

CREDIT TO GIVE FOR RAIN WHEN SCHEDULING IRRIGATIONS IN SEMI-HUMID AREAS*

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INTRODUCTION

A previous investigation, on how much credit to give for rain in semi-arid areas, was reported by the author (3) in 1967. The data used were obtained from evaporimeters and rain gauges placed near orchards. It was concluded (a) that once an irrigation is started it should be continued to completion irrespective of rain, and (b) that no more credit should be given for rain than would raise the moisture content of the soil to field capacity in any part of the field. This latter could be accomplished by adhering to the two following rules:

1. While irrigation is in progress, give credit for rain only up to the evapotranspiration of the day.

2. Between irrigations, give credit for rain only up to the soil moisture balance that was entered at the first setting of the sprinkler line at completion of the previous irrigation. This balance at the first setting occurred at the same time as the balance that represented field capacity at the last setting.

Giving more credit for rain than was allowed by these two rules gave credit for water above field capacity, caused an unwarranted delay in the start of the next irrigation and, in some cases, resulted in very low soil moisture balances before the next irrigation was completed.

Since the above paper was written, daily records of evaporation and rain have been obtained from semi-humid sites in British Columbia. Summer rains were more frequent, and often of much greater daily magnitude, than in the semi-arid areas. An examination of the records led to speculation as to whether an irrigation should be discontinued during rainy

weather, and as to whether methods could be developed for giving more credit for rain in semi-humid areas without undue risk of excessive soil drying.

The problem has, therefore, been re-investigated. It was felt that answers were needed to such questions as the following: (a) Should irrigation be stopped when it rains? If so, how much credit can safely be given for rain? (b) Is it safe to allow the soil at the first setting to dry below 60% available water before starting to irrigate? If so, the procedure used would differ from that previously suggested for Okanagan orchards (2, 4). (c) Can more credit be given for rain by keeping balance columns for more settings than the first one, without undue risk of soil drying? This paper reports the results obtained, and discusses the benefits and risks involved, by use of the procedures that were tried in an attempt to answer these questions.

DEFINITIONS

Definitions of some special terms used are as follows:

Interval. The number of days between the start of an irrigation at any one spot and the start of the next irrigation at the same spot.

Safe interval. The longest interval feasible at a time of peak evapotranspiration, without allowing the soil moisture content at the first setting to fall below 60% available water.

Peak evapotranspiration (peak ET). The greatest total ET in inches that occurs during a safe interval. It is determined by multiplying evaporation in inches from carborundum block evaporimeters by 0.36 (5).

Credit depth. The inches of credit given on a balance sheet for water applied at an irrigation. It is 40% of the available water to effective root depth.

Setting. The area irrigated in a 24-hour period. Each irrigation starts at the first setting and ends at the last setting.

Seasonal net ET. Total ET for the irrigation season minus credit given for rain on the balance sheet. Dividing the seasonal net ET by the application efficiency factor gives the seasonal irrigation requirement.

Artificial model. An irrigation simulation model using hypothetical values for safe interval, number of days required to irrigate, rate of ET per day, amount and times of rain, and credit depth.

Natural model. An irrigation simulation model using daily records of ET and rain obtained at a specified site during an irrigation season.

MODELS USED

Both artificial and natural models were used, as defined above. In the former, ET was assumed to be constant at 0.24 inch per day, the safe interval was nine days, each irrigation took nine days, and the credit depth for irrigation was 2.16 inches. Either single rains of high daily magnitude or longer rainy spells were assumed to occur.

Three types of field record were selected for the natural models: (a) Many rainy days occurred during the season, most of the rains being of low magnitude. Sites selected were at Kersley and Smithers in 1966. (b) Fewer rainy days occurred but there were more rains of high magnitude. Sites selected were at Agassiz and Sumas in 1967. (c) The climate was semi-arid, as represented by an orchard at Summerland.

At each of two sites a dry year and a wet year were compared. It was assumed that the safe interval was ten days and that it took ten days to irrigate. The irrigation season was considered to be from May 1 to Sep-

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tember 15. Some characteristics of these natural models are shown in Table 1.

METHODS AND RESULTS

Several new procedures for giving credit for rain were tested. They were designed primarily to answer the questions posed above in the introduction. In order to coordinate the procedures and results more closely, each method used and the results obtained using it are presented together.

Standard method (method 1)

The procedure for this method has already been described (3). Each irrigation is started when the soil at the first setting holds about 60% available water. On the first day of irrigation a credit is given for irrigation that brings the soil at the first setting to field capacity. On each subsequent day a debit is entered for ET, and a credit is given for rain in accordance with the two rules noted in the introduction. When the balance drops to 60% available water at the first setting, the next irrigation is started. As a check on the danger of severe soil moisture deficits developing in other parts of the field than at the first setting, daily bal-

ances were kept for the center and last settings as well.

The results obtained using natural models varied widely (Table 2). The lowest balance shown at the last setting was 45% available water. This was less severe than the 36% reported in a previous investigation (2). Not shown in Table 2 are the data from Summerland in 1967, where the seasonal net ET was 23.33 inches and the lowest balance was 44% available water, nor the data from Sumas in 1967, where the results were similar to those for Agassiz.

Stopping an irrigation because of rain (method 2)

Artificial models were used that differed in the amount and persistence of rain. With both artificial and natural models, irrigation was stopped whenever the rain amounted to as much as the ET of the same day. Credit for rain was then given in the same manner as during a layoff period between irrigations (rule 2 above). By a modification (2A), credit was given at the first setting for rain up to field capacity, and irrigation was started again when the balance was reduced to the same point as when irrigation had been discontinued. By another modifica-

tion (2B) the sprinkler line was moved back to the first setting every time enough rain fell to wet the whole field to field capacity.

Method 2 resulted in some saving of time and water, with little if any greater risk of serious moisture deficits. This is indicated by a comparison with method 1 in Table 2. Method 2A gave much more credit for rain as shown in Table 2, but increased considerably the risk of soil drying. The balance at the last setting was as low as 17% available water. In an artificial model (Table 3) the lowest balance was 24% available water. In comparison with method 1, the stoppages of irrigation were approximately doubled. Method 2B gave results quite comparable to those of method 2. The work involved in moving sprinklers would, however, be greatly increased.

Allowing balance to reduce to a specified value below 60% available water (method 3)

This was the same as the standard procedure (method 1) except that the start of each irrigation was delayed until the balance at the first setting indicated 50% available water. The irrigation water applied was increased by 10% available water for all irrigations except the first, to bring the soil moisture back up to field capacity again. By a modification (3A) the irrigation was not increased, so that after completion of each irrigation the moisture content of the soil was presumably below field capacity.

Method 3 resulted in an average saving of 0.90 inch or 7% of the seasonal net ET when compared with method 1 (Table 2). The lowest balance, however, was 33% available water compared to 45% by method 1. Method 3A had a somewhat higher seasonal net ET than did method 3, but an average least balance of about 52% available water. It was comparable to method 1.

Regulation of credit for rain by use of first, center and last settings (method 4)

Balances were kept for the first, center and last settings. Credit was given for rain up to field capacity at that setting with the highest balance; then this same credit was given to the

TABLE 1. SOME CHARACTERISTICS OF THE NATURAL MODELS USED*

Location	Year	Total ET	Peak ET**	Total rain	No. of rainy days	Highest daily rainfall.
		<u>inches</u>	<u>inches</u>	<u>inches</u>		<u>inches</u>
Agassiz	1967	14.74	1.32	10.33	33	1.53
Sumas	1967	15.36	1.59	7.55	21	1.04
Kersley	1966	9.97	1.29	7.71	60	0.63
Kersley	1967	17.04	1.61	5.29	39	0.59
Smithers	1966	10.60	1.30	7.13	54	0.90
Summerland	1964	16.26	1.71	6.37	35	0.94
Summerland	1967	24.04	2.41	1.97	16	0.36

* The values shown are for the 138-day period from May 1 to September 15 inclusive.

** The safe interval used in determining the peak ET was ten days in all cases.

balances for the other two settings. Each irrigation was started when the balance at the first setting was at 60% available water, and was carried through to completion without stopping for rain. As a check on possible soil moisture deficits, balances were entered for every setting of the sprinkler line.

Application of this method to artificial models indicated a greater risk of soil drying than by method 1. The lowest balance (Table 4) was 42% available water, compared to 60% by method 1. The lowest balance was also lower with the natural models (Table 2). In some of the more humid areas, however, the savings in water and time as compared with method 1 were considerable (Table 2). In most cases the lowest balance occurred at other parts of the field than the first, center and last settings. Problems encountered with method 4 were the extra time taken to keep three balances instead of one, and the confusion involved in giving the right credit for rain.

Other methods tried

Various combinations of method 4 and the other methods were tried. These usually gave even more credit for rain than did method 4, but produced lower balances. The procedures were also much more difficult to follow.

Two further modifications of method 2 were tried. By the first, irrigation was not discontinued until the day following the rain. By the second, the records for ET and rain were entered on the balance sheet on the day following their occurrence. The reason for trying them was that the grower cannot foretell when rain will fall. The first of these modifications reduced the layoff period because of rain by one day, and reduced the credit for the rain slightly. The second simply delayed all results by one day but did not change them.

Statistical studies

An analysis of variance was conducted for each parameter shown in Table 2. In every case the F values for differences between sites and for differences between methods were highly significant ($P = \text{less than } 0.01$).

Coefficients of correlation were de-

termined for each pair of parameters, with the following results:

Seasonal net ET \times credit for rain	—1.00
Seasonal net ET \times least balance	+0.86
Credit for rain \times least balance	—0.86
Seasonal net ET \times layoff time	—0.90
Least balance \times layoff time	—0.81

Data from the seven sites (Table 1)

were used, differences between sites were eliminated, and the degrees of freedom were 28. The reason for the perfect negative correlation between seasonal net ET and credit for rain was that these two values were complementary.

DISCUSSION

The balance-sheet procedure has been found to be a most useful research tool for study of scheduling practices. The effects of each practice on the moisture content of the soil in different parts of a field can be assessed with reasonable accuracy by keeping a balance column for every

TABLE II. SOME RESULTS OF APPLYING DIFFERENT METHODS OF GIVING CREDIT FOR RAIN TO NATURAL MODELS

Site	Method*	Seasonal net ET	Rain given credit	Least balance**	Layoff time **
		<u>inches</u>	<u>inches</u>	<u>%</u>	<u>%</u>
Agassiz (1967)	1	13.31	1.43	48	28
	2	13.05	1.69	47	33
	2A	7.24	7.50	17	56
	3	11.38	3.36	33	49
	4	9.88	4.86	38	42
Kersley (1966)	1	5.45	4.52	62	67
	2	5.51	4.46	60	69
	2A	3.69	6.28	55	78
	3	4.61	5.36	57	78
	4	4.48	5.49	56	71
Kersley (1967)	1	14.67	2.37	47	34
	2	14.45	2.59	48	35
	2A	13.41	3.63	41	36
	3	13.94	3.07	41	49
	4	13.42	3.62	43	37
Smithers (1966)	1	7.46	3.14	45	56
	2	6.98	3.62	44	60
	2A	5.66	4.94	39	64
	3	6.06	4.54	41	71
	4	6.03	4.57	33	64
Summerland (1964)	1	13.83	2.43	52	40
	2	13.37	2.89	51	45
	2A	10.11	6.15	47	56
	3	12.96	3.30	52	49
	4	11.82	4.44	42	56
Average (7 sites)	1	13.10	2.33	51	41
	2	12.72	2.71	51	44
	2A	10.08	5.35	40	54
	3	12.20	3.23	45	56
	4	11.40	4.03	43	50

* Method 1 is the standard of comparison; method 2 is stopping for rain; 2A is the same but gives credit for rain up to field capacity; 3 is delaying the start of each irrigation; and 4 is regulating the credit for rain by maintenance of three balance columns.

**The least balance is expressed in per cent of available water, and the layoff time in per cent of the irrigation season.

setting. Although irrigation experiments were not conducted at the sites of the natural models, the balance-sheet procedure has been found by ten years of field experience (1, 4) to provide a reliable guide to relative soil moisture contents.

It is obvious from the results obtained that any method that gives more credit for rain than the standard method (method 1) is likely to produce a greater risk of excessive soil drying. In an area with frequent summer rains the greater risk may, of course, be well justified.

An apparent exception to the above was stopping an irrigation for rains (method 2). The least balance was practically the same as by method 1, and the average seasonal net ET was reduced by about 3%. When more credit was given for rain, however, than was allowed for by the rules of method 1, both the seasonal net ET and the least balance were reduced substantially.

The differences between seasons are of great importance in assessing the risks involved. This can be seen from the Kersley data in Table 2. It seems obvious that the method used should take into account the greater risk that is likely to occur during a dry summer. This may reduce the credit for rain below what seems reasonable during wet summers; but giving more credit for rain in wet summers would automatically increase the risk of soil drying in dry summers. There is as yet no way of knowing ahead of time just how dry the summer is going to be.

A reasonably good indication of the risks involved can be obtained by comparing the method under test with the standard method. In practical application, method 1 has proved to be satisfactory for tree fruits in semi-arid areas, though in some cases temporary wilting of the cover crop has occurred (4). In this investigation the least balance obtained by this method was 45% available water. Any method that gave balances lower than this would, therefore, produce greater risk of soil drying, and such a method could not be recommended for areas with dry summers.

Inherent in most of the methods tried were practical operational difficulties, and these should be taken

into account by an irrigator before he decides on the method to use. The least confusing were found to be the standard method (method 1), and method 3 in which the balance was allowed to drop to a specified value below 60% available water. Stopping for rain involved some confusion because the operator would not know just when a rainy spell had ended. In addition, some irrigation districts re-

quire notification a day or two ahead of time before making a change in water delivery. Keeping three or more balances (method 4) added considerably to the difficulty, and would not likely prove popular with most of the growers. Combinations of method 4 and the other methods gave even more credit for rain but proved to be even more cumbersome.

TABLE III. EFFECT OF METHOD 2A ON BALANCE USING AN ARTIFICIAL MODEL*

Day	ET	Rain	Balance***		
			First setting	Center setting	Last setting
	<u>inches</u>	<u>inches</u>	<u>inches</u>	<u>inches</u>	<u>inches</u>
17	.24		3.48	4.44	3.24
18	.24		3.24	4.20	5.16
19**	.24	2.40	5.40	5.40	5.40
20**	.24		5.16	5.16	5.16
21**	.24		4.92	4.92	4.92
22**	.24		4.68	4.68	4.68
23**	.24		4.44	4.44	4.44
24**	.24		4.20	4.20	4.20
25**	.24		3.96	3.96	3.96
26**	.24		3.72	3.72	3.72
27**	.24		3.48	3.48	3.48
28**	.24		3.24	3.24	3.24
29	.24		5.16	3.00	3.00
30	.24		4.92	2.76	2.76
31	.24		4.68	2.52	2.52
32	.24		4.44	2.28	2.28
33	.24		4.20	4.20	2.04
34	.24		3.96	3.96	1.80
35	.24		3.72	3.72	1.56
36	.24		3.48	3.48	1.32
37	.24		3.24	3.24	3.24

*Method 2A provides for stopping of irrigation when it rains. Here the safe interval was nine days, 100% available water was 5.40 inches, 60% was 3.24 inches, and the credit depth for irrigation was 2.16 inches.

**Days when no irrigation water was applied.

***The balances are expressed as inches of available water. The cross lines in these three columns indicate the time of irrigation at each setting.

When all factors are taken into account the following conclusions appear to be justified:

1. Where an operator can turn his water on or off at will, stopping for rains in semi-humid areas seems to be worthwhile. Care must be taken to follow the rules laid down by the standard method for giving credit for rain.

2. In semi-humid areas a promising procedure is to allow the soil at the first setting to dry to less than 60% available water; for example, to 50% as tried in this investigation. The risks involved in doing this in a specified district should be well weighed prior to recommending it, possibly by applying the method to records of ET and rain already taken in the district during years with dry summers.

A method that would allow more credit for rain than any reported in this paper would be to wet the whole field in one day. The irrigation water would, of course, have to be available whenever the balance sheet indicated it was needed. Major problems would be the cost of the irrigation system and the possible unavailability of the large flow of water required.

SUMMARY

Simulated irrigation was conducted by use of scheduling procedures on artificial models of specified evapotranspiration and rain; also on natural models consisting of evapotranspiration and rainfall records taken in both semi-arid and semi-humid parts of British Columbia. Each irrigation was started when the balance at the first setting of the sprinkler line represented an available water content of about 60% in the soil. Balances were also kept at other settings as required for estimation of potential soil moisture deficits. Stopping an irrigation because of rain gave a little more credit for the rain with little if any added risk of severe soil moisture deficits. Allowing the soil to dry to 50% available water instead of 60% increased appreciably the credit given for rain and increased in like degree the danger of soil drying. These two methods showed good promise for use in semi-humid areas. Other methods tried were either too difficult to operate, or produced balances low enough to be accompanied by excessive soil drying.

TABLE IV. EFFECT OF METHOD 4 ON BALANCE USING AN ARTIFICIAL MODEL*

Day	ET	Rain	Balance***		
			First setting	Center setting	Last setting
	<u>inches</u>	<u>inches</u>	<u>inches</u>	<u>inches</u>	<u>inches</u>
16	.24		4.20	5.16	3.96
17	.24		3.96	4.92	3.72
18	.24	.48	4.20	4.68	3.96
19	.24	.48	4.44	5.40	4.20
20**	.24	.48	4.44	5.40	5.40
21**	.24	.48	4.44	5.40	5.40
22**	.24	.48	4.44	5.40	5.40
23**	.24		4.20	5.16	5.16
24**	.24		3.96	4.92	4.92
25**	.24		3.72	4.68	4.68
26**	.24		3.48	4.44	4.44
27**	.24		3.24	4.20	4.20
28	.24		5.16	3.96	3.96
29	.24		4.92	3.72	3.72
30	.24		4.68	3.48	3.48
31	.24		4.44	3.24	3.24
32	.24		4.20	5.16	3.00
33	.24		3.96	4.92	2.76
34	.24		3.72	4.68	2.52
35	.24		3.48	4.44	2.28
36	.24		3.24	4.20	4.20

*By method 4, balances were kept for the first, center and last settings, and credit for rain was determined using the highest balance only. Safe interval, available water and credit depth were the same as in table 3.

**Days when no irrigation water was applied.

***The balances are expressed as inches of available water. The cross lines in these three columns indicate the time of irrigation at each setting.

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