The use of a rainshelter to determine yield responses of Russet Burbank potatoes to soil water deficit

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Abstract

The MAF/DSIR rainshelter at Lincoln is described briefly, and some results are presented from an experiment in which yield responses of Russet Burbank potatoes to water deficit were determined. Irrigation treatments were applied to produce soil moisture deficits at varying times, and included a treatment with excess water. Highest yields were obtained from the over-watered treatment. A relatively small maximum potential soil moisture deficit of 45 mm in the 'optimum' irrigation treatment caused a significant 10 t/ha yield reduction. Water deficit during tuber initiation reduced tuber numbers but increased tuber size, so that yields were similar to the optimum treatment. Drought during tuber bulking reduced yields significantly by reducing tuber size. The rainshelter did not affect the crop in any way other than by excluding rainfall.

Additional key words: Solanum tuberosum *L., irrigation, drought, rainshelter.*

Introduction

The complicating effects of unpredictable rainfall in irrigation trials make it difficult to define crop yield and quality responses to timing and severity of water deficit. This means that expensive field trials often have to be carried out over several years to obtain meaningful results, and then the analysis is often complicated by other environmental variation. To avoid this problem, rainshelters, which cover the plots automatically whenever rain falls, are often used to control the amount of water received by experimental crops (Foale *et al.*, 1986). Many older rainshelters have suffered limitations due to restricted covered areas, soil problems such as structure deterioration and build up of soil-borne disease, structural damage caused by strong winds, and high costs. In 1987, MAF Technology and DSIR Crop Research, in oconjunction with the New Zealand Agricultural Engineering Institute, commissioned the design and construction of a rainshelter at Lincoln which has overcome these problems and operated successfully for four seasons.

The first experiment in the rainshelter investigated the yield and quality responses of the potato cultivar Russet Burbank to water deficit. This cultivar is becoming increasingly important in the potato processing industry in New Zealand. The experiment was conducted because Russet Burbank is more sensitive than other cultivars to soil water deficits (Epstein and Grant, 1973; Martin and Miller, 1983), but there was no information on its responses to water deficits under New Zealand conditions.

In this paper we describe the rainshelter briefly. To illustrate its use we then present a summary of results from some of the treatments in the Russet Burbank potato experiment. A comprehensive report on the experiment is being published elsewhere (Martin *et al.*, 1991).

Materials and Methods

Rainshelter

The rainshelter is a durolite greenhouse 54 m long by 12 m wide mounted on wheels which run along parallel rails 12 m apart and 216 m long. The area between the rails is divided into four, and each of these 54 m by 12 m plots is used for an experiment every fourth year, with the three intervening years in pasture. This rotation allows residual treatment effects to be eliminated and prevents the build up of soil-borne diseases and damage to soil structure. Also, when the shelter is not covering the test crop during rainfall it can be parked 54 m away so wind and shade effects are avoided. The shelter is designed to withstand the strongest wind gusts likely to be experienced at this location. The facility is situated on a uniformly deep Templeton silt loam soil.

The rainshelter is moved in both directions by a single cable alongside one of the rails. The cable is driven by an electric motor operating through a hydraulic drive to a winch drum. Four rain sensors are located on the roof of the motor house. When three of these are wet, the computer-controlled drive system is activated and moves the shelter from its parking position to cover the test crop in less than three minutes. The rain sensors are heated to avoid being triggered by dew. There is a delay of 30 minutes when rain ceases before the shelter moves off the test crop. This avoids the potential problem of continual movement during passing showers.

Experimental

On 13 October 1987, Russet Burbank tubers, which had been pre-sprouted, cut and dusted with fungicide, were planted by hand 0.3 m apart in 0.72 m rows in plots 2.9 m (4 rows) wide and 5 m long. Optimum crop management recommendations were followed concerning row moulding, and fertiliser, insecticide, fungicide and herbicide applications.

Results are presented from five of the irrigation treatments in the experiment. These were: a fully-watered 'optimum' treatment which received a 30 mm irrigation whenever the soil moisture deficit reached 50 mm; an 'over-watered' treatment which was irrigated at the same times but with 60% more water than the optimum treatment; and three treatments which were exposed to a target potential soil moisture deficit of 150 mm in either early, middle or late crop development (up to tuber initiation, and during early or late tuber bulking respectively). Soil moisture was monitored by weekly gravimetric and neutron probe measurements. Water was applied through a metered trickle irrigation system with emitters at 0.3 m intervals on lines 0.45 m apart. There were two replicates of each treatment.

The plots were exposed to prevailing climatic conditions except during rainfall, when they were covered automatically by the rainshelter. To check for any direct effects of the shelter on the crop, there were also four plots outside the sheltered area, consisting of two replicates of rainfed or rainfed plus full irrigation treatments.

The crop was harvested on 20 and 21 April 1988, with 20 plants per plot dug by hand.

Results and Discussion

Soil Moisture Deficits

Rainfall during the experiment was only 145 mm, and from 2.8 to 5.1 times that amount was applied to the various irrigated treatments. Maximum soil water deficits were greater for the early and middle drought treatments than the late drought one, but all were less than half that experienced by the rainfed treatment outside the sheltered area (Table 1). The maximum deficit in the optimum treatment was 45 mm.

Yield

Yield variation within treatments was small (C.V. = 3.9%), indicating that the site was uniform and that there was negligible lateral movement of water

TABLE 1: Soil moisture deficits, amount of water applied (irrigation and rainfall), tuber yields, process grade yields, number, mass, and % growth deformities.

Treatment	Maximum potential soil moisture deficit (mm)	Water applied (mm)	Tuber yield (t/ha)	Total tuber number ('000/ha)	Total Tuber Mass (g)	Growth deformities (%)
Inside Rainshelter						
Optimum	45	476	63.5	486	132	8.1
Early Drought	138	369	60.1	299	200	6.3
Middle Drought	135	367	62.5	465	134	12.9
Late Drought	64	403	55.2	384	143	2.6
Overwatered	-	735	73.3	444	166	3.2
L.S.D.(5%)	-	-	5.4	76	30	7.8
Outside Rainshelter						
Irrigated	60	473	67.8	544	124	1.4
Not irrigated	303	145	33.1	530	67	2.9

between plots. Tuber yields for the optimum treatment within the shelter and the irrigated treatment outside were similar (Table 1). This result showed that the effect of the rainshelter on crop growth, as a result of radiation, humidity or wind differences, was minimal.

Highest yields were obtained from the overwatered treatment without any reduction of tuber quality. In this soil, with no impediment to drainage, this degree of overwatering was not expected to affect the crop adversely (Miller and Martin, 1983). In contrast, the yield of the optimum treatment was 10 t/ha less, indicating that the 45 mm deficit was sufficient to cause a yield reduction.

The early and middle drought treatments did not cause significant yield reductions below the optimum treatment. Early drought reduced tuber number, due to its effects on tuber initiation (Salter and Goode, 1967), but yield compensation occurred through increased tuber size. Middle drought had little effect on either tuber number or size, but increased the proportion of tubers with growth defects. This was mainly due to 'second growth', when tubers grow unevenly after a growth check. Painter and Augustin (1976) also found that stress at early tuber set increased the occurrence of malformed tubers. Yield reductions in the late drought treatment were caused by both decreased tuber number and size, even though the maximum soil moisture deficit was less than in the other droughted treatments. However, the stress occurred during the main phase of tuber expansion, which, in Russet Burbank, is very sensitive to water deficit (Gandar and Tanner, 1976).

Conclusions

The rainshelter allowed the responses to water deficit of a potato crop at different stages of development to be determined successfully in a single season. There was no evidence that the rainshelter affected the crop in any way other than by excluding rainfall. The sensitivity of Russet Burbank to small soil water deficits was demonstrated, as were the different effects of drought up to tuber initiation and during tuber bulking.

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