b). Under irrigation and in nitrogen-responsive situations, nitrogen fertiliser greatly increased yield and decreased grain nitrogen content of wheat. If the same relationship between increased yield and decreased grain nitrogen content following the use of nitrogen fertiliser exists in irrigated barley, malting quality may not be impaired.

This report presents the results of four experiments, two following pasture and two following a nitrogen-depleting crop, using two irrigated treatments and two rates of nitrogen fertiliser applied at drilling and at tillering. Grain yield, grain nitrogen content and the screenings percentage were measured and samples were subjected to micro malt testing.

MATERIALS AND METHODS

The experiments were carried out on Lismore stony silt loam at Winchmore Irrigation Research Station from 1977-78 to 1979-80. Zephyr barley was used in all experiments. The previous crop on the experimental sites and the sowing date of each experiment are given in Table 1.Seeding rate was from 145 to 150 kg/ha and 250 kg/ha of superphosphate was applied with the seed. Irrigation and nitrogen fertiliser treatments were indentical over the four experiments and are shown in Table 2. Each experiment consisted of five replicates of a split plot design with irrigation treatments on main plots and nitrogen treatments on sub plots. Sub plots were 20 x 2.5m in 1977-78 and 12 x 2m in 1978-79 and 1979-80. Nitrogen fertiliser as ammonium sulphate was applied by hand top-dressing and irrigation was applied by the border strip method when moisture in the top 150mm of soil fell to pre-determined levels.

TABLE 1: Previous crop and sowing date.

Experiment	Previous crop	Sowing date
1977-78	Oilseed rape	3.10.77
1978-79	Pasture	6.10.78
1979-80a	Pasture	17.10.79
1979-80b	Barley	17.10.79

TABLE 2: Irrigation and nitrogen treatments.

Irrigation (main plots)	1.	No irrigation
	2.	Irrigated at 10% soil moisture (s.m.)
	3.	Irrigated at 15% soil moisture
Nitrogen fertiliser (sub plots)	1.	No nitrogen
	2.	50 kg/ha N at drilling
	3.	100 kg/ha N at drilling
	4.	50 kg/ha N at tillering
	5.	100 kg/ha N at tillering
	6.	50 kg/ha N at drilling +50 kg/ha N at tillering

One header strip was taken from the centre of each plot for grain yield determination. Grain yields were field-dressed and adjusted to 12% moisture content, and the screenings percentage is the weight of grain passing through an A6 (2.37mm) screen. Grain nitrogen content of unscreened samples was determined by the Kjeldahl method and expressed as percentage on a dry basis. Malt quality was determined by micro malting 250g samples (Meredith *et al.*, 1962) and measuring the fine grind extract percentage using the European Method (Pollock, 1962). Grain yield, screenings percentage and grain nitrogen content were measured and statistically analysed on a plot basis. Malt extract was measured on a treatment basis only.

In the statistical analyses of grain yield, screenings percentage and grain nitrogen percentage there was little or no difference between nitrogen applied at drilling and nitrogen applied at tillering. Means for the tillering application have not been presented in the tables but are given in the text where appropriate.

RESULTS

Rainfall distribution from October to January varied considerably in the three year period of the experiments (Table 3). November rainfall was low in 1977 and 1978; in 1977, October was also a dry month and two irrigations were required in November on the 15% s.m. treatment (Table 4). Only one irrigation was required in November on the same treatment in 1978. By contrast, in 1979, October and November were comparatively wet months and irrigation was not required until December.

TABLE 3: Monthly rainfall (mm), October to January

	1977-78	1978-79	1979-80
October	23	91	136
November	24	36	67
December	73	124	49
January	51	39	125
4 month total	171	290	377

TABLE 4: Irrigation dates and growth stages (Feekes scale) in parentheses.

	Irrigated at 10% s.m.	Irrigated at 15% s.m.
1977-78	26 November (8)	17 November (7)
	28 December (11.1)	28 November (8)
		20 December (10.5.2)
		8 January (11.1)
1978-79	29 November (7)	22 November (7)
	20 January (11.1.1)	9 December (10.1)
		12 January (11.1.1)
1979-80a	16 December (10.3)	6 December (8)
		20 December (10.5)
1979-80b	16 December (10.3)	5 December (8)
		19 December (10.5)
		22 January (11.1.2)

Grain Yield

In all experiments there was a response to irrigation at 10% s.m. and a further response to irrigation at 15% s.m. when nitrogen fertiliser had been added (Table 5). In the absence of nitrogen fertiliser, plots irrigated at 15% s.m. were higher yielding than those irrigated at 10% s.m. in only one experiment (1979-80a).

Nitrogen fertiliser responses were influenced by irrigation and previous cropping history. On the two ex-crop experiments (1977-78 and 1979-80b), nitrogen had no effect in the absence of irrigation. There was a small response to nitrogen under 10% irrigation and a much larger response to nitrogen under irrigation at 15%. Yields from the heavier nitrogen rate (100 kg/ha) were higher than those from the 50 kg/ha rate only in 1977-78 in the presence of irrigation.

TABLE 5: Effects of nitrogen fertiliser on barley grain yields (kg/ha) at three irrigation levels.

	1977-78	1978-79	1979-80a	1979-80b
No irrigation				
No nitrogen	2200	4210	2300	2500
50 kg/ha N at drilling	2110	3960	2220	2520
100 kg/ha N at drilling	2110	3850	2570	2310
50 kg/ha N at drilling + 50 kg/ha N at tillering	2250	3630	2680	2810
Irrigated at 10% soil moisture				
No nitrogen	5060	4650	3790	3210
50 kg/ha N at drilling	5310	4620	3740	3820
100 kg/ha N at drilling	6010	4170	3640	3470
50 kg/ha N at drilling + 50 kg/ha N at tillering	5750	4280	3840	3750
Irrigated at 15% soil moisture				
No nitrogen	5110	4830	4760	3440
50 kg/ha N at drilling	6370	5270	4720	4690
100 kg/ha N at drilling	6760	5220	5070	4630
50 kg/ha N at drilling + 50 kg/ha N at tillering	6880	5070	5110	5060
SE$\bar{x}$ for comparing				
(i) Nitrogen treatments with the same irrigation treatment	233	139	169	148
(ii) Irrigation treatments with the same nitrogen treatment	247	134	233	155

TABLE 6: Effects of nitrogen fertiliser on barley screenings percentage at three irrigation levels.

	1977-78*	1978-79	1979-80a	1979-80b
No irrigation				
No nitrogen	5.8	12.9	7.0	4.1
50 kg/ha N at drilling	8.9	20.9	12.0	10.1
100 kg/ha N at drilling	9.2	23.4	12.3	15.0
50 kg/ha N at drilling + 50 kg/ha N at tillering	10.4	30.0	11.6	13.1
Irrigated at 10% soil moisture				
No nitrogen	2.6	18.9	3.8	3.7
50 kg/ha N at drilling	2.6	38.9	5.7	5.2
100 kg/ha N at drilling	2.6	53.3	6.5	7.2
50 kg/ha N at drilling + 50 kg/ha N at tillering	3.1	57.7	5.9	9.7
Irrigated at 15% soil moisture				
No nitrogen	2.3	7.5	7.4	4.1
50 kg/ha N at drilling	2.2	10.9	9.2	7.9
100 kg/ha N at drilling	2.3	14.5	14.1	11.3
50 kg/ha N at drilling + 50 kg/ha N at tillering	2.3	17.7	14.1	12.6
SE$\bar{x}$ for comparing				
(i) Nitrogen treatments with the same irrigation treatment	0.22	2.74	0.99	0.71
(ii) Irrigation treatments with the same nitrogen treatment	0.22	2.75	1.27	0.80

* Because of considerable variation in the non-irrigated plots only the irrigated treatments were statistically analysed.

TABLE 7: Effects of nitrogen fertiliser on barley grain nitrogen content (%) at three irrigation levels.

	1977-78	1978-79	1979-80a	1979-80b
No irrigation				
No nitrogen	2.50	1.70	2.10	1.70
50 kg/ha N at drilling	2.68	1.96	2.42	1.96
100 kg/ha N at drilling	2.62	2.29	2.63	2.32
50 kg/ha N at drilling + 50 kg/ha N at tillering	2.66	2.26	2.59	2.31
Irrigated at 10% soil moisture				
No nitrogen	1.49	1.65	1.62	1.29
50 kg/ha N at drilling	1.80	1.96	2.04	1.55
100 kg/ha N at drilling	1.98	2.17	2.24	1.94
50 kg/ha N at drilling + 50 kg/ha N at tillering	2.02	2.20	2.27	1.88
Irrigated at 15% soil moisture				
No nitrogen	1.43	1.48	1.59	1.34
50 kg/ha N at drilling	1.48	1.60	1.72	1.37
100 kg/ha N at drilling	1.75	1.89	2.09	1.61
50 kg/ha N at drilling + 50 kg/ha N at tillering	1.83	1.85	2.08	1.78
SE$\bar{x}$ for comparing				
(i) Nitrogen treatments with the same irrigation treatment	0.056	0.038	0.045	0.039
(ii) Irrigation treatments with the same nitrogen treatment	0.070	0.042	0.065	0.043

On one of the ex-pasture experiments (1979-80a) nitrogen had no effect on yield in the absence of irrigation while on the other ex-pasture experiment (1978-79), yields were depressed. Under irrigation, the application of nitrogen had no significant effect in either experiment. Yields from the heavier rate of nitrogen were higher than those from the lower rate in 1979-80a but in 1978-79, yields were depressed by the heavier rate.

The split application of nitrogen was no different to the single rate of 100 kg/ha at tillering in any of the experiments but in 1979-80b it was slightly higher yielding than the single 100 kg/ha rate at drilling on the non-irrigated and 15% s.m. treatments. The timing of nitrogen application had an effect on the yield only in 1979-80. Yields from the tillering application were higher than those from the drilling application in 1979-80a (3660 cf. 3900) and in 1979-80b they were higher only in the absence of irrigation (2410 cf. 2920). The nitrogen rate x time interaction was significant only in 1979-80b; the heavier rate depressed yields when applied at drilling but increased yields when applied at tillering.

Screenings percentage

In 1977-78, both irrigated treatments reduced the screenings percentage to a similar level (Table 6). In 1978-79, screenings were increased by irrigation at 10% s.m. and decreased by irrigation at 15% s.m. In both experiments in 1979-80, irrigation at 10% s.m. reduced screenings while irrigation at 15% s.m. had no significant effect.

Nitrogen fertiliser increased screenings in the absence of irrigation in 1977-78 while in the other three experiments nitrogen increased the screenings at all irrigation levels. Screenings were higher with the heavier rate of nitrogen under both irrigated treatments in 1978-79 and under all irrigation treatments in both 1979-80 experiments.

The split application of nitrogen produced similar screenings to the 100 kg/ha nitrogen rate applied either at drilling or at tillering in all experiments. The nitrogen rate x time interaction was not significant in any of the experiments.

Grain nitrogen

In all experiments, irrigation significantly decreased grain nitrogen content (Table 7). Irrigation at 15% s.m. decreased grain nitrogen more than irrigation at 10% s.m. except in 1979-80a.

Nitrogen fertiliser increased grain nitrogen content in all experiments, particularly on the non-irrigated and 10% s.m. treatments. Raising the nitrogen rate from 50 to 100 kg/ha also increased grain nitrogen content. In all experiments, the split application of nitrogen had the same effect as applying 100 kg/ha of nitrogen at either drilling or tillering and the time of nitrogen application had no significant effect on grain nitrogen content.

Malt Extract

The malt extract results showed the reverse of the patterns with grain nitrogen content. In all experiments, irrigation increased malt extract, with irrigation at 15% s.m. giving higher extract then irrigation at 10% s.m. (Table 8).

TABLE 8: Effects of nitrogen fertiliser on malt extract (%) at three irrigation levels.

	1977-78	1978-79	1979-80a	1979-80b
No irrigation				
No nitrogen	76.7	80.5	79.2	81.0
50 kg/ha N at drilling	75.1	76.6	76.4	80.0
100 kg/ha N at drilling	74.1	75.8	75.7	78.3
50 kg/ha N at drilling + 50 kg/ha N at tillering	74.2	76.5	76.7	78.5
Irrigated at 10% soil moisture				
No nitrogen	81.1	79.7	81.6	83.7
50 kg/ha N at drilling	80.6	77.1	79.6	83.0
100 kg/ha N at drilling	79.4	77.7	77.2	80.8
50 kg/ha N at drilling + 50 kg/ha N at tillering	78.8	76.1	78.5	81.9
Irrigated at 15% soil moisture				
No nitrogen	82.4	81.4	81.6	84.3
50 kg/ha N at drilling	82.2	82.2	80.1	83.1
100 kg/ha N at drilling	81.0	78.7	78.7	82.3
50 kg/ha N at drilling + 50 kg/ha N at tillering	79.6	78.8	79.0	81.2

Nitrogen fertiliser reduced malt extract at all irrigation levels in all experiments and the reduction was generally greater with the heavier nitrogen rate. The split application of nitrogen was similar to 100 kg/ha nitrogen applied at either drilling or tillering and there was no difference with time of nitrogen application.

DISCUSSION

Different rainfall patterns in the three year period resulted in contrasting irrigation responses. Low rainfall throughout the 1977-78 growing season restricted the non-irrigated yield to 2200 kg/ha and the response to irrigation at 15% s.m. with nitrogen fertiliser applied was over 200% (4430 kg/ha averaged over the five nitrogen treatments). In the following season, heavier rainfall early in the season and again in mid-season produced a non-irrigated yield of approximately 4000 kg/ha and the response to 15% s.m. irrigation in the presence of N was only 33% (1280 kg/ha). In 1979-80, December rainfall was comparatively low and responses to 15% s.m. irrigation with nitrogen applied were 105% (2620 kg/ha) in 1979-80a and 76% (2040 kg/ha) in 1979-80b. Although total rainfall over the four month growing period in 1979-80 was more than twice that in 1977-78, the difference in yield on the non-irrigated treatment in the two seasons was not very large. This result illustrates the importance of adequate moisture in the critical ear emergence phase, which in these experiments occurred in mid-December.

In the absence of nitrogen, irrigating at the 10% s.m. level was comparable to 15% s.m. irrigation only in the nitrogen-deficient conditions of the ex-crop experiments and in the low irrigation-response 1978-79 experiment. Thompson *et al.*(1974) also found that two irrigations per season (applied at 10% s.m.) had the same effect as more frequent applications when no nitrogen fertiliser was applied.

The nitrogen response, with irrigation, was particularly large in the two ex-crop experiments, indicating that the previous crop reduced mineralisable soil nitrogen to a level insufficient to sustain barley yield. In contrast, mineralisable nitrogen accumulated under pasture was almost sufficient for the barley crop to realize its yield potential under the prevailing conditions of the ex-pasture experiments. Comparing the two ex-crop experiments, the much higher yield in 1977-78 was probably due to a combination of factors. These could include (a) the general fertility of the site, including soil nitrogen, (b) climatic conditions other than rainfall, (c) higher incidence of diseases in the second barley crop, (d) different inter-plant competition for nutrients and light arising from possible differences in tiller production and survival, and (e) difference in previous crop (Malcolm and Thompson, 1968).

Components of yield were not measured in these experiments. However, it is probable that the large response to irrigation in 1977-78 was due to increases in all components. Since irrigation at 15% s.m. did not begin until the second node stage (Feekes, G.S. 7), tiller production would not have been inhibited by moisture stress but tiller survival was probably improved by irrigation. Later irrigations would probably have ensured grain filling at all the grain sites. The 1978-79 season was characterised by low rainfall in the pre-boot phase and again at grain filling (G.S. 11.1-11.2) and high rainfall at ear emergence (G.S. 10. 1-10.5). There was a comparatively small response to irrigation in this season and the high proportion of screenings was an outstanding feature of the results. Although the 10% and 15% s.m. treatments were irrigated at the grain-filling stage, the 10% s.m. treatment had much higher screenings than the 15% s.m. treatment indicating that the former treatment may have suffered some moisture stress as soil moisture approached 10% s.m.

thereby limiting grain development (Aspinall, 1965; Lawlor *et al.,* 1981). Although heavy rain fell early and late in the 1979-80 season, the yield on the non-irrigated treatments was still well below that of the irrigated treatments. The yield component responding most to irrigation during booting and ear emergence was probably grain number as the percentage of screenings was not reduced by frequent irrigation.

The increase in the percentage of screenings with nitrogen fertiliser, even under irrigation, may be associated with increased ear number and grains per ear. Dyson (1977) found that nitrogen fertiliser increased grain number more than it increased grain yield. Both times of application would have ensured adequate nitrogen for maximum tiller development and survival and spikelet initiation, resulting in a large number of grains to be filled. The increase in grain nitrogen content suggests there was a limiting factor other than nitrogen availability which stopped carbohydrate synthesis before the grain was completely filled; thus not only were the screenings increased but the protein which is layed down in early grain development was not diluted by carbohydrate (Harris, 1962). This could also explain the increase in grain nitrogen content when nitrogen fertiliser application was increased from 50 kg to 100 kg/ha. Increase in grain nitrogen content with added nitrogen under irrigation contrasts with the results of similar irrigation and nitrogen fertiliser experiments on spring-sown Karamu wheat (Drewitt, 1979a). In those, grain nitrogen content was also increased by nitrogen fertiliser in the absence of irrigation but with irrigation at 15% s.m., grain nitrogen content was unaffected by nitrogen fertiliser when the wheat followed pasture and decreased by nitrogen fertiliser when following a previous nitrogen-depleting crop.

Malt extract is one of the most important malt quality parameters. Because the main components of malt extract are the products of starch hydrolysis, malt extract is positively correlated with grain size and negatively correlated with grain nitrogen content (Russell and Bishop, 1933). Consequently either an increase in screenings or grain nitrogen content results in a decrease in malt extract.

CONCLUSIONS

High yields of good malting quality barley can be grown under irrigation on the light stony soils in Canterbury. In the presence of adequate nitrogen, irrigation at 15% soil moisture was more effective in raising the yield than irrigation at 10% soil moisture and it may be that a higher level of irrigation may further increase the yield. Under irrigation, nitrogen fertiliser greatly increased the yield without seriously reducing malting quality of barley following a nitrogen-depleting crop. However, nitrogen fertiliser should not be applied to barley crops following pasture as it had little effect on yield but increased the screenings percentage. On the nitrogen-responsive crops, 100 kg/ha of nitrogen was only marginally higher yielding than 50 kg/ha and small differences in yield due to time of nitrogen application and splitting the heavier nitrogen rate were insufficient to cover additional application costs.

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