THE EFFECT OF IRRIGATION ON THE YIELD COMPONENTS AND NITROGEN UPTAKE OF THREE WHEAT CULTIVARS

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SUMMARY

Irrigation was applied to three winter-sown wheat cultivars. Aotea, Arawa and Kopara when soil moisture fell to 10% or 20%. Nitrogen 50 kg/ha was applied at four four-weekly intervals commencing at shoot emergence.

Dry weight of straw, head and grain was increased by irrigation. Nitrogen effects on total plant yield were inconsistent under no irrigation and irrigation at 10%; under irrigation at 20%, nitrogen, greatly increased the dry weight of the total plant. Nitrogen percentage in all parts of the plant was decreased by irrigation and increased by fertilizer nitrogen.

Irrigation increased grain yield on all three cultivars: two irrigations at 10% soil moisture gave the same yield as five irrigations at 20% on Aotea and Kopara, Arawa responded slightly more to the heavier rate. Grain yields of Arawa and Kopara were not significantly different, averaging 2760, 4550 and 4800 kg/ha for non-irrigated, 10% and 20% respectively; Aotea yields were lower at all irrigation levels: 2290, 3610 and 3530 kg/ha respectively. Nitrogen had no effect on grain yield. The number of ears/ha and 1000 grain weight were increased by irrigation on all cultivars.

INTRODUCTION

On the light soils of central Canterbury, wheat yields are affected by low soil moisture conditions at one stage or other in all seasons. The stage at which the moisture stress occurs adversely affects the yield component which is developing at the time, (Robbins and Domingo 1962; Langer 1970). Conversely moisture supplied by irrigation can increase the contribution of certain components depending on the stage of development at the time of irrigation (Storrier 1964). In a series of experiments carried out at the Winchmore Irrigation Research Station, irrigation has given large increases in Aotea wheat yields (Drewitt & Rickard 1971). Of the three main components of yield, number of ears, number of grains per ear and grain weight, only the latter was measured in detail in these experiments. In the work described in the present paper, the number of ears per hectare and the grain weight were measured for three cultivars, Aotea, Arawa and Kopara grown without irrigation and at two irrigation levels. Nitrogenous fertilizer was applied at different times.

EXPERIMENTAL DETAILS

The experiment was carried out on Lismore stony silt loam as a first cereal crop following five years in irrigated pasture. Soil text analysis of the top 150 mm at the time of drilling was pH 5.8, Ca 6, K 6, P 7. Wheat cultivars were drilled on 28 July 1971; superphosphate 250 kg/ha was applied with the seed. Nitrogen in the form of ammonium sulphate was applied at the rate of 50 kg/ha (of nitrogen) at four-weekly intervals commencing at shoot emergence. Irrigation was applied by the border-strip method when soil moisture in the top 150 mm fell to 10% or 20%. The experiment was a split-split-plot design with main plots – irrigation (three treatments) 50m x 9m; split-plots-cultivars (3) 50 m x 3 m and split-split-plots – nitrogen (5) 10 m x 3 m. There were six replicates giving a total of 270 plots.

Grain yield and grain weight are expressed on a 12% moisture base on samples retained on A5.5 screen. Ear counts were made on samples drawn from two 1.22 m x 0.35 m quadrats per plot at the time of harvest.

The number of grains per ear were calculated from the grain yield, grain weight and number of ears. Broken and shrivelled grains were discarded and all comments therefore refer to grain suitable for milling.

The total above-ground crop was sampled six times between late September and harvest, and for the last three of these samplings the contribution of ear and stalk plus leaf was determined.

RESULTS

Dry-matter yield

In the present paper, the final sampling only will be discussed.

Irrigation greatly increased the total botanical yield of wheat, as shown in Table 1.

TABLE 1. Dry-matter yields (kg/ha)

	NI	10%	20%
Total plant	6930	11070	12190
	cC	bB	aA
Straw	3340	5350	6590
	cC	bB	aA
Ear	3590	5720	5600
	bB	aA	aA

This effect was the same for the three cultivars. Irrigation at 10% increased both the straw and ear component by 60%; irrigation at 20% increased the straw component by a further 10%, but decreased the percentage of ear slightly.

The relative contributions of straw, chaff (ear less millable grain) and grain to the total plant are shown in Table 2.

The difference in the percentage of grain and the percentage of straw between no-irrigation and irrigation at 10% was very slight, except in the case of Kopara where the percentage of grain was higher on the 10% than on the non-irrigated.

Irrigation at 20% increased the percentage of straw on all cultivars and decreased the percentage of grain on Aotea and Arawa.

In the absence of irrigation and also at the 10% irrigation treatment nitrogen applications had no consistent effect on the total plant yield, or on either the straw or ear yields.

At the 20% level of irrigation, there was a 1% significant response in total plant weight to nitrogen applied at shoot emergence, and a 5% response to the 4 and 8 weeks applications. The two earliest applications increased the percentage of straw slightly, the later two had no effect (Table 3).

TABLE 2. Components of dry matter yield in kg/ha and as a percentage of the total plant.

	Total Plant kg/ha	%	Straw kg/ha	%	Chaff kg/ha	%	Grain kg/ha	%
Aotea								
NI	6590	100.0	3430	52.0	1140	17.3	2020	30.7
10%	10650	100.0	5500	51.7	1970	18.5	3180	29.8
20%	11200	100.0	6430	57.4	1660	14.8	3110	27.8
Arawa								
NI	7190	100.0	3390	47.1	1300	18.1	2500	34.8
10%	11600	100.0	5680	49.0	1960	16.9	3960	34.1
20%	13130	100.0	7130	54.3	1690	12.9	4310	32.8
Kopara								
NI	7000	99.9	3200	45.7	1430	20.4	2370	33.8
10%	10960	99.9	4870	44.4	2030	18.5	4060	37.0
20%	12230	100.0	6200	50.7	1880	15.4	4150	33.9

TABLE 3. Dry-matter yields (kg/ha) at 20% irrigation

	Total plant	Straw	Ear
No Nitrogen	11310 cB	6050 dB	5260 bB
N at shoot emergence	12950 aA	7140 aA	5810 aA
N at 4 weeks after emergence	12480 abAB	6910 abA	5580 abAB
N at 8 weeks	12420 abAB	6610 bcAB	5810 aA
N at 12 weeks after emergence	11770 bcAB	6250 cB	5520 abAB

There were no interactions between cultivars and nitrogen treatments.

Nitrogen concentration

Analysis of samples taken throughout the growing season (data not given in the present paper), showed that there was a rapid drop in nitrogen percentage in the total plant from early tillering to ear emergence (about the end of November) and a very slow further decrease from then until harvest. This latter decrease tended to be accentuated by irrigation, mainly because of a reduction in the nitrogen concentration in the ear, compared to the increase that occurs without irrigation.

The main effects of irrigation on the nitrogen percentage of the various plant fractions are shown in Table 4.

TABLE 4. Nitrogen percentage

	NI	10%	20%
Total plant	1.53	1.28	0.99
	aA	bB	cC
Straw	0.53	0.58	0.44
	aA	aA	bB
	2.46	1.92	1.63
Ear	aA	bB	cC

The nitrogen percentage in the total plant was significantly reduced by irrigation. The nitrogen percentage of the straw plus chaff was affected to a lesser extent – there was no significant difference between the non-irrigated and the 10% treatment, and a small (but significant) difference between these treatments and the 20%. By contrast, the greatest drop in the nitrogen percentage of the grain, occured between the non-irrigated and the 10%, with the 20% treatment producing a lesser – although still significant – further reduction.

The only significant interaction between cultivar and irrigation occured with the grain, and the differences in nitrogen % between cultivars decreased with increasing irrigation: (Table 5).

TABLE 5. Nitrogen percentage in the grain

	NI	10%	20%
Aotea	2.95 aA	2.07 bA	1.74 a
	aA	bB	cC
Arawa	2.90 aA	2.20 aA	1.81 a
	aA	bB	cC
Kopara	2.74 bB	2.16 abA	1.73 a
	aA	bB	cC

Application of nitrogen increased the nitrogen percentage of all parts of the plant, and although there were no consistent differences between times of application there was a tendency for the earlier applications to have more effect. (Table 6).

TABLE 6. Nitrogen percentage

	No N	Shoot	+4	+8	+12
Straw and Chaff	0.69	0.81	0.82	0.78	0.75
	bB	aA	aA	aA	abAB
Grain	2.06	2.35	2.30	2.27	2.29
	cB	aA	abA	bA	abA

The only interaction between nitrogen application and irrigation level occurred in the grain as shown in Table 7. In the absence of irrigation, nitrogen applied at all but the last application gave a highly significant increase in nitrogen percentage. At the 10% level, all nitrogen applications gave significant responses in nitrogen percentage; at the 20% level, only the first and last applications produced a significant difference in grain percentage nitrogen. The extent of the increase in nitrogen percentage due to the application of nitrogen tended to decrease with increasing irrigation.

TABLE 7. Nitrogen percentage, Grain

	NI	10%	20%
No N	2.62 dC	1.92 bB	1.63 cB
	aA	bB	cC
Shoot	3.04 aA	2.21 aA	1.80 abA
	aA	bB	cC
+ 4 weeks	2.97 abA	2.19 aA	1.75 bAB
	aA	bB	cC
+ 8 weeks	2.91 bAB	2.16 aA	1.75 bAB
	aA	bB	cC
+ 12 weeks	2.78 cC	2.23 aA	1.86 aA
	aA	bB	cC

Nitrogen Uptake

The greatest uptake of nitrogen occured on the 10% irrigation treatment (Table 8).

TABLE 8. Nitrogen uptake (kg/ha)

	NI	10%	20%
Total plant	105.7	141.3	120.6
	aC	aA	bB
Straw	17.9	31.3	29.4
	bB	aA	aA
Ear	87.8	110.0	91.2
	bB	aA	bB
Straw and Chaff	40.4	61.2	52.8
	cB	aA	bA
Grain	65.4	80.1	67.9
	bB	aA	bB

Most of the nitrogen in the total plant is contained in the grain, although the relative proportion decreases with irrigation.

All nitrogen applications significantly increased the nitrogen uptake in the total plant (Table 9) but the time of application had no effect.

TABLE 9. Nitrogen uptake (kg/ha)

No N	Shoot	+ 4 weeks	+ 8 weeks	+ 12 weeks
109.1	126.6	127.7	123.4	126.0
bB	aA	aA	aAB	aA

For the straw plus chaff the earlier nitrogen applications had the greater effect, but for the grain the latest application gave significantly higher uptake than the earlier (Table 10).

TABLE 10. Nitrogen uptake, (kg/ha)

	No N	Shoot	+ 4	+ 8	+ 12
Straw and Chaff	43.6	55.7	56.5	50.8	50.7
	bB	aA	aA	aAB	aAB
Grain	65.6	70.9	71.2	72.6	75.3
	cC	bB	bB	bAB	aA

Grain yield

Irrigation at 10% significantly increased the grain yield of all three cultivars; irrigation at 20% did not give any further increase for Aotea or Kopara, but did give an increase, significant at the 5% level for Arawa. Yields of both Arawa and Kopara were considerably higher than Aotea.

TABLE 11. Grain yield (kg/ha)

	NI	10%	20%
Aotea	2290 bB	3610 bB	3530 bB
	bB	aA	aA
Arawa	2840 aA	4500 aA	4900 aA
	cB	bA	aA
Kopara	2690 aA	4610 aA	4710 aA
	bB	aA	aA

Nitrogen had no significant effect on grain yield, regardless of the time of application. There were no significant interactions between nitrogen application and irrigation, or between nitrogen and cultivar.

Components of yield

Components of grain yield are shown in the following table:

TABLE 12. Yield components of grain

Cultivar	Irrigation	Ears/ha x 1000	Grains/ear	Wt. 1000 Grains
Aotea	NI	4340 bB	16.5 bB	32.3 bB
	10%	5480 aA	20.0 aA	33.1 bB
	20%	5580 aA	17.8 bAB	36.4 aA
Arawa	NI	3190 bB	24.1 bB	37.2 bB
	10%	4420 aA	24.4 bB	42.1 aA
	20%	4220 aA	27.9 aA	42.3 aA
Kopara	NI	3890 bB	22.0 bB	31.8 bB
	10%	4780 aA	26.2 aA	36.7 aA
	20%	4790 aA	26.6 aA	37.5 aA

Irrigation at 10% increased the number of ears per hectare on all cultivars; irrigation at 20% had no further effect. Although the main effect of irrigation was to increase the number of grains per ear, the situation was different for the three cultivars: this point will be discussed later.

With the exception of the 10% treatment on Aotea, irrigation significantly increased the grain weight. The two early nitrogen applications increased the number of ears per hectare, but reduced both the number of grains per ear and the grain weight. The net result was that nitrogen had no effect on final grain yield.

DISCUSSION

As grain weight was measured only on grain of millable size, and the number of grains per ear was calculated on this basis, the results given above are not an exact representation of yield components as influenced by moisture stress. Although no information on total number of grains was available, it is the yield of millable grain which is of greatest concern to the wheat grower.

No measure of plant stress was available, but there is little doubt that the non-irrigated plants were stressed from the commencement of heading (Feekes 10.2) until the mealy ripe stage (Feekes 11.2). With the exception of grain/ear on Aotea, all components were significantly reduced on the non-irrigated treatment.

It is also probable that, at certain times, the 10% treatments were also stressed, and although arbitrary definitions of stress can be made on the basis of soil moisture levels, such an approach is not likely to explain all the results obtained. It is probable that similar soil moisture conditions at different growth stages can result in different stress levels in the plant, or that different cultivars will respond differently to imposed stress conditions.

Irrigation at 20%

If it is assumed that none of the cultivars suffered from stress on the 20% irrigation treatment, then the response to this level of irrigation was due to highly significant responses in all yield components, with the exception of number of grains/ear on Aotea.

For Kopara, the yield response was caused almost equally by increases in the three yield components, with increases in the number of ears/hectare being the most important.

For Arawa, the yield response was caused mainly by an increase in the number of ears/hectare (approximately half the response) with increases in the number of grains/ear and the grain weight being of about equal importance.

For Aotea, the increase in ears/hectare was again the largest contributing factor to the increased yield, the increase in grain weight was of less importance, and the effect on number of grains/ear was not significant.

Irrigation at 10%

At the 10% level of irrigation, the increase in yield on Kopara (over non-irrigated) was again caused almost equally by increases in the three components, in almost exactly the same proportion as occurred with the heavier rate of irrigation. It seems likely that this cultivar did not suffer from stress at any stage on this treatment.

For Arawa, however, the yield increase was mainly due to an increase in the number of ears/hectare. There was no difference in the number of grains/ear between the non-irrigated and the 10% treatment, indicating that this cultivar probably suffered from stress during spikelet formation (booting).

For Aotea, the increase in grain yield was the result almost equally of an increase in the number of ears/hectare and the number of grains/ear. There was no increase in grain weight, which would indicate that this later-maturing cultivar suffered some stress during the milk or mealy-ripe stage.

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