EVALUATION OF IRRIGATION SCHEDULING METHODS AVAILABLE TO POTATO GROWERS

by
Claudio O. Stockle and Larry K. Hiller

Introduction

Given the crop sensitivity to water stress, proper irrigation scheduling is critical for potato production and quality. Irrigation scheduling is also critical due to the large potential for chemical leaching resulting from three main factors: the crop requirement for very frequent irrigations, the crop preference for coarse-textured soils, and the shallow root system of potatoes. Several irrigation scheduling techniques are available to farmers in the region, which should be evaluated for their suitability to ensure high yields and quality while minimizing chemical leaching.

Objective

Compare irrigation amount, number of irrigations, tuber yield, and tuber quality resulting from irrigation scheduling using infrared thermometry, a computer-assisted irrigation scheduling program, and soil water monitoring with a neutron probe.

Methods

The experimental work reported here was conducted at the Othello Research Unit, Othello, Washington, during the growing seasons of 1990 and 1991, using the potato cultivar Russet-Burbank. During the first year, a field trial with randomized complete block design, including four treatments for irrigation scheduling and six replications, was implemented. Treatments consisted of two canopy-temperature based methods, a computer-assisted method, and a method based on soil water monitoring using a neutron probe. During the second year, the number of plots was increased to accommodate six treatments for irrigation scheduling and six replications. These treatments consisted of four criteria for triggering irrigations using a canopy-temperature based method, which provided increasing levels of water stress, a computer-assisted method and a neutron-probe based method. The four canopy-temperature based treatments were established to determine the optimum criterion for scheduling irrigations with this method. Each plot of this experiment was individually monitored, and irrigation water was also individually scheduled and applied to each plot using a micro-sprinkler system.

This Presentation is part of the Proceedings of the 1992 Washington State Potato Conference & Trade Fair.

Canopy temperatures were measured around noon on sunshine days using the SCHEDULER, a commercial sensor. This instrument provides a crop water stress index (CWSI) based on an empirical regression, which is used to determine irrigation timing. This index will be referred to as ECWSI. In addition, canopy temperature measurements and weather information obtained from the Washington State University's Public Agricultural Weather System (PAWS) were utilized to calculate a more theoretical index for determining irrigation timing, to be referred to as TCWSI. Both indices provide a number from 0 to 10, where 0 corresponds to no stress while 10 identifies maximum stress. Both, ECWSI and TCWSI indices were compared in 1990, while only ECWSI was used during 1991. During 1990, irrigations were scheduled each time the CWSI was greater than 0.5 for two consecutive days. During 1991, the triggering point for irrigations was given by CWSI values of 1 (CWSI1), 2 (CWSI2), 3 (CWSI3), and 4 (CWSI4) for two consecutive days. Because canopy-temperature methods are unable to determine the irrigation amounts to be applied, these quantities were obtained from the crop evapotranspiration (ET), estimated as in the computer-assisted method and accumulated since the previous irrigation.

The computer-assisted irrigation scheduling method (CAS) consisted of a soil water balance program developed using a computer spreadsheet which tracked the soil moisture depletion in the root zone. The soil water extraction by the crop was estimated using the values of potential ET reported by PAWS multiplied by a crop coefficient for potatoes which fluctuated depending on crop ground coverage and growth stage. Irrigations were scheduled every time that the soil moisture was estimated to be depleted below 70% of the maximum water holding capacity of the soil explored by roots.

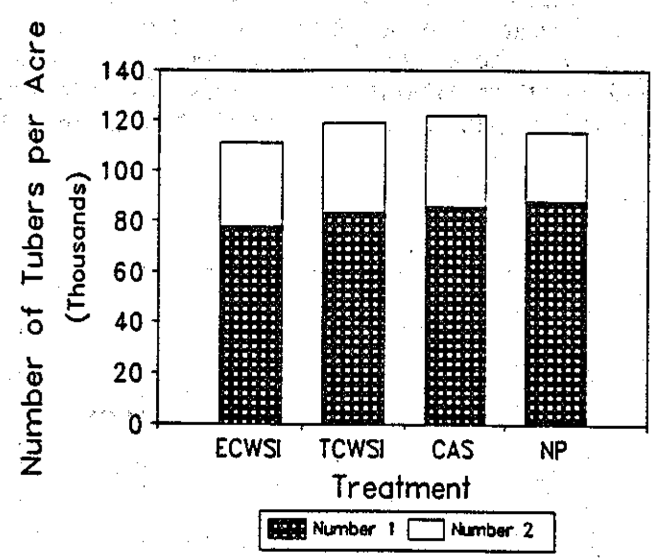
The neutron-probe based irrigation scheduling method (NP) consisted of frequent (twice a week) soil moisture measurements to a depth of two feet and estimates of crop ET, similar to those described for the CAS method. Irrigations were scheduled to avoid soil water depletion below 70% of the maximum water holding capacity of the soil.

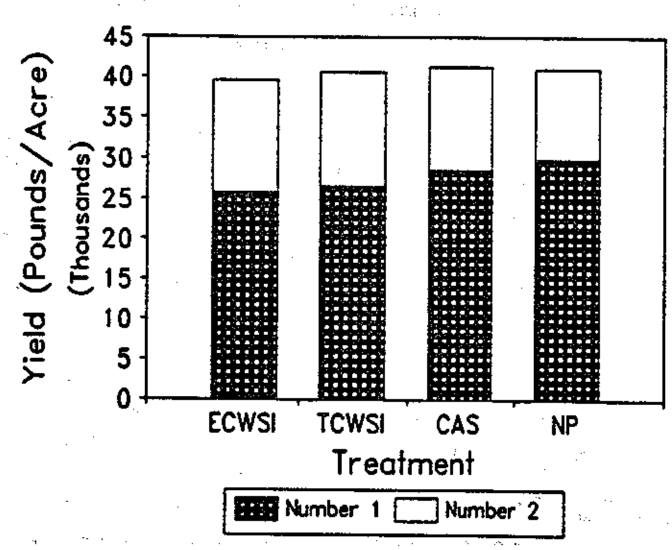
A printout of the SCHEDULER readings was transmitted daily by fax to Pullman. PAWS weather and ET data was also retrieved via modem from Pullman on a daily basis. The recommendations for irrigation were determined and instructions were sent by fax to Othello for implementation. The application rate of the micro-sprinkler system was measured for all plots and found to be reasonably constant (0.4 in/hr). Irrigation duration was determined by dividing the scheduled irrigation amount by the application rate. For practical reasons, a maximum of three hours of irrigation was allowed in any given day. Soil tensiometer stations of 6, 12, and 18-inch units were established in random plots and monitored daily for additional information on soil water levels throughout the season. In 1991, Watermark resistance blocks were also installed in selected plots.

The data collected throughout the growing season allowed determination of irrigation timing and amount for each individual plot and changes in soil water in selected plots.

Measurements of leaf water potential and stomatal conductance were also performed during 1991 to establish possible stress effects of the four irrigation timing criteria used with the canopy-temperature based irrigation scheduling method. At harvest, potato yields and number of tubers were determined for each plot, and the tubers were classified into the following categories: a) number one tubers, b) number two tubers, c) malformed tubers, d) tubers with knobs, e) tubers with growth cracks, and tubers with pointed ends.

Figure 1.

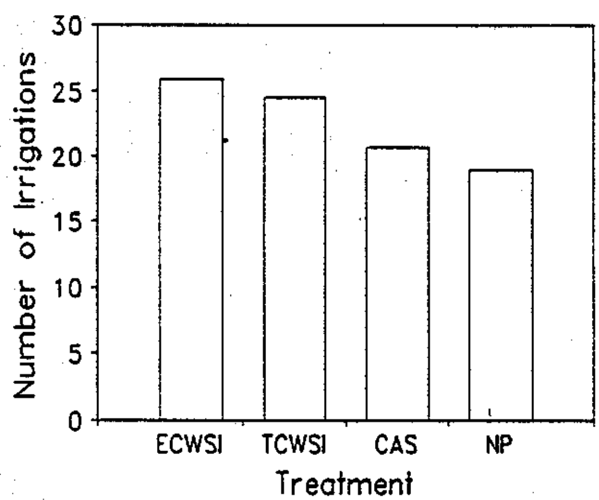


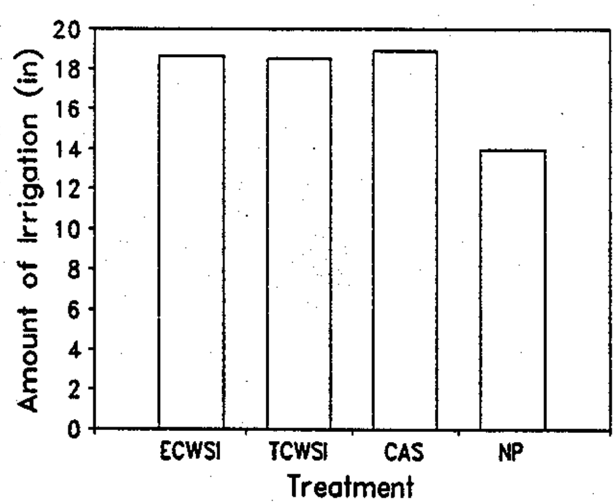


Results

A partial summary of the results obtained during 1990 is presented in figures 1 and 2. The four treatments applied on that year did not show statistical differences for the total number of tubers. In terms of total yield (pound/acres), TCWSI, CAS and NP were not different, while ECWSI was significantly lower ($p<0.05$) than CAS, which obtained the higher yield. The effect of treatments was more significant when the yield of number one tubers were compared. Yields decreased in the sequence NP > CAS > TCWSI > ECWSI, with NP yields being statistically different to ECWSI at $p<0.05$ and to TCWSI at $P<0.1$. NP and CAS treatments were not different. The sequence of treatments was similar for number of number one tubers, but the differences were not statistically significant. The number of irrigations applied (Fig. 2) decreased in the sequence ECWSI > TCWSI > CAS > NP, with NP and CAS treatments showing a small difference.

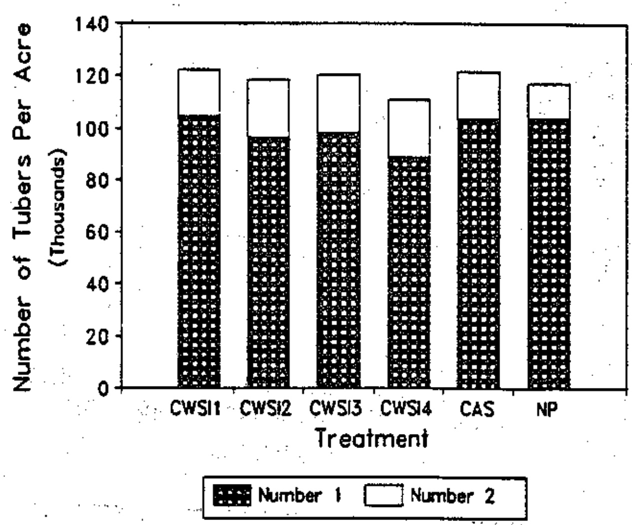
Figure 2.

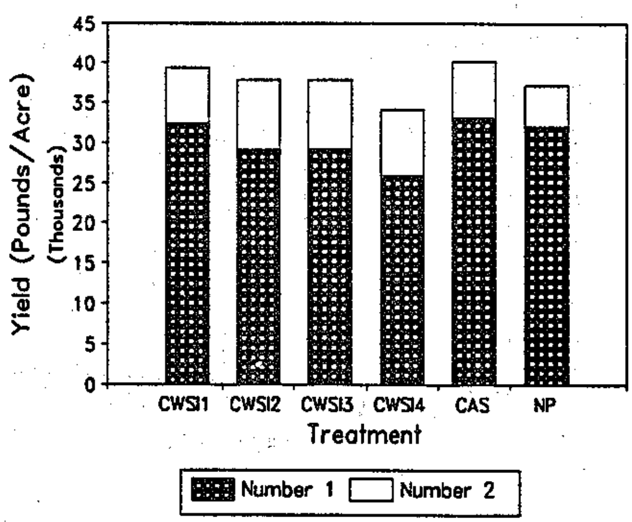




In terms of amount of water applied, NP used clearly less water than the other treatments, which were very similar. The larger amount of water applied by treatments other than NP was likely the result of overprediction of potential ET by PAWS. The crop coefficients utilized to estimate crop ET are relatively well established.

Figure 3.

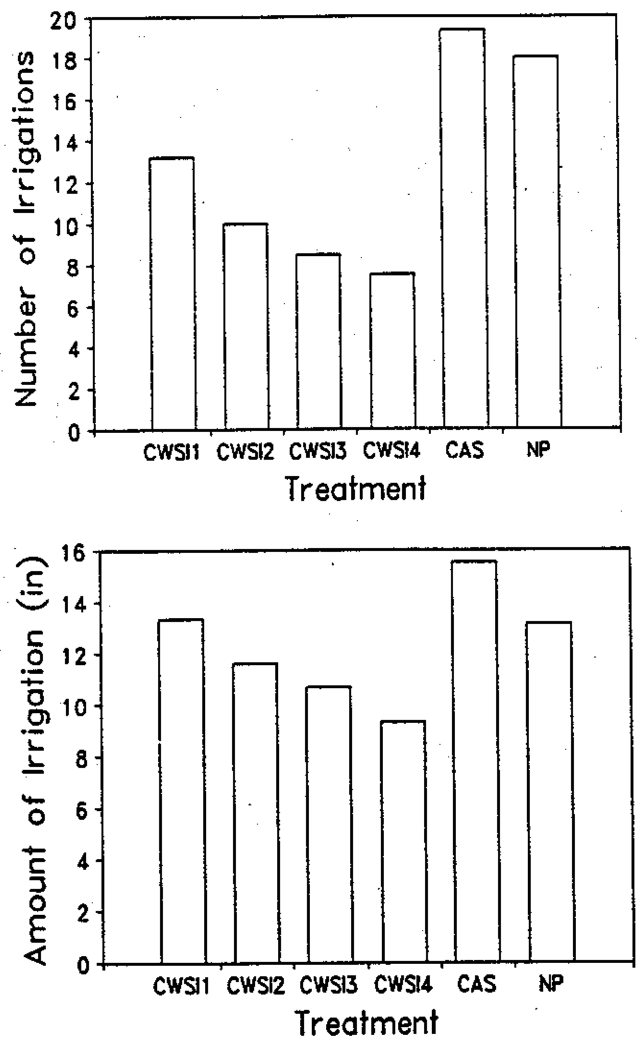




Some of the results obtained during 1991 are shown in figures 3 and 4. During this year, the irrigation scheduling treatments were not different in terms of total yield (pounds/acre) or total number of tubers. The canopy-temperature based method with larger water stress (CWSI4) produced the lowest total yield, but this was not statistically different to the yield of any other treatment.

The effect of treatments was more pronounced when yield and tuber number of number one potatoes were compared. The CWSI4 treatment yielded statistically less than CWSI1 ($p<0.1$), CAS ($p<0.07$), and perhaps NP ($p<0.12$). The trend was similar but slightly less marked for tuber number of number one potatoes.

Figure 4.



Treatments CWSI2 and CWSI3 yielded less than CWSI1, CAS, and NP, but the difference was not statistically significant. In terms of number of irrigations, NP and CAS were very similar and with a markedly greater number of irrigations than the canopy-temperature based treatments. These latter treatments presented a declining number of irrigations in the sequence CWSI1 > CWSI2 > CWSI3 > CWSI4, as expected. The amount of irrigation followed a similar trend, but with less differences.

This year, CAS and CWSI1 treatments applied a more similar amount of water compared to the NP treatment than during 1990. This resulted from reduction in 1991 of the crop coefficients utilized to calculate crop ET as a means of compensating for possible PAWS overprediction of potential ET. The different canopy-temperature based methods should have applied a relatively similar amount of irrigation because, although the number of irrigation scheduled were decreasing from CWSI1 to CWSI4, the amount to be replenished was not expected to be very different. However, the limit imposed to the duration of each scheduled irrigation (3 hours) contributed to also reduce the total amount of water applied.

Conclusions

The three methods of irrigation scheduling (neutron probe, canopy temperature, and computer-assisted) seem capable of producing reasonable schedules that preserve maximum yield and tuber quality. However, in terms of the amount of water applied, which must be carefully controlled to avoid nitrate leaching, soil moisture monitoring appears as a safer method. The computer-assisted and canopy-temperature based methods improved substantially in this respect during 1991. The determination of irrigation amounts with these methods should further improve with additional reduction of the crop coefficient. Crop ET was still overpredicted during 1991.

The computer-assisted approach with a minimum soil moisture checking (two or three times during the growing season) is probably a more cost effective and as accurate of a method as is frequent monitoring of the soil moisture using a neutron probe. More attention should be given to this approach as well as to improving the quality of potential ET data from the PAWS network.

The canopy-temperature based methods seem to have some serious shortcomings. The main one is the fact that the method can not be applied with confidence until the crop covers completely the ground, and furthermore, is also of little use once the crop canopy begins to decline (senescence) when the readings become erratic and unresponsive to water applications. No difference was found in the performance of the two indices (ECWSI and TCWSI) utilized in 1990. Water application amounts can not be determined with the canopy-temperature based method and they must be calculated in a similar fashion than the computer-assisted method. The method is therefore also dependent on the availability of good information from PAWS.

The method can be an excellent complement to computer-assisted scheduling, especially as a quick way of checking the spatial variability of the crop water balance in the field.

Although potato is a crop sensitive to water stress, water applications could be reduced to some extent without dramatic reduction of yield and quality, as shown by the CWSI treatments during 1991. This has some implications for the implementation of management practices aimed to reduce the potential for nitrogen leaching from potato fields.

Not all the data collected and analyses performed are presented in this brief report. For example, the analysis of the incidence of malformed tubers and other characteristics reducing the quality of tubers as well as details of other results (leaf water potential, stomatal conductance, and others) obtained during the two years of this project are not presented here. A written communication to the 1992 Summer Meeting of the American Society of Agricultural Engineers is under preparation, which will include a more thorough report of the activities of the project in the first two years. Also, a paper to a scientific journal will be prepared during the summer 1992. All this material will be available from the authors upon request.