MAXIMUM WHEAT PRODUCTION UNDER IRRIGATION

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INTRODUCTION

This paper is a review of 14 years experience of irrigating wheat on the light stony soils at Winchmore. Naturally, over such a long period there have been some contrasting results, but I will summarise the results of our trials and where possible, make suggestions for obtaining the maximum benefit from irrigation. Significant grain yield responses to irrigation have been recorded in all seasons, except 1976-77, since the trials began in 1966, so I do not need to spend time expounding the virtues of irrigation on the light soils of Canterbury.

Some general information about the trials is necessary before discussing the results

- * When phosphate was not a factor in the trials, superphosphate was applied at the rate of 150-250 kg per ha.

- * Work in 1968-69 indicated that potassium was not involved in irrigation responses and potassic fertiliser was not generally used unless the soil potash level was low.

* Nitrogen was a factor in many trials and was invariably applied in the form of ammonium sulphate.

* Seed rates were in the 100-150 kg per ha range for winter sowing, slightly higher for spring sowing.

* Irrigation by the border-strip method was applied to all trials according to the soil moisture level in the top 150 mm of soil. Two levels of soil moisture, 10% and 15%, have been used throughout the series; these levels normally equate to wilting point and 25% available soil moisture respectively. Heavier rates have been employed from time to time and in many instances irrigation treatments have been coupled with stage of growth. Early work showed that irrigation after the soft dough stage was not beneficial.

Two very important aspects emerged early in our trials and they have remained unchanged by time.

* Irrigation requirements of winter-sown and spring-sown wheat are different.

* Yield responses to irrigation are influenced by fertility, both natural and artificial, especially nitrogen.

Winter wheat requires less frequent irrigation than spring wheat for two main reasons. Firstly, winter-sown wheat has a larger and more widely developed root system and therefore the ability to exploit a larger area of soil from which to draw moisture. Secondly, in winter-sown wheat the most acute moisture sensitive phase in the development of the plant, the shooting/ear emergence phase, occurs earlier in the season when the temperature is cooler.

The effectiveness of irrigation is greatly reduced by a shortage of available nitrogen. Because of their low natural fertility the light stony soils are frequently incapable of supplying nitrogen quickly enough to satisfy the plants requirement, especially of fast growing spring-sown crops. Where supplementary nitrogen is required the timing of application determines the level of irrigation response and the efficiency of different rates of irrigation.

IRRIGATION RESPONSES IN WINTER-SOWN WHEAT

One irrigation when soil moisture falls to 10% is the most effective irrigation treatment for winter-sown wheat; the small additional response to more frequent irrigation does not normally justify the extra effort and cost involved.

The mean results of a six year series of trials from 1967-68 to 1972-73 using Aotea were as follows:

TABLE 1. GRAIN YIELD, KG/HA

No irrigation	2,590
Irrigated at 10% sm until flowering	3,840
Irrigated at 15% sm until maturity	4,100

In five of the six years only one irrigation was required on the 10% soil moisture treatment whereas the 15% soil moisture treatment required an average of three irrigations (Drewitt, 1974). An analysis carried out on four of the above trials showed that grain yield was influenced more by soil moisture conditions at ear emergence than at any other growth stage (Drewitt and Rickard, 1971).

After Kopara had been introduced in the early 1970's, five trials were carried out comparing it with Aotea. Kopara generally outyielded Aotea under good fertility conditions but the response to irrigation was similar.

Nitrogen and irrigation interdependence

In winter-sown trials following a period in pasture there was no response to fertiliser nitrogen at any irrigation level and the responses to different irrigation treatments did not vary with nitrogen application. In other words, there was sufficient nitrogen in the soil to satisfy the plant's requirement at all irrigation levels (Drewitt and Rickard, 1971). However, in crops grown under low fertility conditions the response to irrigation may be improved by the addition of fertiliser nitrogen. The following result is an example of the fertiliser nitrogen and irrigation interaction on the yield of Aotea wheat.

TABLE 2. GRAIN YIELD KG/HA

	No irrigation	*Irrigated at 10% sm (1 irrigation)*	*Irrigated at 15% sm (3 irrigations)*
No nitrogen	2,670	3,090	3,020
50 kg/ha N at tillering	3,140	3,980	4,440

In the absence of nitrogen, one irrigation increased the yield by 420 kg per ha and there was no further increase with three irrigations. In the presence of nitrogen at tillering the response to one irrigation was 840 kg per ha and there was a further marginal response of 460 kg per ha with three irrigations.

Summary

To sum up the position with winter-sown wheat, our earlier recommendation to apply one irrigation at 10% soil moisture is still the best we can offer. Any further irrigation is not generally necessary and I will show later why irrigating excessively should be avoided. In nitrogen-responsive crops nitrogen applied at the tillering stage will improve the yield response to irrigation.

Measuring soil moisture

Most growers do not have the facilities for measuring soil moisture; therefore, stage of growth, or a calendar date are more useful standards for timing irrigation.

For winter wheat on the light soils in low rainfall areas in Canterbury 10% soil moisture is usually reached at the booting/ear emergence stage and in most years this occurs in early to mid November. There will of course be exceptions to this general rule; for instance, a prolonged dry spell in October will advance the onset of booting and similarly, hot dry conditions in November-December may mean that a second irrigation is required. Also, unpredictable rain may cancel out the advantage of irrigation. Following the recommendation outlined above may occasionally lead to a small loss of potential yield but I believe the advantage of being able to plan an irrigation schedule well ahead more than compensates for any loss of yield.

IRRIGATION RESPONSES IN SPRING-SOWN WHEAT

Spring sown wheat requires more frequent irrigation than winter sown wheat to achieve its maximum yield. Two irrigations are needed in most years; any additional response to heavier irrigation is largely dependent on the fertility status of the soil.

In the past our recommendation for spring wheat has varied between irrigating at high (Drewitt, 1974) and low (Drewitt, 1979a, 1979b) soil moisture levels. The key factor regulating the yield response to irrigation in spring wheat is again nitrogen, perhaps even more so than in winter wheat.

Nitrogen and interdependence

In a series of five trials with Karamu in which nitrogen was applied at drilling, four irrigations at 15% soil moisture were little more productive than two irrigations at 10% soil moisture (Drewitt, 1979b).

TABLE 3. MEAN GRAIN YIELD, KG/HA. (1974-75 1975-76)

No irrigation	*Irrigated at 10% sm (2 irrigations)*	*Irriated at 15% sm (4 irrigations)*
2,550	3,880	4,070

When nitrogen was applied a little later, at shoot emergence, the difference between the two irrigated treatments was still not significant (Drewitt, 1979a). However, when nitrogen was applied at later growth stages in another trial the balance between the irrigated treatments tipped in favour of the heavier irrigation rate. (Table 4).

This trial followed a crop of oilseed rape and before that the area was in pasture for several years. The site was reasonably fertile for a second crop on light stony soil.

TABLE 4. GRAIN YIELD, KG/HA. (1977-78)

	No irrigation	*Irrigated at 10% sm (2 irrigations)*	*Irrigated at 15% sm (4 irrigations)*
No nitrogen	1,890	3,150	3,770
50 kg/ha N at drilling	1,770	3,700	4,320
50 kg/ha N at tillering	1,960	3,650	4,960
50 kg/ha N at booting	1,860	3,310	4,610

There was a large yield response to both irrigated treatments but the difference between them varied according to the time at which nitrogen was applied. In the absence of nitrogen and also with nitrogen at drilling the additional response to the heavier rate was 620 kg per ha whereas when nitrogen was applied at tillering and at booting the additional response was 1,300 kg per ha. The most productive treatment in this trial was the combination of nitrogen at tillering and irrigation at 15% soil moisture. Assuming that most growers on the light soil would apply some fertiliser nitrogen to spring-sown wheat following a non-leguminous crop the decisions regarding the timing of nitrogen application and the level of irrigation should be made concurrently.

Timing of irrigation

It is rather more difficult to be precise about the best irrigation treatment for spring wheat than it is for winter wheat. Under good fertility conditions, or where fertiliser nitrogen is applied at drilling to poorer fertility crops, irrigating at 10% soil moisture will provide an excellent return in most years; however if nitrogen is applied at tillering, irrigating at a higher level is likely to be more beneficial. At the 10% soil moisture level two irrigations are normally required, one at booting or ear emergence, in mid to late November and one at the milk stage in mid to late December. At 15% soil moisture, irrigation begins in mid November and continues at two to three week intervals until the soft dough stage in early January.

Nitrate level tests

Since the yield response to irrigation is so dependent on nitrogen there is obviously a need for a reliable method of determining the availability of nitrogen to wheat crops on the light soil similar to that evolved by Ludecke (1974) for the heavier soils. On the light shallow soils, soil nitrogen reserves are low and a single soil nitrate test in early spring is inadequate for predicting the response to fertiliser nitrogen. A measure of soil organic nitrogen and the rate at which nitrogen becomes available to the plant would be a more useful guide for estimating the fertiliser nitrogen requirement. Techniques for developing a simplified test are being examined at Winchmore.

EFFECT OF IRRIGATION ON YIELD COMPONENTS

The increased yield with irrigation may be due to an increase in

* The number of ears harvested.

* The number of spikelets per ear.

* The number of grains per spikelet.

* Grain weight.

* A combination of any of the components.

On the other hand, one component may be improved at the expense of another; the compensatory behaviour of the components is complex. However, the effects of nitrogen and irrigation on the development of the various components have been graphically illustrated by Langer (1978) who found that on the heavier soils the number of grains produced per unit area is closely related to yield. The number of ears was the most important component, followed by the number of grains per spikelet; grain weight was relatively unimportant except in very dry years when pinched grain may result.

Nitrogen and irrigation interdependence

An examination of the yield components in our trials shows that irrigation responses have been due to a variety of component reactions and once again we have to consider irrigation and nitrogen together.

Under fertile conditions the yield response to irrigation in a winter-sown trial was due to increases in all the components (Drewitt and Rickard, 1973). In two later trials under poorer fertility the response was due almost entirely to increased grain weight with only very small increments in the other components. The probable explanation for this result is that a shortage of nitrogen inhibited an irrigation effect on the number of grains and the apparent increase in grain weight was in fact a measure of restricted grain filling in the absence of irrigation.

In the series of five spring-sown trials referred to earlier in which fertiliser nitrogen was applied at drilling there was a very close relationship between grain weight and grain yield (Drewitt, 1979b). A full yield composition analysis was carried out on two of these trials, one following pasture, the other following a previous wheat crop, both in the same season. In Table 5, fertiliser nitrogen was applied at shoot emergence.

TABLE 5. YIELD COMPOSITION AS AFFECTED BY EARLIER LAND USE

	Ex Pasture			*Ex Wheat*		
	Grain yield kg/ha	*Ears/m²*	*Grain wt mg*	*Grain yield kg/ha*	*Ears/m²*	*Grain wt mg*
No irrigation	3180	354	30.7	3090	311	33.5
Irrigated at 10% sm	4380	342	43.0	4060	331	43.1
Irrigated at 15% sm	4850	412	43.0	4260	331	46.3

The most substantial contribution to the irrigation response came from increased grain weight; small variations in the number of spikelets per ear and grains per spikelet had little or no effect on grain yield (Drewitt, 1979a). An increase in the number of ears harvested provided the extra response to the heavier irrigation treatment on the more fertile plots, indicating better tiller survival, probably due to earlier rather than more frequent irrigation at 15% soil moisture.

We have already seen that the combination of fertiliser nitrogen applied at tillering and irrigation at 15% soil moisture was the highest yielding treatment in a spring-sown trial in 1977-78. Why was the 15% soil moisture treatment so much more productive than the 10% at this time of nitrogen application? If we examine the yield structure we find that an increase in the number of ears made a significant contribution to the irrigation response while grain weight played a relatively minor role:

TABLE 6. YIELD STRUCTURE IN SPRING SOWN TRIAL

	Ears/m²	*Spikelets/ear*	*Grains/spikelet*	*Grain weight mg*
No irrigation	402	9.00	1.98	36.7
Irrigated at 10% sm	585	8.26	2.11	41.4
Irrigated at 15% sm	563	10.61	2.61	41.1

Both irrigated treatments produced almost the same number of ears and identical grain weight, so the yield discrepancy between these two treatments was entirely due to the other components; 15% irrigation produced 28% more spikelets per ear and 24% more grains per spikelet. These figures suggest that the 15% treatment enjoyed more favourable soil moisture conditions than the 10% at the time these two components were developing.

It would be impossible in a paper of this nature to discuss all the ramifications of yield structure. These few examples, drawn from a long list of trial results, have been chosen to demonstrate the inter-relationship between irrigation and nitrogen. It would appear that we can exercise some control over the yield components by adjusting the moisture and nitrogen supply; how successful we are in achieving the desired end result is uncertain.

Grain weight will always respond to irrigation on the light soils in Canterbury and the best opportunity for raising the present yield level under irrigation is afforded by increasing the total number of grains produced. To achieve this, we need to know more about the nitrogen and soil moisture interaction on the wheat plant; our present work at Winchmore will go some way towards providing the answer.

Sowing rates

Adjustments to seed rates may provide another avenue for raising grain yield under irrigation but seed rate trials at Winchmore have so far failed to achieve this objective. Increasing the seed rate above traditional levels simply increased the number of ears at harvest at the expense of the other three components, with no improvement in yield. I am tempted to suggest that nitrogen, or rather the lack of it, was again the evil influence, but provisional results from a recent trial showed that yields from low, medium and high seed rates did not differ greatly over a wide range of nitrogen treatments.

EFFECT OF IRRIGATION ON GRAIN QUALITY

No discussion on irrigating wheat on the light soils in Canterbury would be complete without some reference to the effect of irrigation on grain quality.

Protein

Grain nitrogen percentage, and therefore protein, is heavily reduced by irrigation, the more frequent the irrigation the lower the protein. The reduction in grain nitrogen associated with improved yield under irrigation is due to the dilution of available nitrogen by the higher starch yield. Applying nitrogen fertiliser at the later stages of plant growth will normally result in higher grain nitrogen than the same amount applied at early growth stages. Table 7 illustrates the effect of irrigation and nitrogen on grain nitrogen percentage in spring-sown Karamu.

TABLE 7. GRAIN NITROGEN PERCENTAGE

	No irrigation	*Irrigated at 10% sm (2 irrigations)*	*Irrigated at 15% sm (4 irrigations)*
No nitrogen	2.52	2.34	1.77
50 kg/ha N at drilling or tillering	2.65	2.43	1.95
50 kg/ha N at booting	2.53	2.52	1.16

The figures for irrigation represent a substantial drop in grain protein, especially under the heavier irrigation treatment, and they demonstrate the importance of avoiding unnecessary irrigation.

Recent work has shown that late applied nitrogen may be fully recovered by the plant but that cultivars vary in their ability to translocate late nitrogen to the grain (Quin and Drewitt, 1979). For example, under irrigation the grain nitrogen index of Karamu was lower than Oroua, Rongotea and Pahau in the absence of applied nitrogen, but when nitrogen was applied the grain nitrogen index of Karamu increased while that of the other cultivars decreased.

Baking quality

Tests carried out by the Wheat Research Institute in Christchurch show that the baking quality of wheat is also reduced by irrigation. However, baking quality and grain nitrogen are not always closely related; the baking quality of Karamu is always adversely affected by irrigation regardless of grain nitrogen level, but not all cultivars are as sensitive to irrigation and nitrogen. The adverse effects of irrigation on grain quality appear to be less severe under good natural fertility than in crops relying on supplementary nitrogen.

SUMMARY

Nitrogen is the key to successful irrigation of wheat on the light soils in Canterbury. Under good natural fertility and where fertiliser nitrogen is applied at drilling one irrigation will normally be sufficient for winter-sown crops and two for spring-sown crops. To get the full benefit of heavier irrigation rates it will generally be necessary to add fertiliser nitrogen at the tillering stage. Excessive irrigation should be avoided because of its effect on grain quality. The recommendations presented are intended as broad guide-lines only; individual growers should make their own minor adjustments.

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