THE EFFECT OF IRRIGATION AND OTHER AGRONOMIC TREATMENTS ON THE YIELD OF POTATOES GROWN ON TEMPLETON SILT LOAM

R. J. Martin
Ministry of Agriculture & Fisheries
Lincoln, Canterbury

ABSTRACT

Three experiments were carried out over two seasons to investigate the effect of irrigation, fertilizer, seed size spacing and cultivar on potatoes grown on Templeton silt loam.

In the 1976-77 season yields were low and yield responses only occurred with furrow irrigation after flowering and with increased nitrogen fertilizer rates. Irrigation before flowering, increased phosphate rates, potash and dipping seed tubers in sodium hypochlorite solution had no effect on total yield.

In the 1977-78 season, considerably drier than 1976-77, two trials were undertaken. In one, using sprinkler irrigation, which added 20 mm water each time the soil moisture fell to 22% gave similar yields to adding 40 mm water at 22% soil moisture. Altering the distance between plants in the row, and reducing seed size had no effect on yield.

In the second trial, yields when furrow irrigation was applied at 16% soil moisture were not significantly different to yields when furrow irrigation was applied at 22%. Ilam Hardy out-yielded Kennebec, Wha and Whitu.

INTRODUCTION

With the development of the New Zealand potato processing industry (Driver, 1971), which has specific size and quality requirements, and the increasing area of potatoes grown under irrigation on the silt loam soils west of Christchurch, a reassessment of the irrigation and related agronomic requirements of the potato crop is required.

On light stony Lismore soils, irrigation increased potato yields by an average of 60% over 8 years (Drewitt, 1970). There is little information on irrigation responses on heavier soils, although Driver (1971) recommended three irrigations after flowering for maximum yield. However, Drewitt (1970) obtained marked differences between cultivars in their irrigation requirements. With the development of new cultivars specifically aimed at the processing market (Driver, 1974), further irrigation studies are required.

Because of potato cyst nematode (*Heterodera* species) infestations in some seed growing areas, dipping of seed tubers in sodium hypochlorite solution is used to decontaiminate infested seed. However, the effect of dipping on subsequent crop performance is not clear (Wood, 1976).

General fertilizer recommendations for main crop potatoes have been 26 kg nitrogen and 34 kg phosphorus per hectare (Claridge, 1972), although During (1972), reviewing results from a number of trials, recommended 67 kg nitrogen and 67 kg phosphorus per hectare and, where necessary, 168 kg potassium per hectare.

One of the major costs facing potato growers is the purchase of seed. The amount of seed used could be reduced by increased spacing of plants and reducing the size of seed planted. The effect of spacing and seed size varies according to the cultivar grown (Smith, 1968). McLeod (1973) found that table yields of Rua did not decrease with increasing spacing within the row.

Because of the large number of factors affecting the yield of potatoes, three trials were carried out over two seasons to delineate those areas in which more detailed studies may be required. Irrigation timing, frequency and intensity were examined together with fertilizer, seed size and spacing, and cultivar. The experiments were carried out on a Templeton Silt Loam at the Ministry of Agriculture and Fisheries Templeton Research Station, 19 km west of Christchurch. Chemical and physical properties of the soil are given in Tables 1 and 2 respectively.

TABLE 1: Chemical properties of the soil in the 0-150 mm depth at the sites used for the experiments.

	pH	Ca	K	Mg	P (Olsen)
1976-77	5.9	14	9	27	45
1977-78	5.4	8	7	16	19

TABLE 2: Physical properties of the soil in the 0-300 mm depth at the site of the 1977-78 experiments.

Depth (mm)	Bulk density (g/ml)	Field capacity (w/w%)	Wilting point (w/w%)	Available moisture (v/v%)	Available moisture (mm)
0-150	1.03	32.7	10.0	23.4	35.1
150-300	1.10	26.2	9.2	18.7	27.6

MATERIALS AND METHODS

Experiment 1

A split plot experiment with two replicates was laid down on November 10 1976, on a site which had previously grown barley after wheat. Ilam Hardy seed potatoes (60 - 113 g) were planted at 300 mm spacing in 760 mm rows using a single row planter. Subplot size was 3 rows by 72 metres. There were 6 main plot treatments, 3 irrigation treatments by 2 dipping treatments. Planned irrigation treatments were –

1. Not irrigated.
2. Furrow irrigated each time the soil moisture in the 150-300 mm depth in the ridge fell to 16% by weight. Irrigations to continue until the end of flowering.

3. Furrow irrigated each time the soil moisture in the 150-300 mm depth in the ridge fell to 22% by weight. Irrigations to continue until the end of flowering.

Dipping treatments were –

1. Not dipped.
2. Dipped in 1% sodium hypochlorite solution for two hours, then washed with cold water and dried.

Six fertilizer combinations were to be applied as subplot treatments. The planned levels (kg/ha) of nitrogen, phosphorus and potassium were as follows:

Treatment	N	P	K
1	26	34	0
2	75	34	0
3	26	75	0
4	75	75	0
5	26	34	75
6	75	75	75

The nitrogen was applied as ammonium sulphate, phosphorus as superphosphate and potassium as potassium sulphate. The fertilizer mixtures were applied as a band on either side of the seed at planting. Actual levels of fertilizer applied were within 6% of planned except for treatment 5 where only 60% of the planned amount was applied.

The experiment was harvested on April 18 1977 using a single row digger. Four 5m lengths of the centre row were taken for yield and quality determinations. Tubers were divided into those over 50 mm diameter (table) and those between 30 mm and 50 mm diameter (seed). Specific gravities were determined on a 3.6 kg sample of table tubers using a hydrometer and were converted to dry matter percentage using a local processor's conversion table. DSIR Crop Research Division tested bulked samples from the irrigation and fertilizer treatments for steaming quality and crisp colour. Steaming quality scores are based on sloughing, colour, texture, flavour and stem end blackening, and a high overall score may or may not be desirable depending on the end use of the potato. For crisp colour a score of over 4 (cream to slightly brown) is considered to be an acceptable colour and under 4 (dark brown to black) is unacceptable.

Experiment 2

A split plot experiment with 3 replicates was laid down on October 19 1977 on a site which had previously been under Tama ryegrass. There were 3 main plot treatments –

1. Not irrigated.
2. Addition of 20 mm water by sprinklers when the soil moisture in the 150-300 mm depth fell to 22% by weight.
3. Addition of 40 mm water by sprinklers when the soil moisture in the 150-300 mm depth fell to 22% by weight.

Sub plot treatment factors were within-row spacings of 200, 300 and 400 mm and seed sizes of 30 - 60 g and 60 - 113 g.

Sub plots were 4 rows wide by 20 m long. Immediately before sowing, 60 kg nitrogen, 72 kg phosphorus and 40 kg potassium per hectare were broadcast in the form of ammonium sulphate, superphosphate and potassium chloride respectively. The experiment was planted by hand, and harvested using a single row digger on May 9 and 10 1978, the centre 15 m section of the middle two rows being analysed for yield and quality as in Experiment 1.

Experiment 3

This experiment was carried out adjacent to Experiment 2, and paddock history and fertilizer dressings were identical. A split plot design with three replicates and three furrow irrigation treatments as main plots was used. The irrigation treatments were as follows:

1. No irrigation.
2. Furrow irrigation when the soil moisture in the 150-300 mm depth in the ridge had fallen to 16% by weight.
3. Furrow irrigation when the soil moisture in the 150-300 mm depth in the ridge had fallen to 22% by weight.

Sub plots were the varieties Ilam Hardy, Kennebec, Wha and Whitu.

Each sub plot was 5 rows by 20 m. Seed size was 60 - 113 g and spacing was 300 mm in 760 mm rows.

The experiment was planted by hand on October 20 1977. One replicate was harvested on May 15 and the other two on May 29 and 30 1978. The centre 15 m of the middle three rows were used for yield and quality determinations as in Experiment 1.

RESULTS

Rainfall

Rainfall data for the two seasons are given in Table 3, together with the average monthly rainfall at Christchurch Airport, 12 km north-east of Templeton. Both seasons were drier than average, but measured soil moistures did not fall to wilting point.

Experiment 1

Because of the large difference between planned and applied fertilizer applications in fertilizer treatment 5, data from this treatment were omitted from the analyses.

Irrigation

Due to the high soil moistures, treatment 2 was not irrigated by the end of flowering, which occurred during January. Therefore this treatment was altered to irrigation at 22% soil moisture (by weight) in the 150-300 mm depth in the ridge from the end of flowering until the tops started to die off.

Overall yields were low and there was no response to irrigation before flowering (Table 4). Irrigation after flowering increased total yield by 30% and table yield by 72%. This increase seemed to be due to an increase in the size of tubers, since the total number of tubers was unaffected by irrigation. Irrigation after flowering reduced the dry matter percentage of table potatoes compared to the non-irrigated treatment. Irrigation after flowering also resulted in a lower steaming score and reduced lighter coloured crisps than the other irrigation treatments.

TABLE 3: Rainfall (mm) over the two seasons and minimum soil moisture (w/w%) for the non-irrigated treatments of the three experiments.

	RAINFALL			MINIMUM SOIL MOISTURE		
	1976-77	1977-78	Average (Ch.ch Airport)	Experiment 1 (1976-77)	Experiment 2 (1977-78)	Experiment 3 (1977-78)
October	52	16	46	–	–	–
November	41	24	47	22.6	22.8	21.9
December	90	42	52	22.6	14.9	15.6
January	30	40	50	13.0	13.2	12.2
February	44	2	46	12.8	14.0	13.1
March	5	21	53	–	14.4	11.8
April	30	187	67	–	13.5	12.3
Total	292	332	361			

Dipping

Dipping in sodium hypochlorite solution tended to reduce total and table yield, but the reductions were not significant.

Fertilizer

Higher rates of nitrogen increased total and table yields by 11% and 28% respectively (Table 4). These yield increases wer due to larger tubers, as tuber numbers were unaffected. Also the increase mainly occurred with table yield in the non dipped treatments (Table 5), the interaction being carried over into total yield. Nitrogen also significantly reduced percentage dry matter. Higher rates of phosphorus had no effect on yield. When potassium sulphate was applied in addition to high levels of nitrogen and phosphorus, it increased table yields but decreased seed yield and percentage dry matter. Fertilizer applications had no effect on crisp colour or steaming test score.

Experiment 2

Irrigation

Irrigation significantly increased total yield by 31% and table yield by 42%, there being no significant difference between the two levels of irrigation (Table 6). Crisp colour was considerably lighter under the 40 mm water added treatment, but irrigation had no effect on steaming scores.

TABLE 4: Yields (t/ha), number (no/m^2) and dry matter percentage for Experiment 1.

Treatment			Total Yield	Table Yield	Seed Yield	Total No. of Tubers	% Dry Matter
Irrigation							
No Irrigation			30.0 bB	16.1 bB	13.9 aAB	32.4 a	23.7 aA
Irrigated before flowering (2 irrigations)			32.2 bB	17.7 bB	14.5 aA	34.0 a	23.7 aA
Irrigated after flowering (2 irrigations)			38.8 aA	27.3 aA	11.5 bB	34.4 a	22.1 bA
s.e. mean			1.09	1.32	.42	.88	.35
Dipping							
Not dipped			34.9 a	22.2 a	12.7 a	33.2 a	23.0 a
Dipped in sodium hypochlorite solution			32.4 a	18.6 a	13.9 a	34.0 a	23.3 a
s.e. mean			.89	1.08	.34	.72	.29
Fertilizer rates (kg/ha)							
N	**P**	**K**					
26	34	0	30.9 cB	17.1 cB	13.7 bAB	32.6 abA	23.7 aA
75	34	0	35.2 aA	22.1 bA	13.2 bB	34.1 abA	22.8 cbAB
26	75	0	32.3 bcAB	16.8 cB	15.5 aA	35.4 aA	23.8 aA
75	75	0	34.7 abA	21.6 bA	13.2 bB	34.3 abA	23.3 abA
75	75	75	35.4 aA	24.3 aA	11.0 cC	31.6 bA	22.2 cB
s.e. mean			.93	.76	.50	1.07	.27
Response to nitrogen			+3.4**	+4.8**	- 1.4**	- 0.3	- 0.7*
Response to phosphorus			+0.5	- 0.4	+0.9	+1.6	+0.4
Interactions			Dipping x Nitrogen (5% sig.)	Dipping x Nitrogen (1% sig.)	–	–	–

TABLE 5: Interaction between dipping in sodium hypochlorite solution and rates of nitrogen on table yields (t/ha).

	Low nitrogen	High nitrogen
Not dipped	17.5	24.7
Dipped	16.5	18.9

s.e. (mean) horizontal comparisons = .73
s.e. (mean) vertical comparisons = 1.34

Seed Size and Spacing

Seed size had no effect in total or table yield (Table 6) but there was a slight increase in seed yield and tuber numbers with the larger seed size. Spacing had no effect on total or table yield or dry matter percentage, but there were significant decreases in tuber numbers and weight of seed size tubers as the distance between plants increased from 200 mm to 400 mm. The interaction between irrigation, seed size and spacing was complex with no clear trends.

Experiment 3

Irrigation

Irrigation increased yields by an average of 44% for total yield and 50% for table yield, and there was no significant difference between the irrigated treatments (Table 7). Irrigation also produced lighter coloured crisps, but did not affect the steaming score.

Cultivar

Ilam Hardy gave the highest yield of total and table potatoes. It outyielded Wha and Whitu because of larger tubers, the three cultivars having similar tuber numbers. Kennebec, although having the lowest total and seed yield, had the second highest table yield. There were significant differences in dry matter percentage, Whitu having the highest and Ilam Hardy and Kennebec the lowest. Ilam Hardy produced darker coloured crips than the other cultivars. In the steaming tests, Wha had the highest score and Ilam Hardy and Kennebec the lowest.

DISCUSSION

The low yields in Experiment 1, in a year when growers experienced good yields can be attributed to a number of factors, including poor land preparation, damage to badly sprouted seed at planting, late planting and late blight (*Phytophthora infestans*). These factors were avoided in the second season when yields from the non-irrigated treatments in both experiments were nearly as high as the best yields in Experiment 1.

Non irrigated yields in Experiments 2 and 3 were considerably higher than those obtained on shallow Lismore soils by Drewitt (1970), but yielded differences between the two soils were not so marked under irrigation. Smaller responses to irrigation on Templeton soils compared to Lismore soils have also been found with peas (Stoker, 1977).

In contrast to Experiment 1, and the results of Drewitt (1970), irrigation significantly increased the number of tubers formed in Experiments 2 and 3. This indicates that, in the 1977-78 season, yield was influenced by both irrigation before flowering, which affects tuber initiation (Salter and Goode, 1967), and irrigation after flowering, which affects tuber size.

In Experiment 2 there was no significant difference in yield between the 20 mm and 40 mm water added treatments, despite the latter having nearly 60% more water added in its six irrigations than the former in its seven irrigations. As the 40 mm treatment was designed to bring the soil moisture in the top 300 mm of the ridge back to field capacity, there appears to be scope for future research into partial restoration of the moisture deficit in the soil under potatoes.

TABLE 6: Yields (t/ha), number (no/m^2) and dry matter percentage for Experiment 2.

Treatment	Total Yield	Table Yield	Seed Yield	Total No. of Tubers	% Dry Matter
Irrigation					
Nil	34.3 bB	23.5 bB	10.8 a	32.5 bA	22.5 bA
20 mm added per irrigation (7 irrigations)	46.5 aA	34.9 aA	11.6 a	38.1 aA	23.2 aA
40 mm added per irrigation (6 irrigations)	43.1 aA	31.8 aA	11.2 a	35.7 abA	22.7 bA
s.e. mean	.97	.94	.23	.95	.11
Seed size					
34 - 60 g	41.2 a	30.8 a	10.4 bB	33.9 bA	22.8 a
60 - 113 g	41.3 a	29.3 a	12.0 aA	36.9 aA	22.8 a
s.e. mean	.89	.76	.35	.82	.07
Spacing in row					
200 mm	41.7 a	28.6 a	13.1 aA	38.7 aA	22.7 a
300 mm	42.0 a	30.9 a	11.1 bB	35.1 bAB	22.8 a
400 mm	40.1 a	30.8 a	9.4 cB	32.5 bB	22.9 a
s.e. mean	1.08	.93	.43	1.00	.08
Interactions	–	–	Irrigation x Seed Size x Spacing (5% sig.)	–	–

TABLE 7: Yields (t/ha), number (no/m^2) and dry matter percentage for Experiment 3.

Treatment	Total Yield	Table Yield	Seed Yield	Total No. of Tubers	% Dry Matter
Irrigation					
No Irrigation	32.6 bB	24.8 bB	7.8 bA	25.9 bB	22.7 a
Irrigated at 16% soil moisture (8 irrigations)	44.7 aA	36.2 aA	8.6 bA	31.9 aAB	22.8 a
Irrigated at 22% soil moisture (12 irrigations)	49.0 aA	38.0 aA	11.1 aA	36.9 aA	23.2 a
s.e. mean	1.14	.93	.54	1.31	.20
Cultivar					
Ilam Hardy	47.3 aA	37.8 aA	9.5 bA	35.3 aA	21.9 cC
Kennebec	39.2 cC	33.7 bB	5.5 cB	23.0 bB	22.3 cC
Wha	42.8 bB	31.5 cBC	11.3 aA	34.9 aA	23.1 bB
Whitu	39.3 cC	29.0 cC	10.3 abA	33.1 aA	24.1 aA
s.e. mean	.86	.96	.53	.89	.18
Interactions	–	–	–	–	–

The number of irrigations in both irrigated treatments in Experiment 3 were high. This experiment was furrow irrigated, but due to the short length of the furrows and the relatively steep fall of the site, the soil in the ridge was probably not adequately wetted at each irrigation. Also, irrigations were continued through until the end of February, when the later maturing Wha and Whitu were starting to senesce. Thus irrigations continued for a month longer in Experiment 3 than in Experiment 2, which only had the earlier maturing Ilam Hardy.

The slight, but non significant, reduction in yields in Experiment 1 due to dipping in sodium hypochlorite solution agrees with other results obtained with sprouted tubers by Wood (1976).

Increasing the level of nitrogen fertilizer in Experiment 1 had a significant effect on yield, although the response was lower than that to late irrigation. This crop followed two straw crops and so a response to nitrogen could be expected (During, 1972). However, most of the nitrogen response occurred in undipped treatments, indicating that the damage caused to the sprouted tubers by dipping reduced the ability of the plants to respond to nitrogen. Later emergence was observed in dipped treatments in line with the results obtained by Wood (1976), and this may have been followed by delayed tuber initiation and bulking. The lack of response to phosphorus was probably due to the high status of this element in the soil after six years cropping.

The response of Ilam Hardy to changes in within row spacing in Experiment 2 are similar to those reported for Rua (McLeod, 1973). However, other cultivars may respond differently to changes in seed size and spacing (Smith, 1968). As the purchase of seed can be one of the major costs in growing potatoes, the effect of seed size and spacing should be investigated further.

The response from one trial with cultivars grown from seed from various sources must be treated with caution, due to the effect of seed history and storage (Claridge, 1972). Also, the lower dry matter percentage of Ilam Hardy and Kennebec may have been due to irrigations being continued for some time after the tops of these two earlier maturing cultivars had died off. Late irrigation has been shown to be deleterious to potato quality (Salter and Goode, 1967).

These results indicate that further research is needed into irrigation requirements of potatoes. Also the lack of response to changing seed size and spacing requires more investigation.

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