THE EFFECTS OF IRRIGATION AND APPLIED NITROGEN ON THE GROWTH, GRAIN YIELDS AND NITROGEN CONTENT OF WHEAT

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SUMMARY

In the four seasons 1967/68 to 1970/71, yields of Aotea wheat were significantly increased by one irrigation at the 10% soil moisture level. Yield differences between this treatment and more frequent irrigations did not reach statistical significance. Irrigation at 10% soil moisture coincided with the booting to flowering growth stages in the early November to mid-December period. Grain yield was significantly correlated with the calculated soil moisture deficit at all growth stages from tillering to flowering, the strongest relationship occurring at heading.

Irrigation reduced the nitrogen percentage in the grain, and there was a significant negative correlation between this and the total water (rainfall plus irrigation) applied.

There were no economic yield responses to fertiliser nitrogen applied at tillering or at heading irrespective of irrigation treatment. In the absence of irrigation, nitrogen either had no effect or depressed yields. The nitrogen content of the grain was increased by fertiliser nitrogen in a wet season and under irrigation. In dry conditions nitrogen levels were unaffected by nitrogen applications.

INTRODUCTION

In 1966/67 a series of experiments were commenced to investigate the effect of irrigation and applied nitrogen on the growth, grain yield and nitrogen uptake of Aotea wheat. These experiments developed since the first season, but the main objectives were:

(1) To determine the optimum irrigation regime for the wheat crop.

(2) To investigate whether the application of nitrogen has any place in the irrigation of wheat.

By optimum is meant obtaining the highest yield of the best quality with the least amount of irrigation water. Associated with these objectives was a study of the effect of irrigation and nitrogen on the rate of dry matter accumulation and nitrogen uptake at different stages of growth.

EXPERIMENTAL DETAILS

All experiments described were carried out on the Lismore stony silt loam, on areas ploughed out of irrigated pasture. The age of the pasture varied from 14-15 years for the first three years' trials, and three years for the 1969/70 and 1970/71 trials. Analyses of soil samples taken from the 0-15 cm depth gave an average pH of between 5.8 and 6.0 (except in 1967/8, 5.5), calcium levels 5-6, Truog phosphorus 5-6 and variable potassium levels. Organic carbon averaged 2.80% (2.70-3.00) total nitrogen 0.24% (0.23-0.25), giving an average C/N ratio of 11.7. Aotea wheat was winter sown at a rate of 123 kg/ha. Soil moisture was determined gravimetrically on samples taken to the 15 cm depth, and irrigation was supplied by the border strip method. The trials were of split-plot design, with irrigation on the main plots and nitrogen (in the form of sulphate of ammonia) on the sub-plots. Sub-plots were 4.6 m x 8.5 m.

RESULTS AND DISCUSSION

IRRIGATION

A considerable amount of work has been carried out on the effect of irrigation and soil moisture on the wheat crop. In fact, Salter and Goode (1967) state "More studies have been reported on the responses of wheat plants to different soil moisture conditions at various stages of development than for any other single crop". Although an experimental programme on the irrigation of wheat can be based on applying water either at specific growth stages of the plant, or at pre-determined soil moisture levels, it was considered preferable in the present series of trials to use the latter approach. Irrigating solely on a stage of growth basis meant that water could be applied when the soil moisture levels were already high, and that a treatment designed to be irrigated at, say, flowering, may ignore an extremely dry spell during the earlier growth stages. Experience at Winchmore indicated that the best results under local climatic conditions might be obtained by not allowing the soil to fall below a certain minimum value at any time during the growth of the crop. Consequently, two general levels of irrigation were adopted: water applied when the percentage moisture in the top 15 cm reached 15% (or approximately 25% available moisture) and when the top 15cm reached 10% (wilting point, or nil available moisture). Each treatment was applied over the : (a) sowing to commencement of flowering period,

and

(b) sowing to harvest period.

Plus the non-irrigated, there were therefore a total of five main treatments.

(a) Yield of Grain

The results of five years experiments are given in Table I. Over the period of the experiments, the non-irrigated production varied from 1220 kg/ha (18 bushels) in a season with a particularly dry spring - 1969/70 - to approximately 3300 kg/ha (50 bushels) in three comparatively wet seasons.

TABLE 1: Effect of Irrigation on Grain Yield kg/ha in Absence of Applied Nitrogen (13% Moisture) (Number of Irrigations in Brackets).

Season	Non-Irrigated	To Flowering		To Harvest	
		10%	15%	10%	15%
1966/67*	3320				3740 (3)
1967/68*	3260	4650 (1)		4650 (1)	4680 (3)
1968/69	3450 bB	4250 (1) aA	4210 (2) aA	4380 (2) aA	4620 (4) aA
1969/70	1220 dD	3040 (1) aAB	3070 (2) aAB	2710 (2) bB	3290 (3) aA
1970/71	2140 bB	3520 (1) aA	3730 (2) aA	3270 (2) aA	3890 (3) aA

* Statistical analysis not available.

Table 1 shows that there were highly significant responses to irrigation in each season, but the differences between irrigation treatments were slight. For example, in each of the three seasons for which results are available irrigation at 10% soil moisture (wilting point) up to flowering gave highly significant responses over the non-irrigated yield. In each season, one irrigation was required in this treatment. Carrying this irrigation treatment through to harvest generally involved one more irrigation (a total of 2) and gave no further increase in grain yield. Irrigating at a higher soil moisture level (15%) to flowering required two irrigations and did not increase the yield over the 10% level. Irrigating at 15% through to harvest required 3-4 irrigations and gave significant yield increases over the 10% to harvest treatment in one season only. In this particular season however, the latter treatment was significantly less (5%) than either of the two irrigated to flowering treatments. Without considering the question of grain quality, it appears that one irrigation when the soil moisture reaches 10% - that is, one irrigation per season is the most efficient irrigation treatment.

The yield responses obtained from this treatment are given in Table 2.

TABLE 2: Grain (13% Moisture) Yield Responses To One Irrigation.

Season	% Increase Over Non-Irrigated	Grain Yield Response kg/ha
1967/68	43	1390
1968/69	23	800
1969/70	149	1820
1970/71	64	1380

Soil moisture fell to 10% during or after flowering in the three seasons in which "irrigation to flowering" treatments were included and it would be anticipated that the second irrigation on the "10% to harvest treatments" would have a marked effect on grain yield. That it failed to do so is at least partly, if not entirely, due to substantial rainfall immediately following the second irrigation and in the post flowering period generally. Rainfall figures for this period suggest that adequate moisture was available to fill the grain in all seasons:

Season	Rainfall (mm) Flowering to Harvest
1968/69	89.9
1969/70	148.8
1970/71	85.0

Although, as explained above, the irrigation treatments were based on levels of soil moisture, information can also be obtained on the effect of soil moisture conditions at the various growth stages. To do this, six stages, based on the Feekes scale, were selected and the dates for the non-irrigated and irrigated crops in each season were obtained from field observations made at the time. The stages were:

	Feekes Scale
Tillering	1-5
Stem extension	6-9
Booting	10
Heading	10.1-10.5
Flowering	10.5.1-10.5.4
Ripening	11.1-11.4

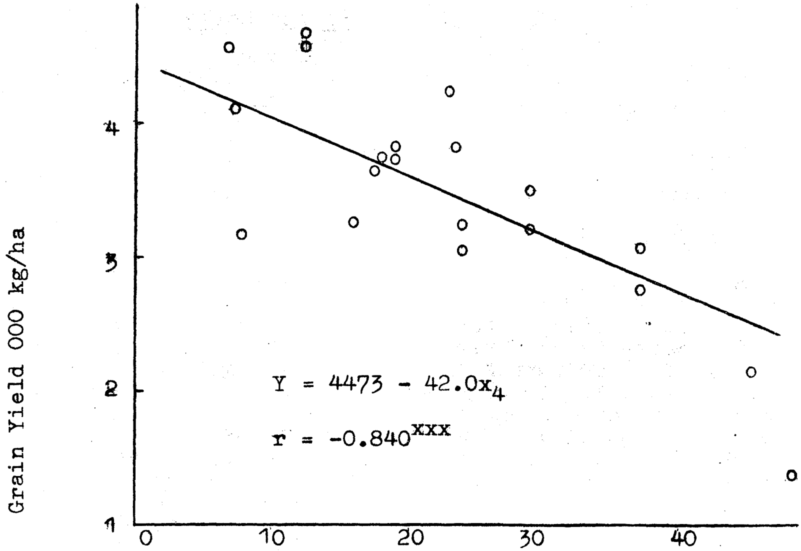
Although soil moisture determinations had been made on all treatments at intervals, they were carried out primarily for the purpose of deciding irrigation times and were not complete enough to allow accurate assessments of conditions during each of the growth stages shown above. Consequently, it was decided to use calculated soil moisture deficits. (Work at Winchmore has shown that the Thornthwaite deficit calculation is highly correlated with measured soil moisture under wheat). The mean soil moisture deficit for the period covering each stage of growth was therefore calculated for each of the irrigation treatments over the five seasons.

The deficits at each particular growth stage were correlated with the final grain yield, and the results are shown in Table 3.

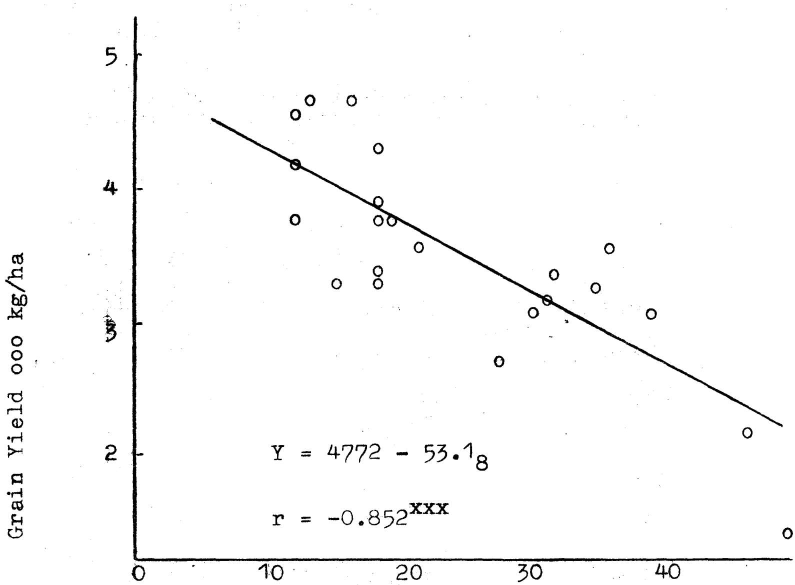
TABLE 3: Relationship Between Grain Yield and Soil Moisture Deficit at Different Growth Stages.

	r	SIG.
$Y = 3894 - 35.6x_1$	-.483	5%
$Y = 3944 - 24.3\ x_2$	-.638	1%
$Y = 4327 - 44.9x_3$	-.709	0.1%
$Y = 4473 - 42.0x_4$	-.840	0.1%
$Y = 4063 - 19.9x_5$	-.751	0.1%
$Y = \quad x_6$	N.S.	
$Y = 4656 - 53.9x_7$	-.828	0.1%
$Y = 4772 - 53.1x_8$	-.852	0.1%

Where Y = final grain yield (kg/ha)
and X = moisture deficit (mm) at; 1, tillering; 2, stem extension; 3, booting; 4, heading; 5, flowering; 6, ripening; 7, booting-heading; 8, booting-heading-flowering.



Mean soil moisture deficit mm at heading.



Mean soil moisture deficit mm at booting/heading/flowering.

FIG.1 : Relationships between grain yield kg/ha and mean soil moisture deficits at (a) heading and(b) booting/heading/flowering.

Of the periods examined, those providing the strongest relationships were the deficit at heading (71% of the variations explained) and the deficit over the booting/heading/flowering stage (73% of the variation explained). These are shown in Figure 1.

Some care should be taken to avoid reading too much into these results; it would be rash, for example, to conclude that soil moisture conditions during tillering were of little importance. Under our climatic conditions, soil moisture levels are not likely to be low during this time, and therefore no information about the possible effect of such conditions can be deduced. Certainly, soil moisture levels during the heading stage are important, and by this time (Mid-November) it is likely that under our climate they will be low enough to adversely effect the final grain yield.

The results of the various irrigation treatments, together with the above regressions can be summarised as follows: under Canterbury climatic conditions wheat should not be allowed to drop below wilting point at any stage up to flowering. This will normally require one irrigation which has, over the last few seasons been applied between November 6 and December 12.

Yellow dwarf virus and leaf rust were observed in severity with irrigation frequency and no doubt had a retarding effect on grain yield. Mildew developed in all seasons and adversely affected yields, although susceptibility to this disease did not necessarily increase under high soil moisture conditions.

(b) Quality of Grain

Total nitrogen percentages were determined on a plot basis for all the experiments (except the pilot trial in 1966/67), and baking scores were carried out by the Wheat Research Institute on a treatment basis.

In general, the percentage of nitrogen in the grain is lower on the irrigated treatments than on the non-irrigated, as shown in Table 4.

TABLE 4: Percentage Nitrogen in Grain From Treatments Which Received No Nitrogen Fertiliser.

Season	Non-Irrigated	Irrigated to Flowering		Irrigated to Harvest	
		10%	15%	10%	15%
1967/68	2.53	(2.40)		2.40	1.80
1968/69	2.51 aA	1.91 bcB	1.79 cB	1.97 bB	1.85 bcB
1969/70	3.24 aA	2.49 bcBC	2.52 bcBC	2.51 bcBC	2.20 cC

This difference was increased with increasing number of irrigations but there was no consistent significant differences between irrigation treatments. Other workers (Stone and Tucker 1969), have obtained correlations between the % grain nitrogen and the total rainfall plus irrigation water applied, and this point was therefore examined. The total rainfall from sowing to maturity plus an assumed 100 mm for each irrigation was calculated for the non-irrigated and for the10% and 15% treatments to harvest, and correlated with the % nitrogen in the grain. The following equation was obtained (Figure 2):

$$N = 107.77\ W^{-0.61} \qquad r = 0.97^{**}$$

Where N= nitrogen percentage;
and W= total water applied (mm);

The regression equation explains some 94% of the variation in grain nitrogen, over the three seasons for which data were available. If a high protein percentage is required, it is obviously preferable to keep the number of irrigations to a minimum.

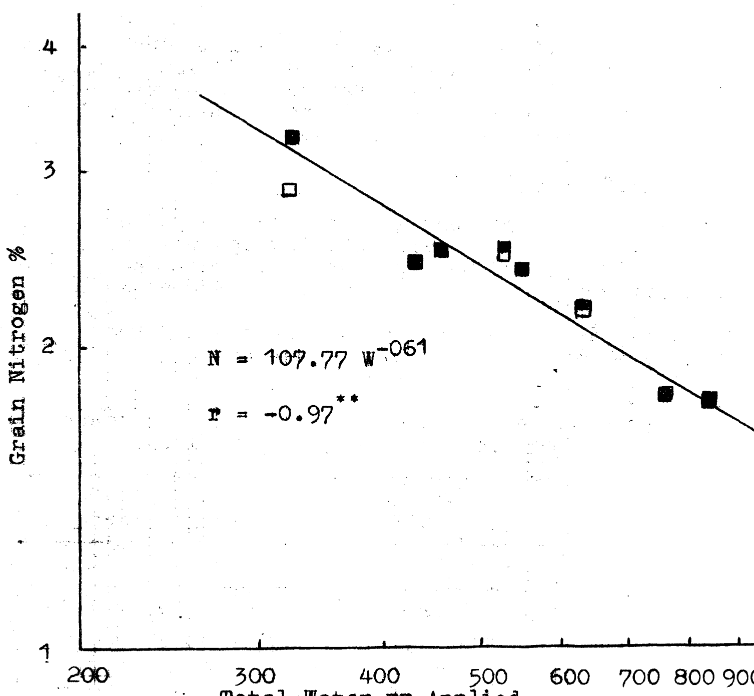


FIG. 2 : Relationship between grain nitrogen % and total water applied.

Although the nitrogen percentage was lower on the irrigated treatments, the yield of nitrogen in the grain was greatly increased in two out of the three years. Table 5. In the other season there was a slight drop.

TABLE 5: Nitrogen Content of Grain kg/ha From Treatments Which Received no Nitrogenous Fertiliser

Season	Non-Irrigated	Irrigated to Harvest		Irrigated to Flowering	
		10%	15%	10%	15%
1967/68	71.8	(96.9)		96.9	73.7
1968/69	75.3	70.6	65.6	75.0	74.4
1969/70	34.3	65.9	67.3	59.2	62.9

The baking score was lower on the irrigated treatments, as shown in Table 6, but it is doubtful if the slight reduction - particularly at the lower irrigation frequency - is important. All values obtained were above the level of 36 designated by Wright (1969) as 'good'.

TABLE 6: Baking Scores of Grain From Treatments Which Received no Nitrogenous Fertiliser

Season	Non-Irrigated	Irrigated to Harvest		Irrigated to Flowering	
		10%	15%	10%	15%
1967/68	44	(41)		41	38
1968/69	41	38	40	38	37
1969/70	42	40	37	39	37

(c) Grain Weight

Ideally, an analysis of grain yield requires knowledge of at least the number of heads, the number of grains per head and the individual grain weight. It has to date been possible to obtain only the grain weight, and the absence of the associated data makes interpretation of limited value. There is, for example, a suggestion that moisture stress prior to booting will reduce yield because of fewer heads and fewer grains per head, and that stress during and after heading may reduce yield because of reduced grain weight. Grain weights for the no-nitrogen treatments are given in Table 7.

Irrigation does not appear to have any consistent effect on grain weight, and a more detailed examination of the data failed to reveal any relationship between grain weight and soil moisture deficits, or total rainfall, from the soft-dough stage to maturity.

TABLE 7: Grain Weight, Grams per 1000 grains

Season	Non-Irrigated	Irrigated to Flowering		Irrigated to Harvest	
		10%	15%	10%	15%
1966/67	42.6				42.3
1967/68	30.0	(35.0)		35.0	38.7
1968/69	40.2	36.1	40.1	37.4	37.9
1969/70	36.7	34.3	33.3	34.4	32.7
1970/71	37.1	40.4	34.7	40.9	34.9

NITROGENOUS FERTILISER

Nitrogen in the form of ammonium sulphate was applied at two rates; 56 kg nitrogen (267 kg ammonium sulphate) per hectare, and 112 kg nitrogen (533 kg ammonium sulphate) per hectare at tillering or at heading.

In the absence of irrigation, the application of nitrogen either had no effect, or significantly depressed yields. In the presence of irrigation, both rates of nitrogen applied at tillering similarly had no effect or depressed yields. In one season out of three nitrogen applied at heading gave a significant response (on the treatment irrigated at 15% to harvest) but not an economic one. These results show that adequate moisture does nothing to improve the nitrogen response on Aotea wheat grown as a first crop after a period in pasture. The effect of applied nitrogen on the percentage of nitrogen in the grain was variable: in a dry season the nitrogen percentage was not affected, in a wet season or with irrigation the nitrogen percentage was increased, although not always significantly. There were no significant trends in the baking scores, apart from a general tendency for these to be slightly higher on the nitrogen treated plots. Nitrogen applied at tillering reduced the 1000-grain weight on both the irrigated and non-irrigated areas, nitrogen at heading had no effect.

ACKNOWLEDGEMENTS

The authors' thanks are due to the many technicians who assisted at all stages of the work. Acknowledgements are also made to the Biometrics Section, Department of Agriculture for all statistical analyses, and to Mr C.Dyson of that section and Mr P.D. Fitzgerald, Winchmore, for regression analyses. Also to the Wheat Research Institute for the determination of baking scores.

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