QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES
DIVISION OF PLANT INDUSTRY BULLETIN No. 586

EFFECTS OF VARIOUS IRRIGATION REGIMES ON YIELD AND QUALITY OF POTATOES

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SUMMARY

From 1960 to 1963 several trials were conducted to investigate the effect of various rates and frequencies of irrigation on the yield and quality of potatoes on the dark-brown alluvial clay soils of the Lockyer Valley, in south-eastern Queensland.

Results generally showed increased yields with increasing amounts of irrigation (up to 2 in. or more of water applied per week), with the optimum yields usually occurring at about 1-1½ in. per week average. Combination of frequency and amount did not seem to be important.

In contrast, the specific gravity of the tubers declined with increased irrigation amount, and was influenced partly by the frequency and amount combinations used.

I. INTRODUCTION

Potatoes have been one of the major irrigated crops in the Lockyer Valley of south-eastern Queensland for several decades. The wartime boost to vegetable production led to increased acreage and mechanization of the industry. Irrigation became more intensive, mainly from spraylines with low-pressure "rose" or "unchockable" nozzles, with an application of about 0·80 in./hr.

The irrigation techniques employed were of no great concern to growers, provided high yields were obtained. The crop was usually harvested at times when the demand for "new" potatoes was such that prolonged storage of the tubers was seldom required. In the late 1950s, however, lower returns from the fresh market created an interest in better quality produce which could be safely stored to await a better market return, or which could be suitable for processing, e.g. into flakes.

The series of trials described in this paper was instituted to determine what influence irrigation management exerted on yield and quality of potato crops under conditions prevailing in the Lockyer Valley. The trials were conducted at Gatton Research Station on a dark-brown alluvial clay soil.

II. METHODS AND MATERIALS

Irrigation.—Although potato crops in the Lockyer Valley are normally spray-irrigated, practical difficulties in this method for experimental use enforced the use of a type of furrow irrigation.

Plants were hilled at as early a stage as possible, and plots comprising four level rows each ½ chain or 1 chain long were formed. The furrows between the hilled rows were linked at each end of the plot. An amount of water calculated to suit each treatment was run into these plots, at a rate of approximately 5,000 gal/hr, and allowed to soak into the soil.

When moderate rain occurred during the treatment period of the trials, allowances were made for the amount applied to each treatment by subtracting the amount of rainfall considered effective from the amount due. When heavy and consistent rain occurred the trials were disregarded, as yields and specific gravities were both low.

Data collection methods.—The centre two rows of each plot were harvested, and yield data taken. Specific gravity was estimated by means of a potato hydrometer, and scab data were obtained by comparison with a standard chart.

Various methods were tried for soil moisture determinations. Gravimetric determinations were found to be most satisfactory on this heavy soil, but the data varied considerably and are not presented.

Treatments.—Initially, treatments in this investigation were chosen to cover a wide range of irrigation regimes. Combinations of 1 in., 2 in. and 3 in. applications at 1, 2 and 3-week intervals between applications were used in the first series of trials.

Treatments, applied over a period of 8 weeks, were—

Treatment	Irrigation Amount (in.)	Irrigation Interval (weeks)	No. of Irrigations	Average Amount per Week (in.)
A	1	1	8	1
B	2	1	8	2
C	3	1	8	3
D	1	2	4	0·5
E	2	2	4	1·0
F	3	2	4	1·5
G	1	3	3	0·33
H	2	3	3	0·67
I	3	3	3	1·0

Trials in which these treatments were imposed were carried out in autumn and spring 1960, autumn 1961 and autumn 1962.

Trends in these trials (Figure 1) indicated that most effective treatments were in the range of 1-1½ in./week average applications. Accordingly, a second series of treatments was imposed in trials in autumn 1962, spring 1962 and spring 1963. These were designed to examine more closely the effects of variations in rates and frequencies of application during the growth of the crop, with a range of weekly average rates of 0·5, 1·0, 1·5 in. and, in spring 1962 and 1963, 2·0 in.

Treatment groups as indicated below were used. The treatment applications week by week which maintained, over a period of 7 weeks, the 1 in./week average are shown below as examples.

Group 1	Even interval (weekly), even amount						
	1·0	1·0	1·0	1·0	1·0	1·0	1·0
Group 2	Interval and amount doubled after 4 weeks						
	1·0	1·0	1·0	2·0	—	2·0	—
Group 3	Constant (weekly) intervals, reduced amount after 4 weeks						
	1·4	1·4	1·4	0·7	0·7	0·7	0·7
Group 4	Interval doubled after 4 weeks, amount constant						
	1·4	1·4	1·4	1·4	—	1·4	—

In spring 1962 and spring 1963, in addition to the 2 in. average treatment, two treatments of a constant interval and increasing amount, at the 1·0 and 1·5 in./week average levels, were included (these are the opposite of group 3).

Group 5	Constant intervals, increasing amounts after 4 weeks						
	0·7	0·7	0·7	0·7	1·4	1·4	1·4

III. RESULTS

(a) Trial Series 1

The results of those trials in series 1 which were carried through to a successful conclusion are presented in graphical form in Figures 1 and 2. The graphs have all been drawn against amount of irrigation water applied, divided by the appropriate frequency to give a weekly basis for comparison. Yields are graphed in tons per acre for both total yield and yield of first-grade tubers.

Scab ratings shown in Figure 2 are the percentage of tuber surface affected by lesions. Except for the autumn 1960 trials, where some ratings exceeded 10%, scab incidence was relatively minor throughout.

Autumn 1960 *trial.*—In this trial total amount of water applied to the treatments appeared to be the important factor in yield rather than frequency or amount. The yield increased with increasing quantity of water up to a maximum first-grade yield of 7·01 tons/ac for the 2 in. every 7 days, and then dropped to 5·77 tons/ac for 3 in. applied every 7 days. The treatments 1 in. every 7 days, 2 in. every 14 days and 3 in. every 21 days all gave practically the same yield (6·58, 6·37, and 6·37 tons/ac first-grade respectively).

Increasing quantity of water decreased specific gravities, the effect being most marked in the 14 and 21-day frequencies. For treatments averaging out at 1 in. per week, 3 in. every 21 days (S.G. 1·073) and 2 in. every 14 days (S.G. 1·073) significantly exceeded 1 in. every 7 days (S.G. 1·067) at the 5% level.

Scab ratings varied from 4·4 to 10·4% tuber surface affected but no significant differences were recorded.

Autumn 1961 *trial.*—A severe attack of target spot (*Alternaria solani*) coupled with a heavy infestation of aphids occurred late in this crop, resulting in a low average trial yield of 4·45 tons/ac.

Two inches applied weekly gave the highest yield of first-grade tubers of 6·42 tons/ac. In contrast to the autumn 1960 trial, all 3 in. treatments in this trial gave significantly lower yields than the corresponding 2 in. treatments.

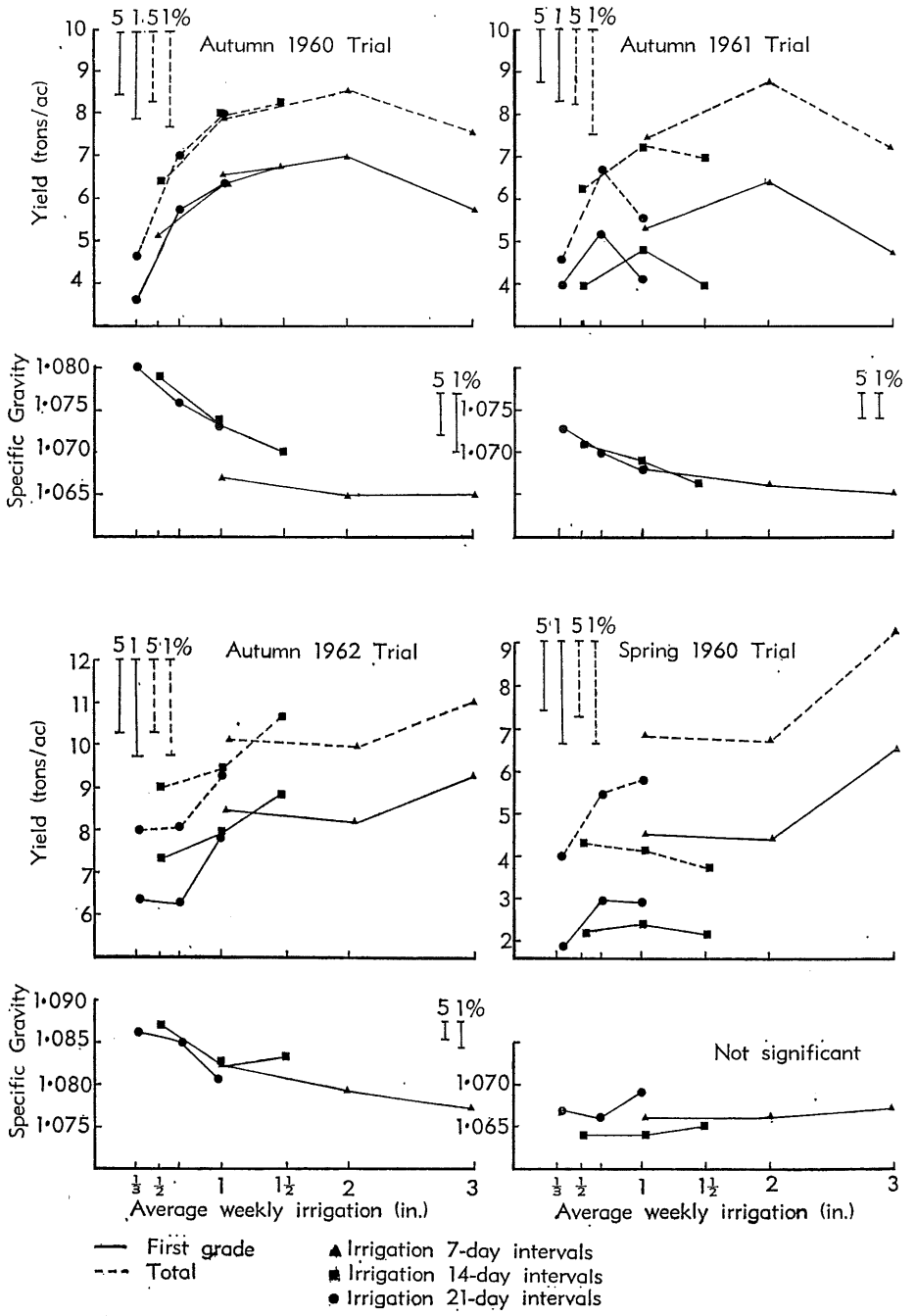

Fig. 1.—Trial series 1: Yields and specific gravities.

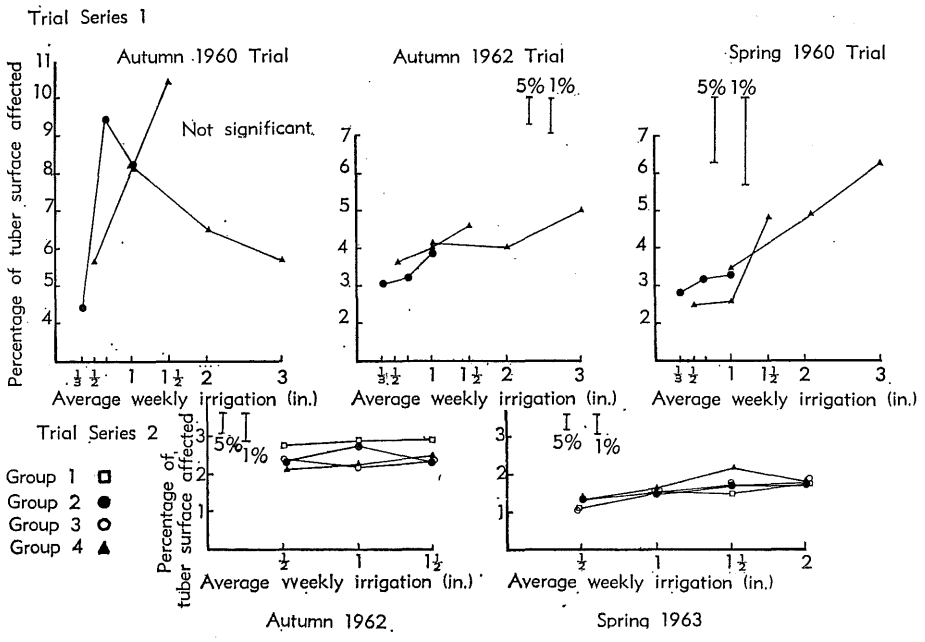

Fig. 2.—Scab ratings.

Specific gravity of tubers decreased with increased total amount of water applied. Values ranged from 1·073 for the 1 in. every 21 days treatment to 1·065 for the 3 in. every 7 days treatment.

No scab of any consequence occurred on tubers in this trial.

Autumn 1962 *trial.*—This trial had ideal growing conditions. Moderate temperatures prevailed and adequate rainfall after emergence kept the plants growing for 5 weeks and interfered with preparation of the plots for the treatment irrigations. Treatments were applied 6 weeks after emergence and only minor rainfalls then occurred, giving ideal conditions for the somewhat short 6-week treatment phase.

Three inches applied weekly gave the highest yield of tubers (9·3 tons/ac first-grade). Increasing the interval between irrigations decreased yield, while increasing amount increased yield. In contrast to the autumn 1961 trial, the 3 in. applications gave higher yields than the corresponding 2 in. applications at the same frequencies. Generally, increasing total water application gave increased yield.

Specific gravity followed the trend of the autumn 1960 and 1961 trials, with decreasing specific gravity as the total water applied increased. The value ranged from 1·086 to 1·076.

The scab ratings in the trial showed an upward trend in percentage of tuber surface affected with increased amount of irrigation water. The effect, however, was only minor, with the highest value being 5%.

Spring 1960 *trial.*—There were two unfortunate features of this trial. Firstly, a severe leaf miner (*Gnorimoschema operculella* (Zell.)) infestation prematurely destroyed much of the foliage, resulting in low yields throughout and a low proportion of first-grade tubers (average yield 3·2 tons/ac first-grade tubers, ranging from 1·8 to 6·6). Secondly, heavy rainfall preceding the sixth treatment application date, at which only the 7-day frequencies were due, resulted in low specific gravities ranging from 1·064 to 1·069, with no significant differences between treatments. Average temperatures were higher than normal, the average maximum for October being 82·4°F (3·8° above normal), while rainfall was sparse up to the storm preceding the sixth treatment irrigation.

Under the conditions prevailing, however, the 3 in. weekly treatment gave the highest yield (6·56 tons/ac first-grade). Irrigation frequency appeared to be important in this trial, the 7-day frequency significantly outyielding the 14 and 21-day frequencies.

(b) Trial Series 2

Yield data from trials in this series are graphed in Figure 3 and scab ratings in Figure 2.

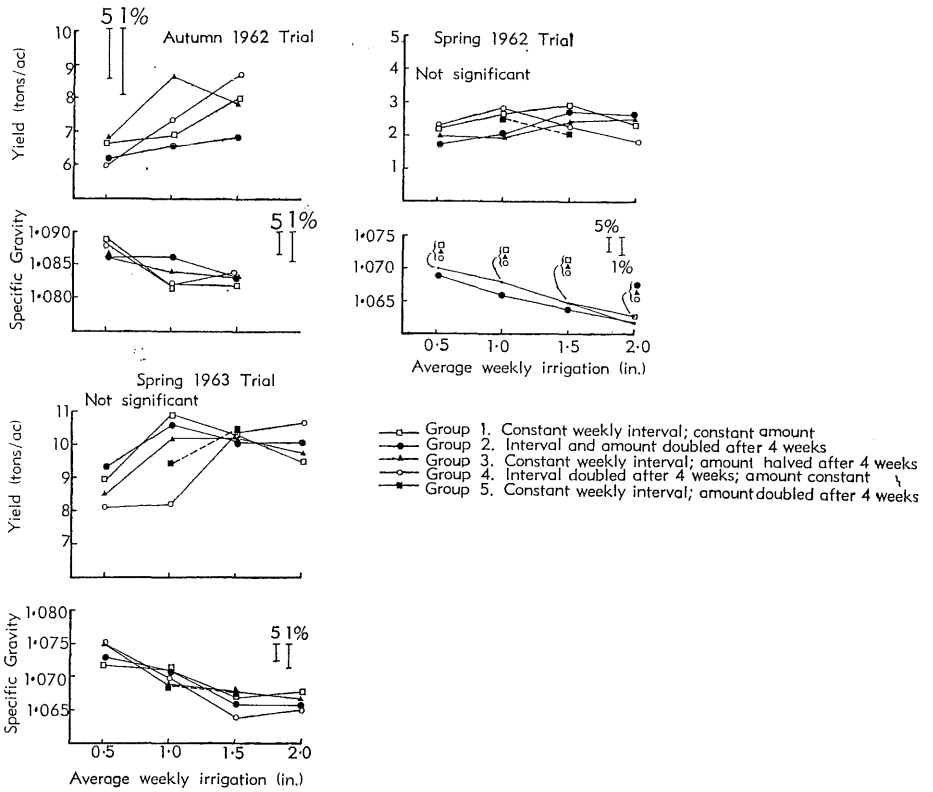

Fig. 3.—Trial series 2: Yields and specific gravities (first grade only).

Autumn 1962 *trial.*—The highest average application of 1·5 in./week gave the highest yields, except in group 3, where 1·0 in./week gave the maximum yield. Specific gravities of the tubers declined as the average application per week increased, the range being 1·089 down to 1·082. Between groups overall there was some effect on yield, but not on specific gravity. Group 3 yield was significantly greater than group 2.

Spring 1962 *trial.*—Early Rhizoctonia infection on plants scattered throughout the trial reduced yields and also resulted in large variations within treatments. Specific gravity again showed a decline with increased total irrigation.

Spring 1963 *trial.*—Average yields of first-grade tubers varied from 8·1 to 10·9 tons/ac. No significant differences were obtained for yield, but the graphed results show a trend for increasing irrigation amount to increase yields up to an average of 1 in./week only. Specific gravity again showed a downward trend from an average 1·074 at 1 in./week average application to 1·066 at 2·0 in./week.

IV. DISCUSSION

Yield.—Yields throughout the series varied widely due to weather conditions, planting times and incidence of insects and diseases.

Within the range of irrigation amounts and frequency combinations used in these trials, the average amount per week, or in other words the total amount of water applied during the treatment period, was the important factor in determining yield rather than frequency used or the amount of individual irrigation applications. The exception to this was the spring 1960 trial, in which the 7-day frequencies significantly outyielded the 14 and 21-day frequencies.

Yields generally rose to a peak between about 1 in. and 2 in. average per week, with no increase beyond 2 in. and, in some cases, distinct yield reduction, according to seasonal conditions. These results appear to approximate those of similar investigations reported in literature.

Cykler (1946, 1947), for example, found that high yields can be obtained by keeping the water content of the soil at a high level (above 50% available soil moisture), while Howe and Rhoades (1948) obtained yields of 600 bus/ac in their high moisture level (16 irrigations) compared with 500 and 470 bus/ac for the medium (7 irrigations) and low (4 irrigations) levels respectively. Jacobs *et al.* (1952) concluded that it is easy to over-irrigate potatoes and that the optimum level of minimum soil moisture applicable to their conditions was 50 to 60% of field capacity, which meant applications of 1·2 in.-2·2 in. applied frequently enough to prevent excessive drying of the soil.

Specific gravity.—Generally, specific gravities recorded in this series of trials were below the generally accepted minimum for processing of 1·080. The trials carried out in autumn 1962 were the only ones in which the majority of treatments exceeded this level.

In the series 1 trials, results showed decreased specific gravity with increasing average weekly amounts of water applied. This appears contrary to the results reported by Jacobs *et al.* (1952) and Box, Stetten, Kyle and Pope (1963), who found that irrigation and high soil moisture increased tuber specific gravity. However, Prince and Blood (1962) found that irrigation *per se* may lower the specific gravity of potatoes but probably not enough to affect marketability.

Some of the series 1 trials not reported here experienced heavy and prolonged rain near the end of the treatment period, and in these specific gravity dropped to uniformly very low values, about 1·062. The series 2 trials were aimed at determining whether amounts and frequencies towards the end of the treatment period could influence the specific gravity. Results, however, still showed much the same type of general decline in specific gravity with increasing amounts of irrigation applied.

Some differences among the frequency groups did occur but these were somewhat inconsistent. In the individual trials there were some significant interactions of groups x amounts. The particular stage of crop growth at the key stages of the experiments, e.g. commencement of irrigation, change of frequency at the fourth week and cessation of the irrigation treatments, would probably account for these inconsistencies from one trial to the next.

The variation in specific gravity between seasons was quite large and probably just as great as any which occurred as a result of irrigation treatments within the one trial. In particular, the spring trials, where tubers were maturing under conditions of increasing temperature, tended to have lower values than the autumn trials, where temperatures were declining towards maturity. This effect is shown in Table 1.

TABLE 1

VARIATION OF SPECIFIC GRAVITY ACCORDING TO SEASON

Season	Specific Gravity		Mean Monthly Maximum Temperature
	Range	Average	
Spring	1·062 to 1·075	1·068	October 83·6°F November 87·2°F
Autumn	1·065 to 1·088	1·079	April 80·6°F May 74·5°F

The flooding system used to apply the irrigation water to the plots could have influenced the tuber specific gravities. This "ponding" tends to cause surface sealing and some temporary waterlogging of the soil. Overall, specific gravities in these trials were lower than those in trials on the Research Station which were spray-irrigated.

Another disadvantage of this method is that treatment irrigations do not commence until the plants are high enough for hilling. de Lis, Ponce and Tizio (1964) reported that the period between appearance of stolons and tuber formation is most important when the effects of a period of moisture stress on yield are considered, stress at this time causing greatest yield reduction. Bradley and Pratt (1955) also demonstrated the importance of high soil moisture level during early growth and development of a potato crop. As the hilling operation in this heavy soil requires relatively dry soil conditions to be effective, a period of moisture stress was necessarily imposed at this important early stage.

It is concluded then that irrigation amount over the middle and late portions of crop development is important in determining yield of tubers from potato crops in the Lockyer Valley. An average weekly amount of about 1-1½ in. appears to be optimum. The frequency and amount combination chosen to apply the watering does not seem to be of overall importance.

Specific gravity is also influenced primarily by irrigation amount. The value decreases as the average amount applied per week increases. There is some indication that the amount x frequency combination used to apply the water can exert an influence on the specific gravity, but the extent of this is only relatively small.

Scab incidence was fairly low throughout but there was a trend to increased ratings at the higher levels of water applied.

V. ACKNOWLEDGEMENTS

The authors wish to acknowledge the assistance of officers and staff of the Gatton Research Station in conducting these trials. The work of the Biometry Branch in carrying out statistical analyses of trial results is also gratefully acknowledged.

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(Received for publication March 9, 1971)

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