COMPARISONS OF METHODS OF SCHEDULING IRRIGATIONS OF POTATOES

S. Dubetz and K. K. Krogman[1]

Abstract

Irrigation of Netted Gem potatoes was scheduled during three growing seasons by three methods: (a) when plants displayed first visual symptoms of moisture stress, (b) when indicated by a soil moisture budget involving estimated evapotranspiration, and (c) on the basis of tensiometer readings of soil moisture suction. When the tensiometer method of scheduling was used, the mean yields of tubers were 55.0 and 25.8 cwt/acre (6160 and 2890 kg/ha) higher than those obtained with the other two scheduling methods. Methods did not affect the specific gravity of potatoes. Method (a) scheduled irrigations least frequently. Scheduling by the budget method was not always adequate because it was based on the assumption that the crop extracted water from a constant 4 ft (1.2 m) profile from planting to full vegetative growth. In one year the budget method scheduled the first irrigation earlier than necessary and delayed the second irrigation during a critical period of crop growth. From full vegetative cover to harvest the irrigation schedules were alike for both the budget and tensiometer methods.

Introduction

In the past, most growers in southern Alberta applied water according to their experience and by observation of the crop and soil. During the past decade some farmers have used the "irrigation budget service" of the Irrigation Extension Service of the Alberta Department of Agriculture. The service provides advice on when to irrigate different classes of crops on the basis of measured soil moisture reserves at the start of the growing season, rainfall, and estimated rates of evapotranspiration (3).

Potatoes require a continuous supply of available soil water that is compatible with proper soil aeration. Bradley and Pratt (1) and Prince and Blood (10) reported that tuber yields were greatest when soil moisture tensions could reduce yields through impaired aeration. Chase et al. (2) found that for efficient water utilization there was no advantage in maintaining the minimum available water above 65%. Motes and Greig (9) reported that varieties responded differently to soil water depletion.

Jones and Johnson (6), Stockton (11), and Timm and Flocker (12) found that the best time to irrigate potatoes was when the soil moisture tension was in the range of 40 to 60 centibars. Irrigating at lower soil moisture tensions could reduce yields through impaired aeration.

This paper presents results of experiments conducted for 3 years to compare three methods of scheduling irrigation for potatoes with respect to yield and soil water supply for the crop.

Materials and Methods

Netted Gem potatoes were grown in 1969, 1970, and 1971 at the

[1]Soil Scientists, Canada Department of Agriculture, Research Station, Lethbridge, Alberta T1J 4B1. Received for publication April 30, 1973.

Canada Department of Agriculture Irrigation Research Substation, Vauxhall, Alberta. The experiments were laid out on a Brown chernozemic (Typic Haploboroll) loam (Chin series) developed on alluvial-lacustrine material. This is one of the predominant soil types in the area. The average density of this soil is about 1.5 g/cc, and the available water-holding capacity to the 4 ft (1.2 m) depth is 5 to 7 inches (13 to 18 cm).

Irrigation was scheduled by three methods: (a) check, irrigate when the plants displayed first visual symptoms of moisture stress; (b) budget, irrigate when about half the available soil water was depleted, as calculated by the budget procedure (3, 4); and (c) tensiometer, irrigate when the soil water suction as measured with mercury manometer tensiometers reached 40 centibars. Description of these methods follows:

(a) The check treatment required an application of 4 inches (10.2 cm) of water when the plants first evidenced moisture stress (foliage dark green and wilting). This method, which is practiced by some growers in the area, scheduled two or three irrigations per year.

(b) The irrigation budget method involved measuring gravimetrically the soil water to the 4 ft (1.2 m) depth in spring; estimating the number of inches of evapotranspiration by multiplying evaporation (cc) from a black Bellani plate atmometer from planting date to June 15 by 0.0013, from June 16 to July 10 by 0.0027, from July 11 to August 20 by 0.0035, and from August 21 to harvest by 0.0024; and maintaining a budget by subtracting withdrawal of soil water, as estimated by evapotranspiration, and adding rainfall and irrigation. Each time the budget indicated that the soil moisture deficit in the 4 ft (1.2 m) depth equalled 2.5 inches (6.4 cm), this amount of irrigation water was applied.

(c) For the third method, duplicate tensiometers were installed at the 1 ft (0.3 m) depth, and 2 to 2.5 inches (5.1 to 6.4 cm) of water was applied whenever the soil water potential reached 40 centibars. This procedure replenished the soil water in the 4 ft (1.2 m) depth to field capacity (about ⅓ bar suction) whenever 50 to 60% of the available water had been depleted (7).

The furrow method of irrigation was used with all three methods of scheduling, and water was measured with household water meters. The fertilizer treatment was based on soil tests and consisted of placing 100 lb N and 50 lb P_2O_5 or 22 lb P/acre (112 kg N and 56 kg P_2O_5 or 25 kg P/ha) in bands near the tuber sets each year. The experimental unit consisted of three rows 36 inches wide and 30 ft long (91 cm wide and 9.14 m long). At harvest, tubers were graded as Canada No. 1, Canada No. 2, and culls. The specific gravity of marketable tubers was determined by the water immersion method. Treatments were arranged in a randomized block design with four replications in each of the 3 years. The significance of differences among data means was assessed by analysis of variance.

Percentages of available soil moisture throughout the growing season were calculated for 1970 and were compared with soil moisture amounts that were measured at harvest. The average daily soil moisture content to 4 ft (1.2 m) for each treatment was calculated as described previously for the budget method, except for the check plots where estimated evapotranspiration was reduced by 30% during periods from 7 days after an irrigation until the next irrigation. Hobbs and Krogman (4) showed that

TABLE 1.—*Summary of irrigation data for three methods of irrigation scheduling conducted at Vauxhall, Alberta, 1969-1971.*

Year	Scheduling method	Irrigations First	Irrigations Mean interval (days)	Irrigations No.	Irrigations Total (in.[1])	Total + rain (in.[1])	Evapotranspiration (in.[1])
1960	Check	July 22	23.0	2	8.0	13.0	......
	Budget	July 20	10.8	5	12.5	17.5	......
	Tensiometer	July 17	9.6	6	15.0	20.0	......
1970	Check	July 15	17.5	3	12.0	19.5	19.2
	Budget	June 11	15.6	6	16.1	23.6	22.8
	Tensiometer	July 10	8.8	7	16.0	23.5	22.5
1971	Check	July 15	21.0	2	8.0	15.5	......
	Budget	June 30	12.2	5	12.3	19.8	......
	Tensiometer	July 6	12.6	6	12.2	19.7	......

[1]1 inch = 2.54 cm.

where irrigation was similarly restricted evapotranspiration averaged about 70% of that where irrigation was ample. On the tensiometer plots, soil moisture expressed as a percent of available soil moisture at the 1 ft (0.3 m) depth was calculated for 3 to 4 day intervals through the use of a soil moisture characteristic curve.

RESULTS

Soil moisture, irrigation, and evapotranspiration

Date of first irrigation, time interval between irrigations, number of irrigations, and total water applied varied among the methods of scheduling (Table 1). The check plots, which were last to receive the first irrigations required only two or three irrigations and the intervals between irrigations were longer than with the other two methods. The tensiometer plots received one more irrigation per year than the budget-scheduled plots. In 1969 the tensiometer plots received 2.5 inches (6.4 cm) more water than the budget plots, but in 1970 and 1971 the total amount of water applied was the same for both methods.

In 1970, soil moisture to the 4 ft (1.2 m) depth was depleted from about 40% of the available range in early May to about 10% in early June, according to the soil moisture budget (Fig. 1). Rainfall totalling 3.4 inches (8.6 cm) restored the average moisture content of the 4 ft (1.2 m) depth to about 45% on the check and tensiometer plots. On the budget plots an additional 3.5 inches (8.9 cm) of water applied by irrigation was required to bring the soil water to field capacity.

On the tensiometer plots, the tensiometer readings showed that soil moisture at the 1 ft (0.3 m) depth was at field capacity after the 3.4 inch (8.6 cm) rainfall occurred on June 10. Thus, rainfall in early June was sufficient to replenish soil moisture to at least the 1 ft (0.3 m) depth, but deeper in the profile the available soil water would have been low.

The data indicate that the opposite situation existed on the budget plots between July 8 and July 14. On July 8 the tensiometers indicated that soil moisture was reduced to about 60% of the available range and

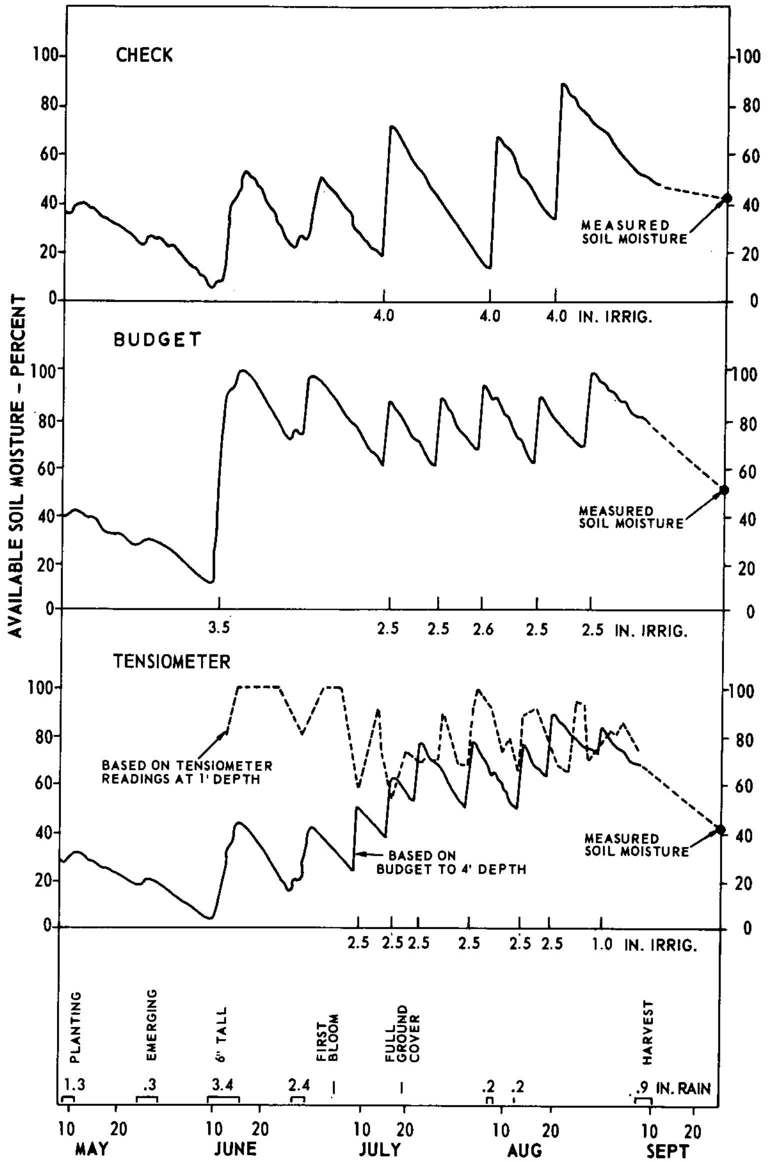

FIG. 1.—Calculated percentages of available soil water in 1970 for a 4-ft (1.2-m) profile, based on a soil moisture budget for three methods of scheduling irrigations and, at the 1-ft (0.3-m) depth, based on soil moisture suction where irrigations were scheduled by tensiometers. (1 inch = 2.54 cm.)

2.5 inches (6.4 cm) of irrigation was required on these plots to restore soil moisture to about 90% of the available range. But irrigation of the budget plots was not scheduled until July 14, by which time the method estimated soil moisure for the 4 ft (1.2 m) depth to be nearing 50% of the available range. Thus, the soil moisture in the top foot of these plots likely was below 50% of the available range and at lower depths likely near field capacity.

From mid-July to the end of the growing season, soil moisture, as assessed by either the budget or tensiometer readings, remained in the upper half of the available range.

The amounts of available water in the check plots as calculated by the budget for the 4 ft (1.2 m) depth were usually below 60% of the available range. However, the rainfalls of early and late June and the three irrigations were sufficient to wet the upper part of the profile to field capacity. Thus, the deficiencies in soil moisure on the check plots were not as severe as indicated by the budget calculation, although moisture stress must have developed before each of the three irrigations.

Seasonal totals of irrigation plus rainfall and of evapotranspiration were similar for the tensiometer and budget plots but were about 3.5 inches (8.9 cm) less for the check plots (Table 1). Data from spring and fall soil moisture samples taken in 1970 were used to calculate seasonal evapotranspiration for that year. The calculated amounts of soil moisture at the end of the growing season and the amounts measured gravimetrically by soil sampling agreed closely (Fig. 1).

Tuber yield and quality

In 1969, yields of Canada No. 1 and total tubers grown on plots irrigated by tensiometer scheduling were significantly higher ($P = 0.05$) than those grown on plots where irrigation was scheduled by the other two methods (Table 2). Yields from the budget plots were significantly higher than those from the check plots. In 1970, total yields from the tensiometer plots were significantly higher than those from plots irrigated by the other methods. In 1971, irrigation treatments did not affect yields significantly, although the yields of the check treatments were the lowest. Irrigation treatments had no effect on yield of Canada No. 2 or cull tubers in all 3 years.

Mean yields (1969-1971) of Canada No. 1 potatoes from the tensiometer plots were 27.0 cwt/acre (3024 kg/ha) higher than those from the budget treatment and 61.6 cwt/acre (6899 kg/ha) higher than those from the check treatment. These increases were reflected in total tuber yields.

The percentages of culls averaged 15.8, 17.1, and 21.1 for the tensiometer, budget, and check treatments, respectively. The quality of potatoes as indicated by specific gravity did not differ significantly among treatments (Table 2).

Discussion

The superiority of the tensiometer method over the budget method is attributed to measurement of soil moisture suction at a depth that is useful for most of the growing season. Recent studies by Kunkel et al. (8) showed that most of the potato roots (70%) are found in the top foot of soil. By comparison, the budget method estimated soil water content in a 4 ft (1.2 m) zone for the entire season even though the roots of potatoes may not have reached full depth until mid-season. In spring, when rooting is shallow and evapotranspiration is low, small rainfalls are

TABLE 2.—*Yield and specific gravity data of potatoes grown under three methods of irrigation scheduling at Vauxhall, Alberta, 1969-1971.*

Year	Scheduling method	Yield (cwt/acre[1]) No. 1	No. 2	Culls	Total	Specific gravity
1969	Check	120.8c[2]	39.4a	42.2a	202.4c	1.0977a
	Budget	172.8b	34.6a	36.0a	243.4b	1.0933a
	Tensiometer	228.0a	33.4a	35.6a	297.2a	1.0970a
1970	Check	220.8a	18.2a	42.0a	281.2b	1.0930a
	Budget	236.0a	17.0a	37.2a	290.2b	1.0952a
	Tensiometer	250.8a	17.2a	43.6a	311.6a	1.0967a
1971	Check	179.0a	29.6a	77.2a	282.8a	1.0967a
	Budget	219.6a	27.2a	73.4a	320.2a	1.0982a
	Tensiometer	226.6a	27.4a	67.8a	322.4a	1.0948a
Mean	Check	173.6c	29.2a	53.8a	255.4c	1.0958a
	Budget	208.2b	26.2a	48.8a	284.6b	1.0956a
	Tensiometer	235.2a	26.0a	49.0a	310.4a	1.0962a

[1]1 cwt/acre = 112 kg/ha.

[2]Any two means, within a subgroup, followed by the same letter are not significantly different.

sufficient to replenish soil moisture to the depth of the young root system. Thus, in 1970, lack of available soil moisture in the lower half of the root zone from planting to mid-June did not inhibit plant growth nor was irrigation really needed.

From mid-June to early July, 1970, the budget method overestimated the amount of soil water available to the crop, again because the profile depth used in calculating the budget was greater than the actual rooting depth. Thus a large portion of the calculated available water was out of reach for plant use. The tensiometer readings showed that available water was rapidly depleted from July 6 to July 10. Further depletion without replenishment in the budget plots probably lowered soil moisture content of the actual root zone to below 50% of the available range. Thus the budget method failed to schedule the second irrigation soon enough. Consequently, soil water stress may have developed during the critical early bloom period and, as a result, yields were reduced.

After the ground was fully covered and the root system fully extended, the budget and tensiometer methods scheduled irrigation with similar frequency. It appears, therefore, that the budget method of scheduling irrigation that was used here could be improved by utilizing soil moisture profiles that vary with the actual rooting depth. The procedure for scheduling irrigation using climate-crop-soil data as described by Jensen et al. (5) includes actual rooting depth in calculating the allowable amounts of soil moisture depletion.

CONCLUSIONS

Irrigation scheduled by the tensiometer method gave higher yields (average of 13 and 9% for Canada No. 1 and total tubers, respectively) than those obtained from irrigation scheduled by a soil moisture budget method that employed a constant depth of rooting. The soil moisture data in 1970 illustrated the possible discrepancies between the two methods although the same discrepancies may not necessarily occur or be the same in all years. If the depth of profile used in calculating the soil moisture budget coincided with advancing depth of rooting, the discrepancies between the tensiometer and budget methods should be reduced or eliminated.

Tensiometers at the 1 ft (0.3 m) depth can be used satisfactorily to schedule irrigations throughout the growing season if the relationship between moisture suction at that depth and the soil moisture deficit for the full root zone is known. A soil moisture budget based on a constant 4 ft depth of rooting provides a satisfactory schedule for irrigation only during the last half of the season.

Acknowledgment

The authors wish to thank the Alberta Potato Commission and the Alberta Agricultural Research Trust for providing financial assistance to conduct this research. The cooperation of Dr. J. A. Robertson, Professor of Soil Science, University of Alberta, Edmonton, is also appreciated.

Literature Cited

1. Bradley, George A. and A. J. Pratt. 1954. The response of potatoes to irrigation at different levels of available moisture. Amer. Potato J. 31: 305-310.
2. Chase, R. W., E. H. Kidder and R. J. Kunze. 1969. Res. Rep. 94. Michigan Agr. Exp. Sta.
3. Hobbs, E. H. and K. K. Krogman. 1968. Irrigation scheduling: An example of research-extension-grower cooperation. Agr. Inst. Rev. 23(1): 23-24.
4. Hobbs, E. H. and K. K. Krogman. 1970. Evaluation of a method of irrigation scheduling. Can. Agr. Eng. 12: 25-32.
5. Jensen, M. E., D. C. N. Robb and C. E. Franzoy. 1970. Scheduling irrigations using climate-crop-soil data. J. Irrig. Drainage Div., ASCE, 96: 25-38.
6. Jones, Sam T. and W. A. Johnson. 1958. Effect of irrigation at different minimum levels of soil moisture and of imposed drought on yield of onions and potatoes. Amer. Soc. Hort. Sci. 71: 440-445.
7. Krogman, K. K. 1967. Evapotranspiration by irrigated grass as related to fertilizer. Can. J. Plant Sci. 47: 281-287.
8. Kunkel, R., M. Campbell and R. Thornton. 1972. Potato fertilizer and moisture management — What's needed? Proc. 11th Annu. Wash. Potato Conf. Trade Fair. pp. 87-98.
9. Motes, J. E. and J. K. Greig. 1969. Effect of irrigation on soil temperature, potato yield and specific gravity during early summer. J. Amer. Soc. Hort. Sci. 94: 510-511.
10. Prince, A. B. and P. T. Blood. 1962. Some effects of irrigation and fertilization on the yield and quality of Kennebec potatoes. Amer. Potato J. 39: 313-319
11. Stockton, J. R. 1962. Potato irrigation studies. 12th Nat. Potato Util. Conf.
12. Timm, Herman and J. J. Flocker. 1966. Response of potato plants to fertilization and soil moisture tension under induced soil compaction. Agron. J. 58: 153-157.