SIMPLIFYING POTATO IRRIGATION SCHEDULING— THE IDAHO PROGRAM

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Introduction

Research has shown that plant water stress at specific growth stages can reduce potato yield and quality. The Russet Burbank variety has proven to be much more sensitive to quality rather than total yield when soil moisture is limited.

Potato Yield and Quality vs. ET Model

In 1980 and 1981, Tom Longley, Ag Engineer at the University of Idaho Aberdeen Research and Extension Center, used two stress levels and three potato varieties to determine the effect of moisture stress on yield and quality during tuber initiation, bulking, and maturity. Figures 1 and 2 show the results. In general, the Russet Burbank variety is affected more by stress than Lemhi or Nooksack. However, all varieties follow the same trends. Mild stress can be defined as irrigation about 10 days later than a normal irrigation at 65% remaining available moisture. Severe stress is about 15 days late.

Doorenbos and Kassam (1979) developed a relationship between water deficit and crop yield. They found that it was possible to evaluate the effect of plant water stress on yield decrease through the quantification of relative evapotranspiration (ETa/ETm). The formula used is:

$$(1 - Ya/Ym) = Ky\ (1 - ETa/ETm)$$

Ky is the slope of the $1 - Ya/Ym$ vs. $1 - ETa/ETm$ curve.

Ya = actual yield ETa = actual evapotranspiration

Ym = maximum yield ETm = maximum evapotranspiration

Model Development and Data

The Russet Burbank variety is very sensitive to soil moisture in terms of both yield and quality. Thus the irrigation scheme should be directed to maximizing yield rather than spreading a limited supply over a larger area. The potato processors' contract provides a base price for 60 percent No. 1's, with a $.01/cwt for each percentage point above 60. So quality is all important to the producer. If quality is too low, he will not be able to sell his potatoes as no one will want them.

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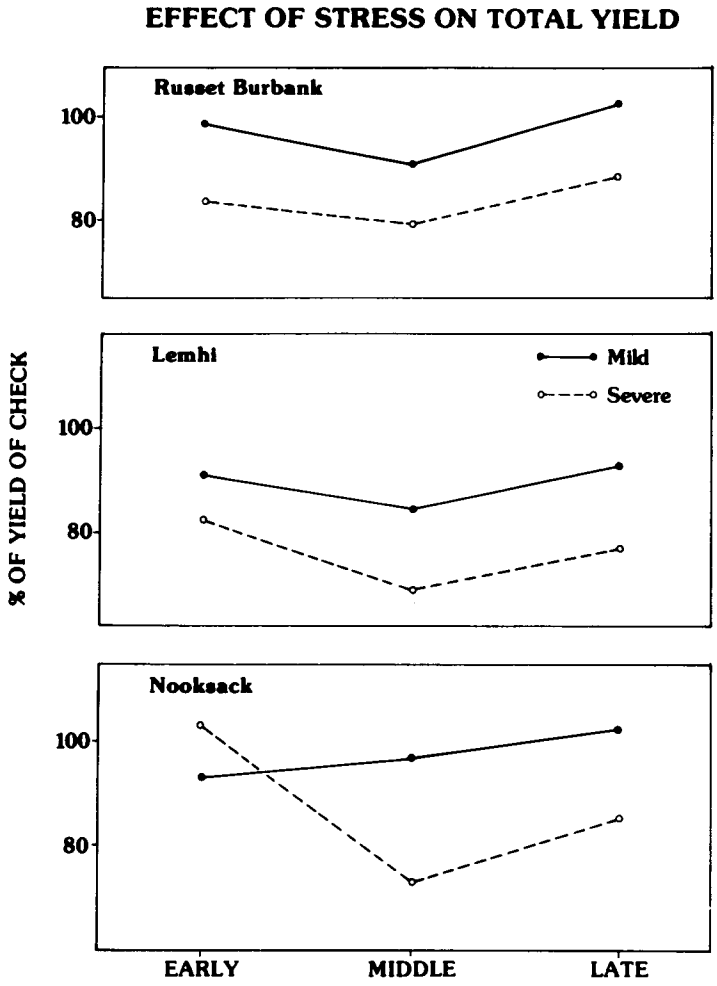

FIG. 1. Effect of mild and severe moisture stress on the total yield of three potato varieties at three growth stages. Aberdeen—Longley 1981. (The check plot was irrigated for maximum yield and quality production.)

The potato growth model for Russet Burbank is shown in Figure 3 and Table 1.

The Ky values for various potato growth stages are shown in Table 2.

ET Changes

Prominent meteorologists at the beginning of this decade predicted wide variations in weather from year to year. Crop water use or ET is determined by weather and stage of plant growth. For instance, water use jumped by almost 20% in 1981 over 1980. Then ET dropped 17% from 1981 to 1982.

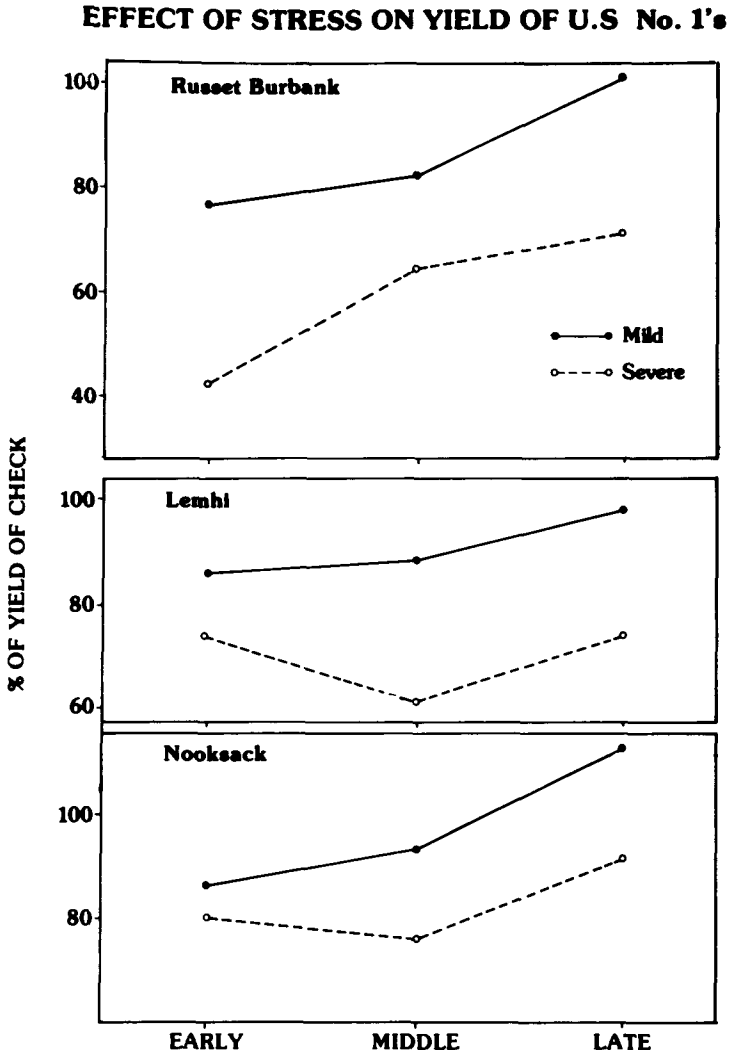

FIG. 2. Effect of mild and severe moisture stress on the yield of U.S. No. 1's of three potato varieties at three growth stages. Aberdeen—Longley 1981. (The check plot was irrigated for maximum yield and quality production.)

Water use data are compared in Figure 4 for the Magic Valley and in Figure 5 for the American Falls-Shelly area. This variation could easily mean a difference of two or three irrigations.

More important is the ET change within a year. Figure 4 illustrates this for the Magic Valley. ET in 1981 started out very low. A cool, rainy spring caused irrigators to delay filling up the root zone and being prepared for peak use. The last of June ET increased rapidly and stayed high during July

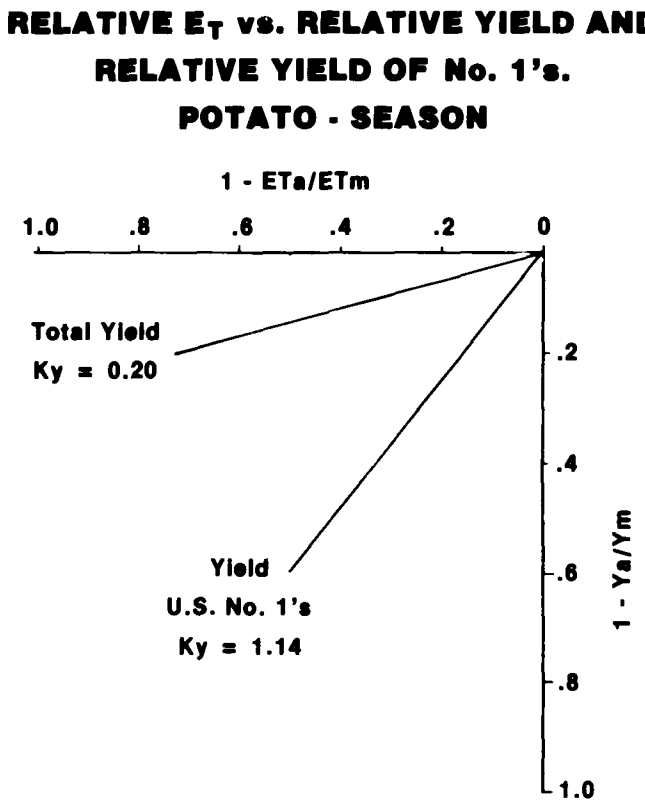

FIG. 3. Relative ET vs. relative yield. Relationship between relative yield decrease and relative evapotranspiration. Russet Burbank variety-Idaho site. Quality and total yield-total season.

TABLE 1. — *Average date and days of various stages of growth for Russet Burbank-Idaho.*

	Days	Model-Starting Date
Establishment	15-25	Planting-May 20
Early Vegetative	15-20	June 4
Stolonization and Tuber Initiation	15-20	June 20
Bulking or Yield Formation	45-55	July 10
Ripening	10-15	August 25
		Harvest-Sept. 15

and the first part of August. Irrigators scrambled to keep up with ET but their irrigation systems did not have the capacity. Either it was a close shave or some farmers' potato yield and quality were reduced because of moisture stress due to excessively dry soils.

TABLE 2. — *Estimated Ky function for various stages of growth for Russet Burbank Potatoes-Idaho.*

	Establishment (Usually Adequate Soil Moisture)	Early Vegetative	Stolonization and Tuber Initiation	Bulking or Yield Formation	Ripening	Total Season
Total Yield	1.0	.4	1.33	.2	.05	0.20
U.S. No. 1's	1.0	1.0	2.0	Very hot season = 1.38 Average .5	Unusually warm = .76 Average .2	1.14

In 1982 early potato crop water use in the Boise Valley was behind the Magic Valley and American Falls-Shelly area. This was due to cool weather and a near record 2 inch rainfall on July 2 in the Boise Valley. This was very unusual. Weekly water use curves are shown in Figure 6 for Kimberly, Idaho for the period 1965 through 1978. Again the variation from year to year is demonstrated.

Calculating ET

In the early 1970's Marvin Jensen and Jim Wright developed an energy balance procedure to determine crop ET. The potential or reference ET (ETr) was calculated using the modified Penman equation or the Jensen Haise formulas.

In Idaho we define the ETr as a crop of alfalfa growing continuously 12″ high.

A crop coefficient is used with ETr to estimate water use of a given crop. Crop coefficients are generally empirical ratios of crop ET to the reference ET and are derived from experimental data. The time distribution of crop coefficients for a particular crop constitutes a "Crop Curve".

James L. Wright, Snake River Conservation Research Center, USDA, Kimberly, Idaho, has developed crop curves for the Russet Burbank potato variety using the expression ETpot = Kcm × ETr, where Kcm is a mean crop coefficient for potatoes. Values of Kcm for potatoes are shown in Table 3. Crop curves for potatoes are shown in Figure 7.

Distribution of ET Data

In the mid-1970's the Bureau of Reclamation, Region I, started to generate the ET for crops grown in the area. A partnership was formed with the

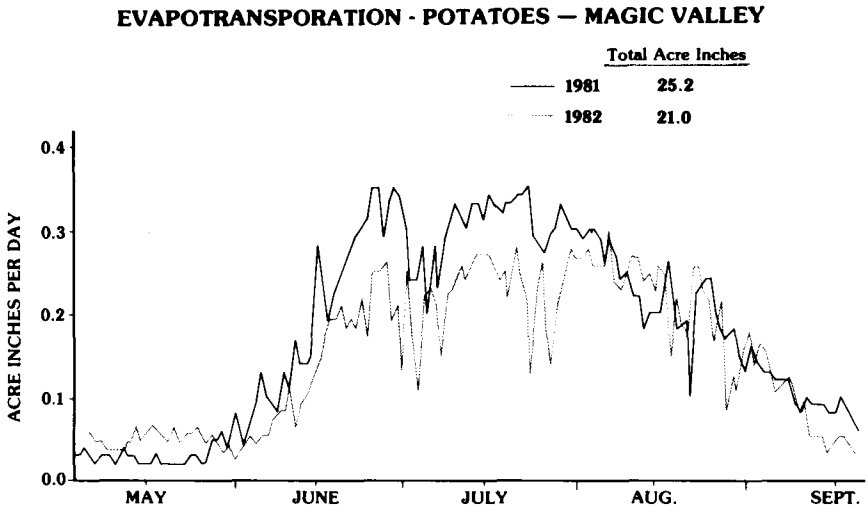

FIG. 4. Daily evapotranspiration or crop water use for potatoes grown in the Magic Valley during 1981 and 1982.

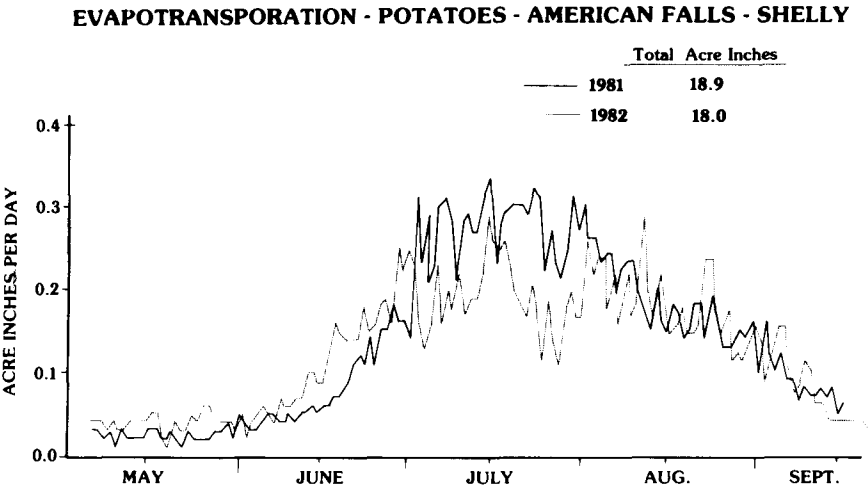

FIG. 5. Daily evapotranspiration or crop water use for potatoes grown in the American Falls/Shelly area during 1981 and 1982.

University of Idaho Cooperative Extension Service to develop a computerized irrigation scheduling program.

Southern Idaho was divided into four areas using four different weather stations—Boise Valley, Magic Valley, American Falls to Shelly, and Shelly to St. Anthony. A weather station is located in each area. The weather data are collected each Monday and Thursday morning by the Bureau of

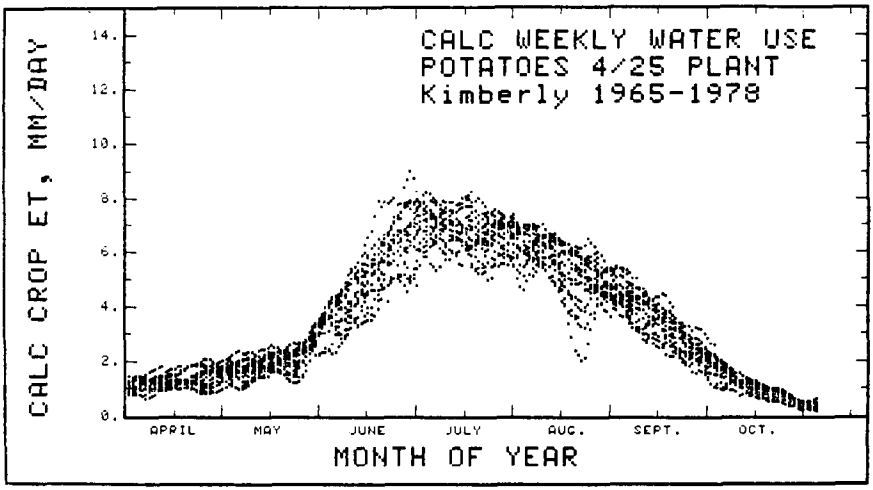

FIG. 6. Calculated weekly water use, potatoes-Kimberly 1965-1978.

TABLE 3. — *Daily mean crop coefficients (Kcm), for normal irrigation and precipitation conditions, for use with an alfalfa reference (Etr) for potatoes grown in an arid region with a temperate intermountain climate. Coefficients were experimentally determined from weighing lysimeters ET data, Kimberly, Idaho 1968-1978 (adjusted in 1983).*

Crop	Kcm Time from Planting to Effective Cover (%)									
	10	20	30	40	50	60	70	80	90	100
Potatoes	.20	.20	.22	.31	.41	.51	.62	.70	.76	.78

Crop	Days After Effective Cover									
	10	20	30	40	50	60	70	80	90	100
Potatoes	.78	.76	.74	.71	.67	.63	.59	.36	.25	.20

Reclamation under the direction of Monte McVey, Boise. The data are transferred to the University of Idaho computer at Moscow. County agents using Apple computers and an 800 telephone number can call and obtain a printout of the ET data the day it is generated. A sample is shown in Table 4. This is printed in eight daily newspapers across southern Idaho on Tuesdays and Fridays. United Press International delivers the chart via wire service to three dailies and another in Boise is delivered by messenger. County agents located in the towns of the other four dailies are delivering the ET data to the papers.

In addition the material is being used by some weekly newspapers and by radio stations. About 15 counties are sending the ET data to a selected list of farmers and fieldmen. This is a seed program. They report receiving many calls for the information when it fails to arrive in the user's mailbox.

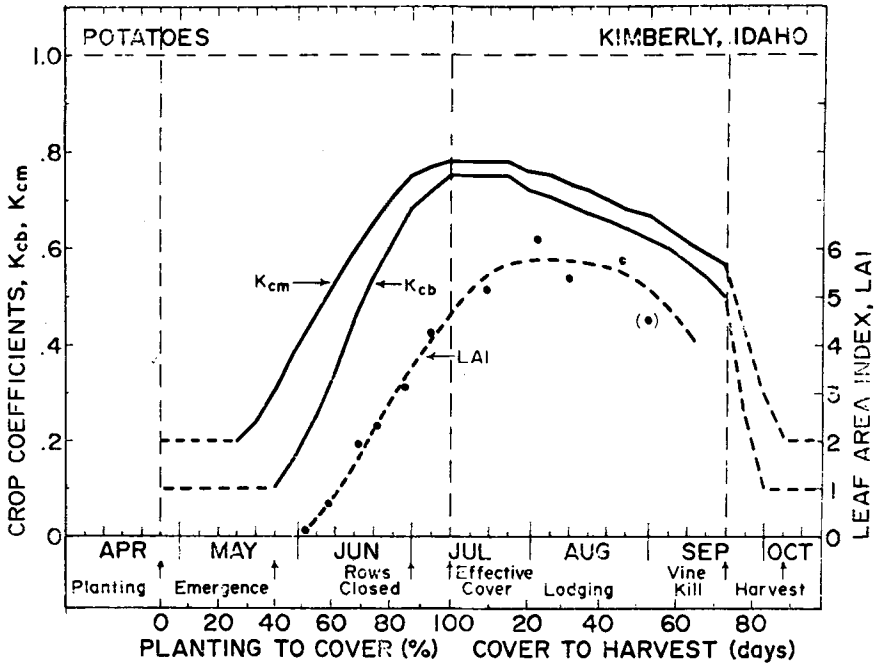

FIG. 7. Crop curve for Russet Burbank potato variety showing mean crop coefficient (Kcm), basal crop coefficient (Kcb) and the leaf area index (LAI).

Shorthand Method

A shorthand method of irrigation scheduling has evolved for potatoes since over 95% of the crop in Idaho is sprinkled. The five step procedure is outlined below.

Step One— Know the special water needs of the potato plant.

Step Two— Keep irrigations timely and in correct priority with other crops by using daily ET data printed in newspapers.

Step Three—Determine how much effective water, in acre inches, your sprinkler applies to the soil in a set.

Step Four— When the accumulated ET from the last irrigation date equals the amount of water applied by your sprinkler in a set, it is time to irrigate.

Step Five— Dig a hole in the plant row at the beginning set in a representative soil area with a good stand and determine if the soil moisture at the 6-8 inch level is at 65% remaining available moisture. If it is, irrigate. Repeat steps 4 and 5 for successive irrigations.

TABLE 4. — *Estimated water use table printed in daily newspapers on Tuesdays and Thursdays in southern Idaho. (Courtesy of USBR and University of Idaho, Extension).*

Estimated Water Use—July 15, 1982										
Crop	Growth Stage	Daily Crop Water Use-Inches ET-July				Daily Forecast (ET)		Accum. Water Use (ET) from date shown in column thru July 14			
		11	12	13	14		13	11	9	7	5
Alfalfa		.24	.26	.27	.27	.27	.5	1.0	1.5	1.7	2.1
Sugar Beet		.25	.27	.29	.29	.29	.6	1.1	1.5	1.8	2.4
Potatoes		.23	.25	.27	.26	.26	.5	1.0	1.4	1.7	2.1
Beans		.27	.28	.31	.30	.33	.6	1.2	1.6	1.9	2.3
F. Corn		.26	.29	.30	.31	.31	.6	1.2	1.6	1.9	2.3
S. Corn		.26	.27	.31	.30	.31	.6	1.1	1.6	1.9	2.3
S. Grain		.28	.30	.32	.31	.28	.6	1.2	1.7	2.0	2.5
Onions		.27	.29	.29	.29	.26	.6	1.1	1.6	2.0	2.4
Mint		.27	.28	.31	.30	.31	.6	1.2	1.6	1.9	2.4
Lawn		.24	.26	.27	.27	.27	.5	1.0	1.5	1.7	2.1

Potatoes should be irrigated when the soil moisture is depleted to 65% at seedpiece level at the first irrigation after planting. Use a depth of 6 to 8 inches for subsequent irrigations and the available soil moisture at irrigation should be 65%. This is the stress point of the soil moisture when irrigation is required for maximum crop yield and quality.

Armed with the general strategy for soil moisture management during the season, an irrigator will know when soil moisture is critical. If the temperature of the soil at the 4 inch depth reaches 68°F or above for an extended period of time, especially during critical parts of the growing season, the potato plant should be protected against rapid changes in growth by keeping the tubers in soil with moisture above 65%. In August, to protect against water and other over-irrigation hazards, be sure the soil moisture is depleted to 65% before the next irrigation is applied.

A sprinkler is designed to apply a specific quantity of water in a 12 hour set. This amount can be found by the following procedure. Using Table 5, determine the nozzle discharge of a 9/64 inch nozzle operated at 50 psi. The discharge is 4.18 gallons per minute. Using this discharge value, refer to Table 6 and determine the rate of application at a 40×50 foot spacing . . . which is 0.20 inch per hour. In Table 7, "Water Applied per Set, Acre Inches at 70% Efficiency", we find that this nozzle will apply a total of 1.54 acre inches in an 11 hour set.

The next step is to watch the daily ET in the newspaper. It will be printed every Tuesday and Thursday. A sample is shown in Table 4 for July 15, 1982. The section "Daily Crop Water Use" shows potatoes used 0.23 acre inch on the 11th of July and 0.26 on the 14th. The "Daily Forecast Section" shows that potatoes are expected to use 0.26 acre inch per day for the

TABLE 5. — *Nozzle discharge vs pressure for various size nozzles.*

	Nozzle Discharge-Gallons per Minute							
p.s.i.	3/32	1/8	9/64	5/32	11/64	3/16	13/64	7/32
20	1.17	2.09	2.65	3.26	3.92	4.69	5.51	6.37
25	1.31	2.34	2.96	3.64	4.38	5.25	6.16	7.13
30	1.44	2.56	3.26	4.01	4.83	5.75	6.80	7.86
35	1.55	2.77	3.50	4.31	5.18	6.21	7.30	8.43
40	1.66	2.96	3.74	4.61	5.54	6.64	7.80	9.02
45	1.76	3.13	3.99	4.91	5.91	7.03	8.30	9.60
50	1.85	3.30	4.18	5.15	6.19	7.41	8.71	10.10
55	1.94	3.46	4.37	5.39	6.48	7.77	9.12	10.50
60	2.03	3.62	4.50	5.65	6.80	8.12	9.56	11.05
65	2.11	3.77	4.76	5.87	7.06	8.45	9.92	11.45
70	2.19	3.91	4.96	6.10	7.34	8.78	10.32	11.95
75	2.27	4.05	5.12	6.30	7.58	9.08	10.66	12.32
80	2.35	4.18	5.29	6.52	7.84	9.39	11.02	12.74
85	2.42	4.31	5.45	6.71	8.07	9.67	11.35	13.11
90	2.49	4.43	5.61	6.91	8.31	9.95	11.69	13.51
95	2.56	4.56	5.76	7.09	8.53	10.2	11.99	13.86
100	2.63	4.67	5.91	7.29	8.76	10.5	12.32	14.23

TABLE 6. — *Average application vs spacing for various nozzle discharges.*

Spacing	Average Application Rate-Inches Per Hour Gallons Per Minute From Each Sprinkler									
Feet	2	3	4	5	6	7	8	9	10	12
20×20	.48	.72	.96	1.20	1.44	1.70	1.95	2.16	2.40	
20×30	.32	.48	.64	.80	.96	1.12	1.28	1.43	1.60	1.93
20×40	.24	.36	.48	.60	.72	.84	.96	1.08	1.20	1.45
30×30	.21	.32	.43	.54	.64	.75	.88	.96	1.07	1.28
30×40	.16	.24	.32	.40	.48	.56	.64	.72	.80	.96
30×50	.13	.19	.25	.32	.38	.45	.51	.58	.64	.76
40×40	.12	.18	.24	.30	.36	.42	.48	.54	.60	.72
40×50	.10	.14	.19	.24	.29	.34	.38	.43	.48	.58
40×60		.12	.16	.20	.24	.28	.32	.36	.40	.48

next three or four days. The last section, "Accumulated Water Use", is for 2, 4, 6, 8 and 10 day intervals. For the interval July 13 and 14, two days, potatoes used 0.5 of an inch. For the 6 day period between July 9 and 14, potatoes used 1.4 inches. If an irrigator had irrigated on July 9 and applied 1.5 inches, the ET form shows 1.4 inches would have been used by July 14. With 0.26 forecast to be used on July 15, an irrigation that day, July 15, would be called for since 0.1 available soil moisture remains.

A farmer should go out to the field and check on soil moisture. The method is predicting that the soil moisture on July 15 at the starting point

TABLE 7. — *Water applied in acre inches at 70% application efficiency for various hours of operation of a sprinkler.*

Hours Operated Per Set	Water Applied Per Set-Acre Inches at 70% Efficiency Application Rate of System-Inches Per Hour											
	.12	.14	.16	.18	.20	.22	.24	.26	.30	.35	.45	.55
1	.08	.10	.11	.13	.14	.15	.17	.18	.21	.25	.32	.39
2	.17	.20	.22	.25	.28	.31	.34	.36	.42	.49	.63	.77
3	.25	.29	.34	.38	.42	.46	.50	.55	.63	.74	.95	1.16
4	.34	.39	.45	.50	.56	.62	.67	.73	.84	.98	1.26	1.54
5	.42	.49	.56	.63	.70	.77	.84	.91	1.05	1.23	1.58	1.93
6	.50	.59	.67	.76	.84	.92	1.01	1.09	1.26	1.47	1.89	2.31
7	.59	.69	.78	.88	.98	1.08	1.18	1.27	1.47	1.72	2.21	2.70
8	.67	.79	.90	1.01	1.12	1.23	1.34	1.46	1.68	1.96	2.52	3.08
9	.76	.88	1.01	1.13	1.26	1.39	1.51	1.64	1.89	2.21	2.84	3.47
10	.84	.98	1.12	1.26	1.40	1.54	1.68	1.82	2.10	2.45	3.15	3.85
11	.92	1.08	1.23	1.39	1.54	1.69	1.85	2.00	2.31	2.70	3.47	4.24
12	1.01	1.18	1.34	1.51	1.68	1.85	2.02	2.18	2.52	2.94	3.78	4.62
15	1.26	1.47	1.68	1.89	2.10	2.31	2.52	2.73	3.15	3.68	4.73	5.78
18	1.51	1.76	2.02	2.27	2.52	2.77	3.02	3.28	3.78	4.41	5.67	6.93
21	1.76	2.06	2.35	2.65	2.94	3.23	3.53	3.82	4.41	5.15	6.62	8.09
24	2.02	2.35	2.69	3.02	3.36	3.70	4.03	4.37	5.04	5.88	7.56	9.24
30	2.52	2.94	3.36	3.78	4.20	4.62	5.04	5.46	6.30	7.35	9.45	11.55

TABLE 8. — *Feel chart for estimating soil moisture.*

% Available moisture	Loam, silt loam, clay loam soil texture	Sand and loamy sand soil texture
Below 20	Powdery, dry, will not form a ball; if soil is crusted, easy to break into powdery condition.	BT: No ball forms. Single grained soil flows through fingers with ease.
35 to 40	Dry, almost powdery. BT: A ball can be formed under pressure, but some soil will fall or flake away when hand is opened. The ball is very crumbly and hardly holds its shape.	BT: Forms weak brittle balls. Fingerprint outline not discernible. No soil sticks to hand. RT: Few soil particles stick to thumb.
50	BT: Forms a ball readily, holds its shape. No moist feeling is left on hand nor will any soil fragments cling to palm. Ball is very brittle and breaks readily. Soil falls or crumbles into small granules when broken. RT: Will not ribbon; soil too crumbly. OPT: Sample very crumbly; readily dissolves into individual particles.	BT: Form very weak ball. If soil well broken up it will form more than one ball upon squeezing. Fingerprint outline barely discernible. Soil grains will stick to hand. RT: No ribboning. Soil particles will just cease to lay down. Patchy soil layer on thumb.

% Available moisture	Loam, silt loam, clay loam soil texture	Sand and loamy sand soil texture
60 to 65	BT: forms firm ball; finger marks imprint on ball. Hand feels damp but not moist. Soil doesn't stick to hand. Ball is pliable. When broken, ball shatters or falls into medium-size fragments. RT: Ribbons out ¼" or just barely ribbons. OPT: Soil breaks down into granules and is a little crumbly. Continues to crumble until a tiny round ball is left in palms.	BT: Form weak, brittle ball. Fingerprint outline not as distinct. Soil particles will stick to hand in a patchy pattern. RT: No ribboning. Soil particles will stick to thumb in a patchy layer.
70 to 80	BT: Damp and heavy; slightly sticky when squeezed. Forms tight plastic ball. Shatters with a burst into large particles when broken. Hand is moist. RT: Ribbons out ½". Moist soil particles left on thumb. OPT: Sample can be molded into a round ball; somewhat plastic, will not shatter readily.	BT: Forms weak ball. Distinct fingerprint outline on ball. Soil particles will stick to palm. RT: No ribboning. Soil particles will stick to thumb during ribboning process in a distinct layer over surface of thumb.
100	BT: Wet, sticky, doughy and slick. A very plastic ball is formed, handles like stiff bread dough or modeling clay; not muddy. Leaves water on hand. Ball will change shape and cracks will appear before breaking. RT: Ribbons readily if not too wet. OPT: Forms a tight ball. Will work into a long round pencil-like shape.	BT: Upon squeezing, no free water appears on ball but wet outline of ball is left on a hand. Ball has some stickiness and a sharp fingerprint outline is left on it. RT: No ribboning. Soil particles will form smooth layer on thumb.

DEFINITION OF TESTS

BT (Ball Test)—Ball formed when a handful of soil is squeezed hard in fist. Observe effect when ball is broken between thumb and forefinger.

RT (Ribbon Test)—Soil rolled out between thumb and forefinger. Thumb and forefinger are kept one-eighth inch apart so little pressure will be exerted on soil.

OPT (Open Palm Test)—Ball of soil rolled gently between open palms.

on the potato field would reach 65% at the 6-8 inch depth. The soil feel method can be used for determining the moisture in the soil. A soil feel chart for estimating soil moisture is shown in Table 8. Then wait for the ET to accumulate to 1.5 inches again or match what is applied during a set by the sprinkler before irrigating again.

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