COMPARATIVE RESPONSES TO IRRIGATION OF FIVE WHEAT CULTIVARS

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ABSTRACT

As a preliminary to breeding wheat cultivars suitable for irrigation farming, it is necessary to test established and new ones for relative responses to irrigation. An experiment is described in which five wheat cultivars were compared at three irrigation levels. Kopara-73 and Aotea, which were winter-sown, significantly outyielded the three spring-sown cultivars; among these Gamenya was intermediate in yield between the wheats bred in Mexico for irrigation, Karamu and Matipo. However, while these latter three cultivars all gave large positive responses to irrigation, Kopara-73 gave only a small response and Aotea none. Analyses of yield components showed that irrigation affected ear numbers and grain weights, but not grains per ear. Irrigation increased straw yield to a greater extent than grain yield. The yield differences among cultivars were mainly caused by variations in ear numbers and grain numbers per ear. The value and limitations of this type of experiment are briefly discussed in the light of the variations observed among cultivars and their responses to irrigation.

INTRODUCTION

The aim of plant breeding is to provide the farming industry with crop cultivars which can be fitted into farming systems so that their genetic potential for producing economic yield can be fully exploited. Many existing cultivars have been bred and selected under dryland conditions so that, although they are increasingly being grown under irrigation, they do not necessarily possess any great inherent capacity to respond to it in all situations. It will therefore become necessary to devote more effort to breeding crop cultivars specifically for irrigation. In the interim some benefit is likely to arise from testing the responses of existing cultivars so that those which are most capable of giving yield and quality responses can be used under irrigated conditions. Testing such as this will give an indication of a cultivar's potential under a known range of conditions and, more importantly, it will indicate cultivar variation in response to irrigation.

Although the yield of wheat in Canterbury is commonly limited by a lack of water, responses to irrigation are variable (Dougherty & Langer 1974; Drewitt 1974). Variations among seasons, sites, soil types and cultivars cause this particularly the amount of soil water available, the water requirement of each cultivar, and the times of rainfall or irrigation relative to the most stress sensitive stages of plant development.

In the experiment described here, the performances of five wheat cultivars were compared without irrigation and at three levels of irrigation. A good indication of variation among the cultivars was gained, because the other factors noted to cause variation in response to irrigation were not operating. The irrigation treatments used to reduce plant water stress were chosen on the basis of previous work describing the most sensitive stages of wheat reproductive development (Langer & Ampong 1970; Salter & Goode 1967).

MATERIAL AND METHODS

A factorial experiment comprising four levels of irrigation and five wheat cultivars was laid down as a split-plot design on a Templeton silt loam soil at Lincoln. All cultivars were drilled in 15 cm rows at the rate of 110 kg/ha in three blocks of twenty 20 m x 1.5 m plots. Aotea and Kopara-73 were drilled on 22 May 1973 while the faster developing Gamenya, Karamu, and Matipo were drilled on 28 August 1973. Superphosphate was broadcast at 300 kg/ha and incorporated before drilling. This was the second successive cereal crop on the experimental site after 5 years in lucerne. In irrigated plots a trickle system was used to apply the following treatments.

- W1: No irrigation.
- W2: Irrigated to field capacity once, on 7 November 1973, during spikelet differentiation.
- W3: Irrigated to field capacity twice, on 7 November and again during early grain filling on 5 December 1973.
- W4: Irrigated six times to maintain soil water potential above -0.8 bar. This was measured at 25 cm depth both gravimetrically and with tensiometers.

Tillers were counted four times during growth, and survival of fertile tillers to maturity was compared among treatments. Before combine harvesting, two 0.25 sq m quadrats per plot were cut to ground level and dried to constant weight. These were threshed and grain and straw weights, corrected to 13% moisture content, were obtained. Subsamples of 1000 grains from each plot were counted and weighed. A random sample of 10 ears was taken from plot and numbers of spikelets, grains per spikelet, and grains per ear were counted. Combine yields were determined by direct heading each plot after the perimeters had been trimmed and discarded.

TABLE 1: Evaporation and rainfall data recorded at Lincoln College

Month	Averages from 1968-69 to 1972-73 Class A Pan Evaporation (mm)	Rainfall (mm)	1973-74 Class A Pan Evaporation (mm)	Rainfall (mm)
August	42.6	24.8	31.4	149.0
September	95.7	29.8	84.5	37.9
October	137.8	43.4	128.6	19.6
November	173.1	39.2	173.5	38.2
December	182.9	44.2	197.6	58.4
January	205.1	47.8	183.2	29.2
Total	837.2	229.2	798.8	332.3

RESULTS AND DISCUSSION

Data from the Lincoln College meteorological station (Table 1) show that because total evaporation from August 1973 to January 1974 was lower, and total rainfall was higher than the averages of the corresponding periods in the preceding five seasons, the evaporation-rainfall deficit for the 1973-74 season was considerably lower than the five-season average. However, regardless of this overall difference, the variations among seasons in patterns of rainfall and high evaporative demand in relation to stages of crop development are very important. In this experiment the W2 and W3 irrigation treatments were applied on 7 November on a stage of growth criterion. Evaporation on the preceding 3 days and the following 3 days was low after 10 mm of rain on 3 November and traces of rain on 4 and 6 November. These coinciding dates of probably low plant water stress and treatment application may account for the poor responses to this treatment. In contrast, the second W3 irrigation, which caused significant yield increases, coincided with a period of high evaporative demand and no rainfall.

Irrigation increased the grain yield of all cultivars (not significantly for Aotea) but the extent of their responses and the amounts of irrigations they required varied (Table 2). All but Aotea responded significantly to the W4 treatment and all benefited from two irrigations (W3 treatment), though the yield increase was significant only for Karamu and Gamenya. Even without irrigation, Kopara-73 and Aotea outyielded the irrigated plots of the other cultivars. Of the others, Karamu outyielded Gamenya which in turn was superior to Matipo. To explain these variations the yield components and their constituents under the different treatments were individually examined and analysed.

TABLE 2: Combine grain yields and significant responses to irrigation

Irrigation Treatment	Grain yields (Kg/ha) Kopara	Aotea	Karamu	Gamenya	Matipo	Mean
W4	6060 aA	5020 aA	3650 aA	3210 aA	2870 aA	4160 aA
W3	5220 bA	5390 aA	3260 aA	2540 bB	2160 bA	3625 bB
W2	4980 bA	4960 aA	2315 bB	2435 bcB	1975 bA	3350 cBC
W1	4775 bA	4720 aA	2170 bB	2085 cB	1835 bA	3185 cC
Mean	5260 aA	5025 aA	2850 bB	2570 cBC	2210 dC	

There were no treatment differences in numbers of plants when they were 10 cm tall so all later variations in tiller numbers were treatment effects. Subsequently, numbers of tillers at three stages of growth and numbers of ears at maturity varied with cultivars and irrigation treatments (Table 3). Treatments were not applied early

TABLE 3: Tiller numbers at four sampling times

Treatment	Tillers per m² When plants 20 cm tall	Just before* ear emergence	14 days after ear emergence	Mature tillers at harvest
W4	504 aA	480 a A	480 a A	456 aA
W3	456 aA	432 bB	492 aA	408 abAB
W2	468 aA	420 bB	468 aA	384 bcB
W1	468 aA	432 bB	420 bB	360 cb
Aotea	732 aA	672 aA	576 aA	540 aA
Kopara	648 bA	552 bB	456 bB	432 bB
Karamu	360 cB	360 cC	444 bB	372 cBC
Matipo	348 cB	340 cC	384 cB	300 dC
Gamenya	324 cB	328 cC	456 bB	336 cdC

* Only W4 treatment applied by this stage

enough to affect tiller production although previous evidence indicates that tillering can be increased by irrigation (Salter and Goode 1967), but more tillers survived in irrigated plots. However their superiority, shown at the third count, was less marked at harvest because they were supporting greater proportions of infertile tillers.

Aotea and Kopara-73 produced more tillers than the other cultivars early in growth (Table 3) and this superiority was retained until maturity. However, they had high tiller mortalities during growth while the losses in Karamu, Gamenya and Matipo were relatively low. This suggests that, in this situation, tiller production did not limit the yields of Aotea or Kopara-73; they produced many tillers early in growth due to either their earlier sowing date and/or a high genetic capacity for tiller production. Conversely, the spring-sown cultivars produced fewer tillers initially and relatively few deaths occured probably because most of them were low order tillers and competition among them was low. It therefore seems likely that the yields of the spring-sown cultivars may have been limited by low tiller populations; these plots probably could have supported more fertile tillers. An irrigation at tillering may have been beneficial but it is possible that there may be a genetic limitation; in that case a cultural change, such as increased sowing rate or autumn sowing, could be used to increase tiller numbers and their contribution to yield.

TABLE 4: Grain weight responses to irrigation

Irrigation Treatment	1000 grain weight (gms)
W4	45.7 aA
W3	44.5 bAB
W1	43.8 bcB
W2	43.4 cB

Thousand-grain weights were highest under the W4 irrigation treatment while W3 caused a significant increase over W2 (Table 4). It is likely, in the light of previous work (Wilson 1972) and from observation but not measurement in this experiment, that the W4 treatment delayed leaf senescence, thus increasing grain weights by allowing assimilate movement to the grains to continue longer (Welbank **et al.** 1966). The W2 and W3 treatments probably increased leaf area (Wilson 1972), thus increasing water use and advancing the cessation of photosynthesis and onset of senescence. However, while the second watering in the W3 treatment delayed this, the W2 treatment became stressed so that its final thousand grain weight was less than that of W3.

Since there were no grain weight differences among cultivars, this factor had no great bearing on the yield variations.

TABLE 5: Cultivar variation in ear components contributing to yield

Cultivar	Spikelets per ear	Grains per spikelet	Grains per ear
Kopara	20.1 aA	2.4 bBC	47.4 aA
Matipo	15.1 cC	2.8 aAB	42.3 abAB
Aotea	17.8 bB	1.9 cC	35.5 cC
Karamu	13.9 dC	2.9 aA	39.8 baBC
Gamenya	14.1 dC	2.7 aAB	38.4 bcBC

It was surprising that grain numbers per ear did not respond to irrigation because others have found that water stress affected both spikelets per ear and grains per spikelet (Langer and Ampong 1970; Salter and Goode 1967). In this experiment, either the plants were not stressed at the critical stages of development or they were all equally stressed due to wrongly timed waterings. However there was variation among cultivars in their grains per ear components (Table 5), the spring-sown cultivars producing fewer spikelets but more grains per spikelet than Kopara-73 and Aotea. Within each cultivar there may not have been much scope for improvement in grain numbers per ear because of the plasticity between these two components.

From the quadrat samples, grain, straw and total sample weights were increased significantly by irrigation but because the relative contributions of grain and straw changed, the harvest index was depressed by all treatments (Table 6). Since quadrat yield was positively correlated with whole plot yield ($r = +0.95^{**}$), the samples were reasonably representative of the whole plot trends. A cultivar comparison (Table 6) showed that although grain and straw weights from Kopara-73 and Aotea were highest, Karamu and Matipo had the highest harvest indices indicating that their economic yields were more efficiently produced.

TABLE 6: Influence of treatments on grain, straw, and total yields and harvest indices from quadrat samples

Treatment	Grain yield (g/m^2)	Straw yield (g/m^2)	Total yield (g/m^2)	Harvest index
W4	776 aA	1324 aA	2100 aA	0.39 bB
W3	672 abAB	1176 bB	1848 bB	0.38 bB
W2	624 bAB	1144 bB	1768 bB	0.39 bB
W1	572 bB	944 cC	1516 cC	0.42 aA
Kopara	1008 aA	1868 aA	2876 aA	0.37 bB
Aotea	908 bA	1876 aA	2748 aA	0.33 cB
Karamu	528 cB	704 bB	1232 bB	0.46 aA
Gamenya	412 dB	716 bB	1128 bcB	0.36 bB
Matipo	452 cdB	572 cB	1024 cB	0.45 aA

The most important aspect of these results was the variability among cultivars both in their responses to irrigation and the structure of their yield components. Among cultivars the differences in distribution of the component contributions to grain yield were obvious. However, the causes of the variable responses to irrigation were difficult to isolate, even between winter-sown and spring-sown cultivars. While grain yields showed a significant (p 0.01) cultivar x irrigation interaction, this did not occur for any of the yield components. The overall yield differences were therefore caused by combinations of small differences among components. The components which did change with irrigation (ear numbers and grain weights) were apparent but, because of the plasticity which exists among the yield determining components, the analyses did not reveal any significant differences in their relative changes for each cultivar. Therefore in this respect the experiment failed to achieve its designed purpose.

In the trial the five cultivars were sown and cultured as they would be in normal farming practice. To suit the chosen cultivars this included two sowing dates and a major complicating factor was thus introducted. Better comparisons would have resulted had all cultivars been sown at each date. As circumstances prevented this we really had comparisons between winter-sown and spring-sown cultivars and among cultivars within these groups.

Each cultivar has its unique genetic make-up which defines its growth characteristics and the response of these to environmental changes. Among wheat cultivars there is variation in type and range of response. Because these results apply to only one site and season it can be assumed that they mainly reflect the individual characteristics of each cultivar. Therefore further similar evaluations over a number of sites and seasons would mainly explore the ranges of response of each characteristic for each cultivar.

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