TECHNICAL BULLETIN No. 118 SEPTEMBER, 1929

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

STUDIES IN TIME AND RATE OF IRRIGATING POTATOES IN COLORADO

By W. C. EDMUNDSON

Horticulturist, Office of Horticultural Crops and Diseases, Bureau of Plant Industry

CONTENTS

INTRODUCTION

According to the 1920 census report (*15*),[1] based on the 1919 crop, 154,054 acres of irrigated potatoes were produced in 13 Western States, namely, Arizona, California, Colorado, Idaho, Montana, Nebraska, Nevada, New Mexico, South Dakota, Oregon, Utah, Washington, and Wyoming.

The influence of irrigation water on potato production has been studied by numerous investigators since the establishment of irrigation projects in the West. There appears to be considerable difference of opinion regarding the proper time of making the initial and subsequent applications of water. Some recommend that the first irrigation should be withheld until the plants have set their tubers or are in bloom; others say it is better not to apply water until the plants show a decided dark-green color; other suggestions are to the effect that the water should not be applied until the foliage begins to wilt. There are also various recommendations regarding the quantity of water that should be applied at ony one time, and a diversity of opinion prevails regarding the advisability of irrigating up the newly planted crop even though the soil does not contain sufficient moisture to insure good germination.

REVIEW OF LITERATURE

In 1921 Clark (*2*) reported the results of irrigation studies conducted at Greeley, Colo., in 1917 and 1918. The different periods in which irrigation was started were designated as "checks," "early," "medium"

[1] Italic numbers in parentheses refer to "Literature cited," p. 21.

and "late." In 1917, when dry-land Pearl seed was planted, the early-irrigated plots yielded 13.3 bushels per acre more than the check plots, whereas the medium-irrigated plots yielded 8.2 bushels less than the checks, and the late-irrigated ones gave 34.5 bushels less than the check plots. In the same year the early-irrigated Pearls from Wisconsin yielded 9.2 bushels per acre more than the checks, the medium produced 10.5 bushels less than the checks, and the late-irrigated plots showed a loss of 36.9 bushels per acre.

In 1918 the early-irrigated plots planted with Pearls yielded 13.5 bushels per acre more than the checks, whereas the late-irrigated plots yielded 43.8 bushels less than the check plots. In the same year plots of the early-irrigated Rural New Yorker variety yielded 5.3 bushels per acre more than the check plots, and the late-irrigated plots yielded 44.7 bushels less than the check plots.

D. G. Martin (*12*), of Idaho, reports that of the plots receiving three, five, and six irrigations, respectively, the latter proved the most successful, producing 201.6 bushels (12,932 pounds) per acre with 2.05 acre-feet of water.

F. D. Farrell (*3*), of Idaho, reporting the results of irrigation studies conducted at the Gooding substation, states that 72, 146, and 131 bushels were produced from 10.44, 17.88, and 24.6 inches of water, respectively.

In 1914 J. S. Welch (*16*), of Idaho, reported the results of two-years' experiments conducted along the following lines: (1) First irrigation when plants were 4 or 5 inches high and subsequently as often as necessary to keep sufficient moisture to furnish good growing conditions until the tubers were the size of an egg, then no more irrigation; (2) first irrigation when plants were 4 or 5 inches high and as often as necessary during the remainder of the season; (3) first irrigation when tubers began to form and as often as necessary during the remainder of the season; (4) first irrigation when the tubers were the size of an egg and as often as necessary during the remainder of the season; (5) no irrigation.

In all cases the last irrigations were applied about the middle of August. The highest yield, 247.45 bushels (14,847 pounds) of marketable tubers, was produced from the plots receiving the first irrigation when the tubers began to form. The next highest yield, 241.73 bushels (14,504 pounds), was obtained on plots receiving their first irrigation water when the plants were 4 or 5 inches high.

D. H. Bark (*1*), conducting an experiment on irrigation at Gooding, Idaho, concluded that the yield of potatoes tended to increase as the supply of irrigation water increased, although the rate of increase grew smaller with the increased quantities of water. In 1910, 0.87 foot of water produced 105.33 bushels (6,320 pounds) per acre, 1.5 feet produced 198.87 bushels (11,932 pounds), and 2 feet produced 215.53 bushels (12,932 pounds) per acre. In 1911, 0.54 foot of water produced 122.48 bushels per acre, 2.2 feet produced 278.97 bushels, and 3.64 feet produced 279.23 bushels per acre. In 1912, 2 feet of water produced slightly higher yields than where 2.52 feet were used. The yields reported for 1913 were very similar to those of 1910 and 1911.

In 1915 F. Knorr (*11*), of Nebraska, reported the following average yields for 1912, 1913, and 1914; 296 bushels per acre by irrigating every row, thus keeping the soil moist and the plants in good grow-

ing condition; 270 bushels per acre by beginning irrigation after the plants seemed to require water, then irrigating every other row; 239 bushels per acre by irrigating alternate rows at such times as the crop required water (with the first irrigation every other row is skipped and with the second irrigation the skipped rows were irrigated and so on); 234 bushels per acre by irrigating every row but permitting the plants to suffer between irrigations; 215 bushels per acre by irrigating every other row throughout the season.

In 1914 Knorr (*10*) reports that the largest yields of potatoes were obtained where the soil was kept moist throughout the season, the average yield being 296.8 bushels per acre. The poorest shaped tubers were produced on plots where the plants were allowed to suffer between irrigations; the yield from such plots was 244.4 bushels per acre.

In 1919 Knight and Hardman (*9*) reported results of a 4-year irrigation experiment in Nevada in which 3, 6, and 9 inch applications were made (1) before the plants showed a tendency to wilt; (2) when plants showed a tendency to wilt; (3) when leaves wilted down once; (4) when plants failed to revive during the night. For the 4-year period the highest yield, 266.28 bushels per acre, was obtained with an average total irrigation of 16.5 inches given in 3-inch applications when the plants showed a tendency to wilt. The next best results, 238.88 bushels per acre, were obtained with eight 3-inch applications given before the plants showed a tendency to wilt.

In 1920 Powers and Johnston (*13*), of Oregon, reported the results of 12 years' irrigation studies, and the following recommendations were made. If the ground is dry at time of planting it is best to irrigate before plowing. The proper time to make the first application of water may be indicated (1) by the darkening of the vines to a dark-green color, (2) weather conditions, (3) moisture content of the soil near roots of plants.

At Corvallis, Oreg., the application of irrigation water when the soil-moisture content had dropped to the 20 per cent point, resulted in an increase in yield of 50 bushels of potatoes per acre. Watering at a higher or lower point decreased the yield.

In 1893 E. S. Richman (*14*), of Utah, reported that the largest yield of marketable potatoes was produced by irrigating every eight days, the plots receiving a total of 14 inches of water producing 239 bushels per acre of large and 80 bushels of small potatoes.

Widtsoe (*17*), of Utah, in 1901 reported that land receiving 40 inches of water in seven applications produced larger yields of marketable tubers than when smaller quantities were given in fewer applications. Small yields were produced with 10 inches of water applied in 5-inch irrigations. He further reported that 15 inches of water gave nearly as high yields as did 40 inches and recommended light frequent irrigation.

In 1903 Widtsoe (*18*) reported that 15 inches of water applied in six irrigations gave nearly two and one-half times as many potatoes as when applied in two irrigations; he recommended light frequent irrigations.

In 1912 Widtsoe and Merrill (*19*) reported results obtained from plots receiving 5, 7.5, 10, 15, 20, 30, 45, and 60 acre-inches of water. The plots receiving 5 acre-inches produced a total of 154 bushels

per acre, whereas the largest yield of 304 bushels was produced on the plot receiving 60 acre-inches of water.

In 1917 F. S. Harris (*6*) reported the results of five years of investigational work in which the greatest yield of tubers was obtained with 1 inch of water weekly, or a total of 12.8 inches of irrigation water for the season, the average yield for this treatment being 337.1 bushels per acre for the five years. When 7½-inch weekly applications to a total of 96 inches were given, the yield was less than when no irrigation water was applied. Irrigations of 5 inches each week were applied at different stages in the growth of the plant. The lowest yield was obtained when the land was watered after planting and before the plants were up. The best stage for a single irrigation was when the plants were in full bloom.

In 1923 Harris and Pitman (*7*) also reported results of a 5-year irrigation experiment. The water, measured by means of a Cippoletti weir, was applied by the flooding method and retained on the plots by banks around the edges. One series of five plots received weekly applications of 1, 2, 3, 4, and 5 inches of irrigation water each during the growing season, beginning when the plants were 6 inches high and continuing until about a month before harvest. Another series of five plots was given the same irrigations on alternate weeks, receiving one-half the total quantity of water of the first series. The other plots received 0, 2.5, 5, 7.5, 10, and 15 inches of irrigation water applied in various combinations. Of the plots receiving 20 inches of irrigation water, those that had the ten 2-inch irrigations gave the highest yield, 254 bushels per acre. Of the 10-inch plots, the ten 1-inch irrigations gave the highest yield, 248 bushels per acre. Of the plots receiving a total of only 5 inches of water, that with five 1-inch irrigations gave the highest yield, 190 bushels per acre.

In 1922 Israelsen and Winsor (*8*) reported that in the results of irrigation studies conducted from 1914 to 1919 inclusive, the yield increased regularly but not proportionately as the water increased. The smallest average yield—less than 40 bushels—was produced with only the 6-inch irrigation before seeding, and the largest yield—about 105 bushels—with 26 acre-inches.

B. P. Fleming (*4*) of Wyoming, in 1902 reported that potatoes grown on three adjacent plots receiving 5, 7, and 10 inches of water from irrigation and rainfall yielded 19.60, 37.17, and 51.15 bushels per acre, respectively, in 1900, and the following season 17, 28, and 48 inches produced respectively 55.53, 65.93, 90.53 bushels per acre.

In summarizing the results of 4-year irrigation studies, Fleming (*5*) states that in 1900 and 1901 the plots that received the largest quantities of water produced the highest yields per acre, but in 1902 and 1903, when the plots received the smaller quantities (between 12 and 18 inches), they produced larger yields. In 1902 and 1903 all water applied was retained on the plots.

A study of the experimental data upon the subject reveals the fact that most of the investigators have measured the water used on the experiment plots and have made recommendations as to the number of inches required to produce a crop on the particular type of soil on which the experiment was conducted. When the great variation in the water-holding capacity of soils is considered, also the influence of temperature, the rainfall, and seasonal conditions, it seems impossible that recommendations on the number of inches of water necessary

to produce a crop can be made to apply to the irrigation of potatoes in general, or even for one locality. It is also apparent that the number of irrigations given a crop must vary with the locality and with seasonal conditions.

OUTLINE OF THE EXPERIMENTS

The irrigation studies reported in this bulletin were conducted at the Colorado Potato Experiment Station [2] located at Greeley, Colo.

The precipitation during the growing season at the station for a series of years is shown in Table 1.

TABLE 1.—*Precipitation at the Colorado Potato Experiment Station, Greeley, by months during the growing season, 1919 to 1926, inclusive*

Month	Precipitation in inches for the year specified at top of column							
	1919	1920	1921	1922	1923	1924	1925	1926
April	0.56	4.43	1.16	1.65	0.85	0.54		1.09
May	.48	1.42	2.26	1.07	1.52	2.77	1.03	.97
June	.18	1.98	3.44	.18	4.77	.21	2.84	.70
July	1.31	.48	1.44	.78	3.12	.25	1.74	1.42
August	.62	1.20	2.28	1.04	2.59	0	3.44	.54
September	1.82	.88	.30	.08	1.01	1.86	.37	.98
Total	4.97	10.39	10.88	4.80	13.86	5.63	9.42	5.70

The type of soil on which the irrigation studies were made was a clay loam. All plots were well drained with the exception of those devoted to the experiment in 1925, when the lower end of the plots was too level for good drianage. The following 4-year crop rotation has been maintained throughout this experiment: Grain, alfalfa two years, and potatoes. Light applications of barnyard manure were made each fall, preceding the crowning of alfalfa. The ground was left rough during the winter, and in the early spring it was plowed about 10 inches deep, and a good seed bed was prepared. During the years 1919 to 1924, inclusive, the irrigation plots consisted of eight rows, each 242 feet long, planted 36 inches apart. In 1925 and 1926, with the exception of one plot irrigated before planting, the plots consisted of four rows, each 484 feet long, planted 36 inches apart. All plots were planted in duplicate or triplicate. Two rows of potatoes were planted between plots in order that irrigation water from one plot would not influence development in adjacent plots. Shortly after planting, all plots received a deep cultivation and were harrowed, and subsequent cultivations were made whenever soil conditions seemed to warrant, until the growth of the vines interferred with cultivation. In 1919, 1920, and 1921 the plots were planted with Peerless [3] (Pearl) and Rural New Yorker No. 2 varieties. Subsequently all plots were planted with Rural New Yorker No. 2, a strain of Rural developed at the station being used in the experiment.

The color of the potato foliage is an index to the amount of moisture in the soil available to the plant. Plants supplied with the proper

[2] The work of the station has been conducted by the United States Department of Agriculture in cooperation with Weld County through the county commissioners and with the State of Colorado through the State Agricultural College. From 1915 to 1924 the experiment was conducted on a 40-acre farm leased by Weld county for the potato-investigation work. In 1925 an 80-acre tract was purchased jointly by Weld County and the State of Colorado, since which time the experiment work has been located on the new farm.

[3] Peerless is the proper name for the variety commercially known in Colorado as Pearl.

amount of moisture for good growing conditions have a normal color of foliage for the variety. As the supply of moisture is diminished in the soil, the foliage assumes a darker green color, and in plants suffering for water to a point where the growth is checked, a decidedly dark blue-green color, whereas an oversupply of water in the soil is indicated by a light-green appearance of the foliage. Occasionally the foliage of some varieties assumes a yellow appearance.

Potato growers differ in their irrigation practices, some supplying moisture for a continuous plant growth, others withholding the water until the foliage turns a dark green, and other growers practicing late irrigation or withholding the first application of water until the plant growth is decidedly checked.

The irrigation studies here presented have been conducted along the following lines: (1) Applying water when the plants require it throughout the growing season to maintain a vigorous growth; (2) applying water when the plants assume a dark-green color; (3) withholding the first application of water until the growth of the plants is checked; (4) irrigating up the newly planted crop when conditions seem to warrant; (5) heavy as compared with light applications of water.

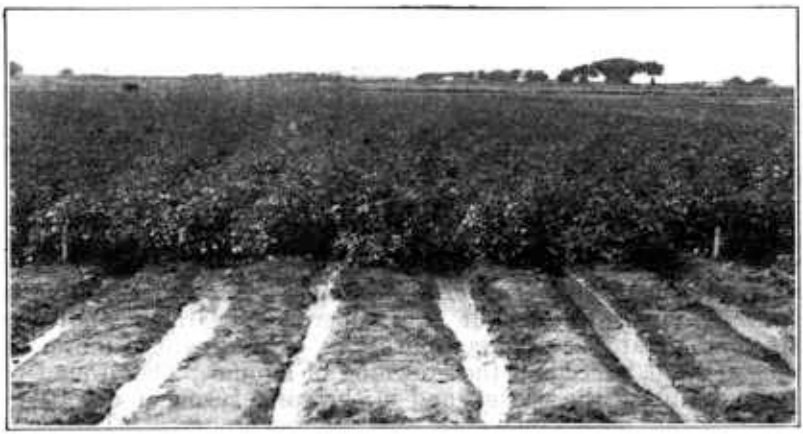

FIGURE 1.—Irrigating experimental potato plots

The first application of water to the various experimental plots was supplied according to this outline of the experiment, but in all irrigation the quantity of water was governed by the condition of the soil at the time of irrigation. All plots were irrigated by running water on both sides of the rows (figs. 1, 2, and 3), careful examination of the soil in the row being made during the irrigation and the flow of water stopped when the moisture had seeped through sufficiently to moisten the soil in the row immediately under the hills. After the first irrigation of any of the plots the soil was kept moist during the remainder of the season by light frequent irrigations until about the first week in September, when irrigation operations were terminated. Such an arrangement allowed about one month to elapse between the last irrigation and the first heavy frost, which usually occurs in the Greeley district about the first week in October.

Tubers weighing from 4 to 10 ounces were selected for planting. The tubers were cut into blocky pieces weighing from 1½ to 2 ounces, after which the seed was spread out in a thin layer on the dugout floor for three or four days until the cut surfaces were healed over. The weight of the seed pieces and the method of handling the seed

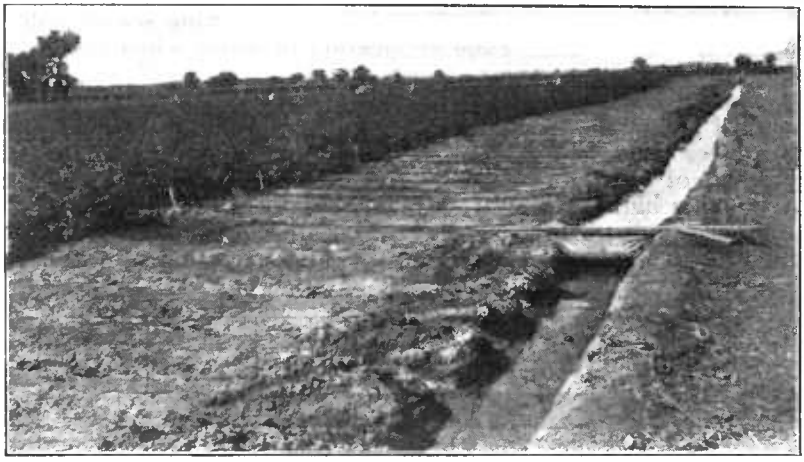

FIGURE 2.—Head ditch with a canvas dam

planted in each plot were the same throughout the experiment except in 1926, when whole seed weighing from 2 to 3 ounces was planted.

When the variation in the water-holding capacity of the soil is considered, also the influence of temperature, the rainfall (Table 1), and the seasonal conditions, it seems impossible that recommendations on the number of inches of water necessary to produce a crop can be made to apply to the irrigation of potatoes in general or even to one particular district. It also seems apparent that the number of irrigations must vary with the soil, the locality, and with seasonal conditions. Therefore, no attempt has been made to measure the quantity of water applied to the different plots of this experiment. It is believed that the object of irrigation should be to supply the soil, regardless of type, with the degree of moisture needed to afford optimum growing conditions, thus enabling the plants to make a continuous growth.

FIGURE 3.—Adjustable canvas check dam used in the head ditch to check the flow and to raise the water level

The method of determining the quantity of water required with each irrigation was to test the soil 6 or 8 inches below the plants in the row by compressing it and judging in that manner whether there

was sufficient moisture for proper plant growth. To afford proper growing conditions, soil, when compressed in the hand, should form into a ball and moisten the hand.

TIME OF IRRIGATION AS AFFECTING PRODUCTION

For the sake of brevity, the application of water as the plants require it to make a vigorous growth throughout the growing season will be termed "early irrigation"; the application of water when the plants assume a dark-green color "medium-late irrigation" or "check plot"; and the withholding of the first application of water until the growth of the plants is checked "late irrigation." In the irrigation studies here discussed, it was the general practice to make the first application of water to the early-irrigated plots when the plants were 5 or 6 inches high, or about the time the stolon growth first starts. In the Greeley district the late crop of potatoes was generally planted about the first week in June, and the first irrigation of the early-

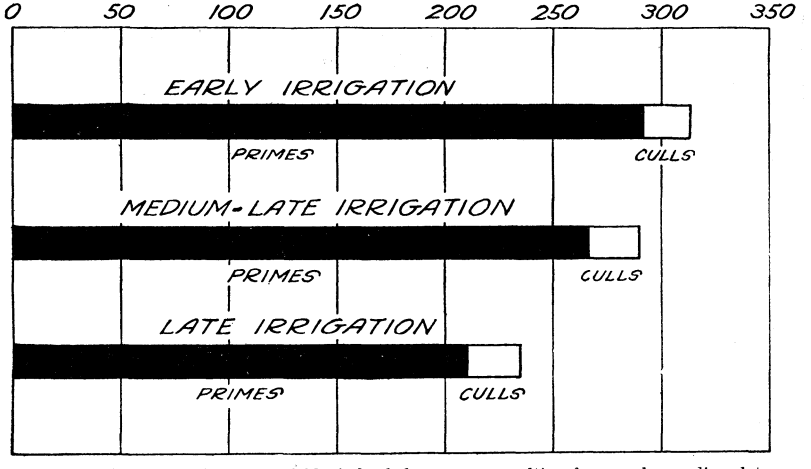

FIGURE 4.—Seven years' average yields, in bushels per acre, resulting from early, medium-late, and late applications of the first irrigation water on potatoes of the Rural New Yorker variety

irrigated plots was given about the second week in July. The time of applying the first water to the medium-late irrigated plots varied with the rainfall and other seasonal conditions, but was generally between July 20 and 25. The late-irrigated plots usually received the first application of water during the first week in August. As previously stated, irrigation with this phase of the experiment was withheld until the plant growth was checked. With a normal rainfall these plots received their first application between August 1 and 9, the time varying with the seasonal conditions.

IRRIGATION STUDIES WITH THE RURAL NEW YORKER VARIETY

In 1919 the early-irrigated plots received the first irrigation July 19 and the medium-late irrigation July 25, whereas the late-irrigated plots received the first application of water August 14. The early-irrigated plots produced 39.14 bushels of primes [4] per acre more than

[4] All the tubers passing over the 1⅞-inch square-mesh screen of the sorter were considered as primes: those passing through it were classed as culls. This statement applies to all of the experimental data presented.

the medium-late irrigated plots and 107.81 bushels of primes more than the late-irrigated plots. The medium-late irrigated plots produced 68.67 bushels of primes more than the late-irrigated plots. (Table 2 and fig. 4.)

In 1920 the early-irrigated plots received the first application of water July 2 and a total of six irrigations for the season. The medium-late irrigated plots received their first irrigation July 21, with a total of four irrigations; the late-irrigated plots received their initial irrigation August 6 and had but two irrigations for the season. The early-irrigated plots produced 7.17 bushels of primes more than the medium-late irrigated plots and 50.44 bushels more primes than the late-irrigated plots. An examination of Table 3 reveals the fact that the percentage of prime tubers also increases with the early irrigations.

TABLE 2.—*Comparison of the relative yields of the Rural New Yorker No. 2 potato variety from early, medium-late, and late irrigations at Greeley, Colo., from 1919 to 1926, inclusive*

Year	Time of irrigation	Number of hills	Weight		Acre yields		
			Primes	Culls	Primes	Culls	Total
			Pounds	*Pounds*	*Bushels*	*Bushels*	*Bushels*
1919	Early (8 rows)	1,458	1,814.5	118.0	226.81	14.75	241.56
	Medium late (12 rows)	2,004	2,252.0	195.0	187.67	16.25	203.92
	Late (8 rows)	1,212	952.0	161.5	119.00	20.19	139.19
1920	Early (8 rows)	1,611	1,970.0	139.5	246.25	17.44	263.69
	Medium late (12 rows)	2,426	2,869.0	187.0	239.08	15.58	254.66
	Late (8 rows)	1,585	1,566.5	233.5	195.81	29.19	225.00
1921	Early (8 rows)	1,576	2,395.0	239.5	299.38	29.94	329.32
	Medium late (12 rows)	2,354	3,223.5	404.0	268.63	33.67	302.30
	Late (8 rows)	1,544	1,477.5	267.5	184.69	33.44	218.13
1922	Early (16 rows)	3,523	5,707.5	429.0	356.72	26.81	383.53
	Medium late (24 rows)	5,189	8,511.5	559.0	354.65	23.29	377.94
	Late (16 rows)	3,117	4,409.5	342.5	275.59	21.41	297.00
1923	Early (16 rows)	3,521	4,771.0	499.0	298.19	31.19	329.38
	Medium late (16 rows)	3,884	4,017.5	564.5	251.09	35.28	286.37
	Late (16 rows)	3,404	3,308.5	566.0	206.78	35.38	242.16
1924	Early (16 rows)	3,571	5,820.0	304.5	363.75	19.03	382.78
	Medium late (16 rows)	3,569	5,444.0	374.5	340.25	23.41	363.66
	Late (16 rows)	3,561	4,659.0	472.5	291.19	29.53	320.72
1925	Early (16 rows)	1,968	3,968.5	226.0	248.03	14.13	262.16
	Medium late (16 rows)	1,960	3,591.5	268.0	224.47	16.75	241.22
	Late (16 rows)	2,099	3,171.0	227.0	198.19	14.19	212.38
1926	Early (16 rows)	3,461	6,726.5	588.0	420.41	36.75	457.16
	Medium late						
	Late (16 rows)	3,461	6,254.0	523.5	390.88	32.72	423.60
Average acre yield, 1919 to 1925	Early				291.3	21.9	313.2
	Medium late				266.5	23.5	290.0
	Late				210.2	26.2	236.4

In 1921 the early, medium-late, and late irrigated plots received their first irrigations July 11, July 19, and August 9, respectively, and correspondingly the number of irrigations were seven, five, and three for the season. A comparison of the 1921 data shows that the early-irrigated plots produced 30.75 bushels more primes per acre than the medium-late irrigated plots, and 114.69 more bushels than the late-irrigated plots. It will also be noted that the medium-late irrigated plots produced 83.94 bushels more primes than the plots receiving their first irrigation late in the season.

The 1922 growing season was very dry, there being but 1.98 inches of rain during the months of June, July, August, and September. In that year the early-irrigated plots received the first application of water July 6 and a total of 11 irrigations for the season. The medium-late plots were irrigated first on July 12 and received 10 irrigations, whereas the late plots received their first irrigation July 26, and a total of 8 irrigations for the year.

It will be noted that in 1922 there was very little difference in yield between the early-irrigated and the medium-late irrigated plots, doubtless owing to the fact that the date of the initial irrigation of the medium-late irrigated plot was considerably advanced in that year. The early-irrigated plots, however, yielded 81.13 bushels of primes more than the late-irrigated plots, whereas the medium-late irrigated plots produced 79.06 bushels per acre more than the late-irrigated plots.

The 1923 irrigation studies with Rural New Yorker again show a consistent increase in yields with the earlier dates of irrigation. The early-irrigated plots, which received their first irrigation July 9, and a total of five irrigations, produced 47.10 more bushels of primes per acre than the plots receiving their first irrigation July 31, and three irrigations for the season. The early-irrigated plot yielded 91.41 bushels more than the late-irrigated plot, which received two irrigations for the season, the first being on August 9. Upon comparison of the data in Table 2 it will also be noted that the medium-late irrigated plots produced 44.31 bushels more in that year than the late-irrigated plots. Table 1 shows that there was an unusually heavy rainfall in June, July, and August of 1923. The yield of primes was materially increased by the early applications of water.

On reviewing the 1924 data, it is seen that the plots receiving the early irrigation produced 23.50 bushels more of primes per acre than the medium-late irrigated plots and 72.56 bushels more than the plots receiving the late irrigation, whereas the medium-late irrigated plots produced 49.06 bushels more than the late-irrigated plots.

The dates of the first irrigation of the early-irrigated, medium-late irrigated, and late-irrigated plots in 1924 were July 14, July 23, and August 4, respectively. Again in 1924 there is a consistent increase in yield of primes with the earlier dates of applying the first irrigation water.

TABLE 3.—*Relative influence of time of irrigation on percentage of prime tubers of the Rural New Yorker No. 2 potato variety from 1919 to 1925, inclusive*

Year	Percentage of prime tubers			Year	Percentage of prime tubers		
	Early irrigation	Medium irrigation	Late irrigation		Early irrigation	Medium irrigation	Late irrigation
1919	72.9	69.2	60.9	1924	79.6	78.0	74.3
1920	75.2	77.2	65.9	1925	72.3	78.8	69.1
1921	67.6	65.5	53.1				
1922	80.9	76.6	74.1	Average [1]	75.3	72.9	67.2
1923	70.8	64.6	61.7				

[1] Average from actual data taken.

The 1925 data were the result of the first year's investigational work on the new farm, which, being in a rather low state of fertility,

did not produce yields comparable with those obtained in previous years on the old farm. Possession of the new farm was not taken until December, 1924. Owing to the lack of winter moisture and early-spring rains, much difficulty was experienced in plowing the ground and preparing the seed bed, which fact partially accounts for the low yields obtained in 1925. However, the early-irrigated plots produced 23.56 bushels per acre more than the medium-late irrigated plots and 49.84 bushels more than the late-irrigated plots.

In 1926 the medium-late irrigated plots were not included in the tests. The early-irrigated plots received the first irrigation July 16 and a total of six irrigations for the season; the late-irrigated plots received their first irrigation August 2 and a total of five irrigations for the season. It will be noted that the early-irrigated plots produced but 29.53 bushels per acre more than the late-irrigated plots, this slight difference in yield doubtless being due to the rainfall during July, when 1.42 inches were recorded.

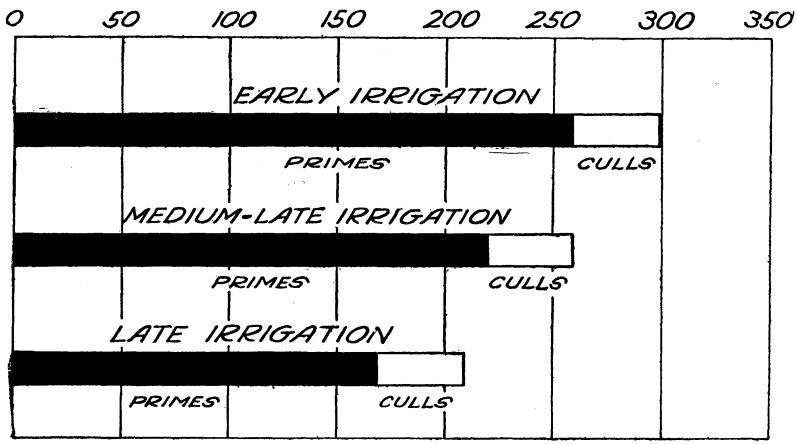

FIGURE 5.—Three years' average yields, in bushels per acre, resulting from early, medium-late, and late applications of the first irrigation water on potatoes of the Peerless (Pearl) variety

IRRIGATION STUDIES WITH THE PEERLESS (PEARL) VARIETY

Table 4 gives a comparison of the relative yields of Peerless (Pearl) potatoes from early, medium-late, and late irrigations from 1919 to 1921, inclusive. (Fig. 5.)

In 1919 the early-irrigated plots received the first application of water July 19 and a total of four irrigations for the season. The medium-late irrigated plots received their first irrigation July 25 and four irrigations, whereas the late-irrigated plots received but two irrigations, the first on August 14. The early-irrigated plots produced 51.18 bushels more primes per acre than the plots receiving their first irrigation six days later and 88.68 bushels more per acre than the late-irrigated plots. The medium-late irrigated plots produced 37.50 bushels more of primes per acre than the late-irrigated plots.

In 1920 the early-irrigated plots of Peerless received their first irrigation July 2, the medium-late ones July 21, and the late-irrigated plots August 6. The plots receiving the first irrigation July 2 produced 27.79 more bushels of primes per acre than the plots receiving the initial irrigation on July 21 and 75.75 bushels more than the plots

receiving their first irrigation August 6. The plots receiving the first irrigation medium late in the season produced 47.96 bushels more than the plots receiving the late irrigation.

TABLE 4.—*Comparison of the relative yields of the Peerless (Pearl) potato variety from early, medium-late, and late irrigations at Greeley, Colo., from 1919 to 1921, inclusive*

Year	Time of irrigation	Number of hills	Weight		Acre yields		
			Primes	Culls	Primes	Culls	Total
			Pounds	*Pounds*	*Bushels*	*Bushels*	*Bushels*
1919	Early (8 rows)	1,406	1,720.5	451.5	215.06	56.44	271.50
	Medium late (12 rows)	1,843	1,966.5	526.5	163.88	43.88	207.76
	Late (8 rows)	1,229	1,011.0	289.5	126.38	36.19	162.56
1920	Early (8 rows)	1,606	2,026.0	226.0	253.25	28.25	281.50
	Medium late (12 rows)	2,392	2,705.5	402.5	225.46	33.54	259.00
	Late (8 rows)	1,615	1,420.0	423.0	177.50	52.88	230.38
1921	Early (8 rows)	1,562	2,474.0	293.0	309.25	36.63	345.88
	Medium late (12 rows)	2,341	3,229.0	491.0	269.08	40.92	310.00
	Late (8 rows)	1,564	1,606.0	242.5	200.75	30.31	231.06

The 1921 irrigation results with Peerless are again similar to those of preceding years. The early-irrigated plots received the first application of water July 11, and seven irrigations for the season. The medium-late plots received the first irrigation July 19 and five irrigations for the year, whereas the late-irrigated plots were watered first on August 9 and received three irrigations for the season. A comparison of yields in Table 4 shows that the early-irrigated plots produced 40.17 bushels of primes per acre more than the medium-late irrigated plots and 108.50 more than the late-irrigated plots, whereas the medium-late irrigated plots produced 68.33 more bushels than the plots receiving their first irrigation late in the season.

IRRIGATING UP

Owing to the insufficient snowfall and spring rains in some districts, together with desiccating winds or continued hot weather, it becomes necessary in some years to irrigate the land before planting, or to "irrigate up" the newly planted crop to insure germination. The term "irrigating up" refers to the applications of water after planting for the particular purpose of supplying moisture to facilitate germination. If spring plowing has been delayed, the land may be irrigated before the operation, to supply sufficient moisture to insure germination. (See fig. 6.) When alfalfa ground has been crowned in the fall or plowed early in the spring it is not practicable to irrigate the soil by the flooding method. Plowed ground is sometimes furrowed or ditched and irrigated before planting, but, as a general rule, if the soil lacks sufficient moisture to germinate the sets, the moisture is not supplied until after planting. When seed of a liberal size has been used and planting has been sufficiently deep, sturdy sprouts may develop from the moisture in the seed pieces and maintain their vigor for some time even though the soil is dry, but moisture must be available before root growth of the sprout can develop. (See fig. 7.)

The studies on irrigating up were made in 1919, 1922, 1925, and 1926 only. During the other years that the experiment was conducted there was sufficient moisture in the soil to insure almost perfect germination. The method followed was to supply sufficient moisture to the soil that came in contact with the seed piece, leaving the top 3 or 4 inches above the seed piece dry if possible, and even though the top soil of the ridge actually became wet from subbing, good results were obtained when the soil was not flooded. At the station, where short rows were employed, it was an easy matter to supply sufficient moisture at the proper height in the ridge by the use of a shallow furrow and a small head of water. In 1919 and 1922 the rows were each 242 feet long, whereas in 1925 and 1926 they were 484 feet long. Although the irrigation water in this experiment was run between each row (fig. 8), it is realized that in many in-

FIGURE 6.—Land irrigated before plowing. The high spot in the field remained dry, resulting in poor germination

stances the watering of every alternate row would be sufficient (fig. 9), the depth of the ditch and the head of water used depending on the length of row, the porosity of the soil, and the slope of the ground. Throughout the experiment, cultivation and harrowing of the soil followed the irrigation as soon as the condition of the soil permitted. A narrow shovel cultivator was employed to pulverize the soil, this type being preferred to the wider one frequently used.

In 1919, 0.56 of an inch of rain fell during the month of April. During May the precipitation was 0.48 of an inch, and for the month of June only 0.18 of an inch was recorded at the station. (See Table 1.) The irrigation-experiment plots were planted June 3. The soil became very dry shortly after planting, and on June 18 three plots of Rural New Yorker and three of Peerless were irrigated up. It is believed that much better results would have been obtained if these plots could have been irrigated up a week earlier. On June 23 a

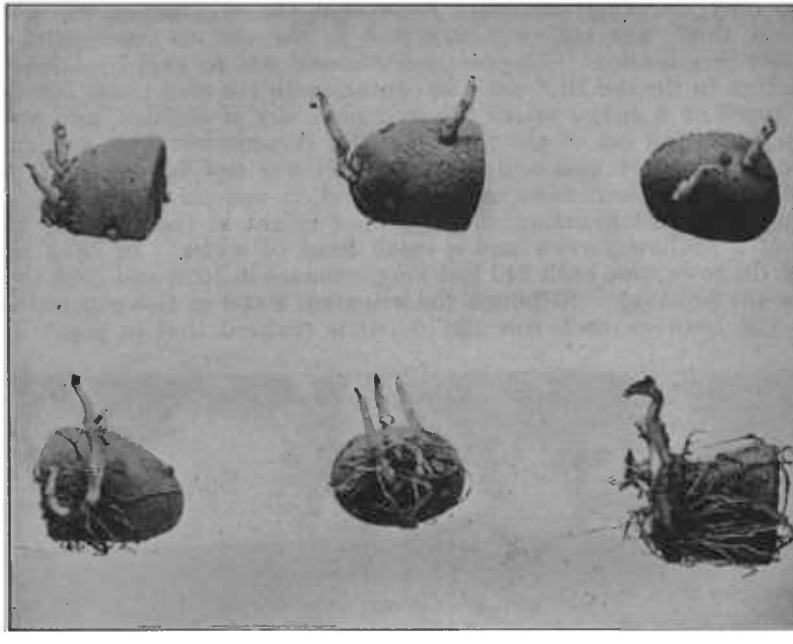

FIGURE 7.—The seed pieces in the top row were taken rom dry soil; those in the hottom row were taken from moist soil. Note the ab_ence of roots on the upper seed pieces. All were planted on the same date

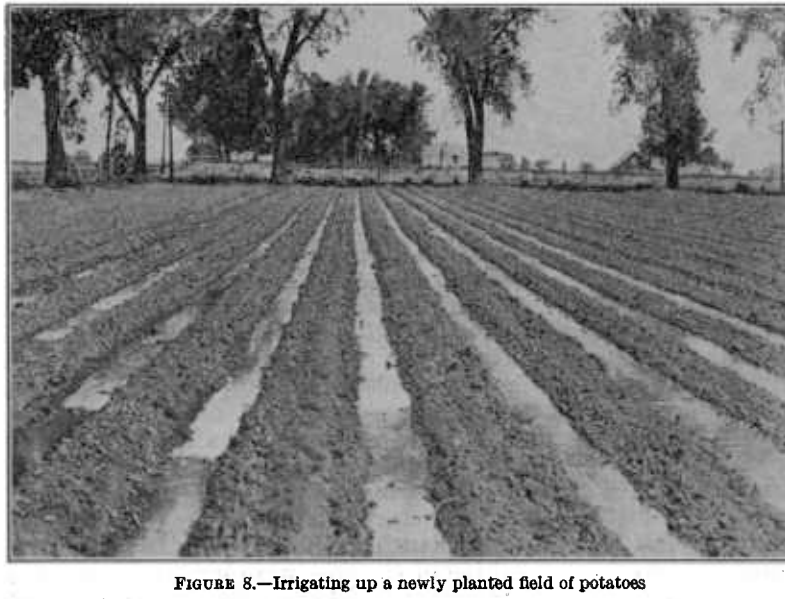

FIGURE 8.—Irrigating up a newly planted field of potatoes

plot each of Rural New Yorker and Peerless that had not been irrigated up on the 18th were watered. The germination of one plot of Rural New Yorker irrigated up on June 18 was 81.50 per cent; the other plot of Rural New Yorker irrigated up on the same date averaged 89.3 per cent. The germination on one plot of Peerless was 86.20 per cent, whereas the other plot of Peerless averaged 86.20 per cent. The plot of Rural New Yorker that was not irrigated up until five days later gave but 67.10 per cent of a stand, while the stand of the plot of Peerless irrigated up on the latter date gave 64.50 per cent. The yield of these plots was governed by the methods followed in later irrigations, but the percentage of stand was influenced by the time of irrigating up. (Table 5.)

FIGURE 9.—Ditches made between alternate pairs of rows for irrigating up. With long rows this is a common method of applying water, although it is not as desirable as that shown in Figure 8

The year 1922 was also a dry one, the moisture being sufficiently low in the soil soon after planting to warrant irrigating up a portion of the experiment. Two 8-row plots were irrigated up on June 16. On reviewing the data for that year (Table 6) it will be seen that 95.70 per cent of a stand was obtained on the plots irrigated up after planting, whereas the two plots that were not irrigated up produced only 84.70 per cent. The yield obtained was in accordance with later irrigations, but the germination was improved in that year by irrigating up the crop.

As previously stated, the work of the potato-experiment station was moved to a new location during the winter of 1924. No crowning was done in the fall of that year, a practice that had been previously followed. At the time the land was being plowed in the spring of 1925, the soil was deemed sufficiently dry to afford an opportunity for a comparison of results obtained from irrigating land before plowing and irrigating up after planting. A 2-acre plot of ground was therefore irrigated by the flooding method the middle of May, plowed five days later, fitted, and the plots planted May 26.

TABLE 5.—*Relative germinaiion and yield from plots of Rural New Yorker and Peerless (Pearl) varieties of potatoes irrigated up on different dates but otherwise given the same irrigation and plots irrigated up but given more frequent irrigations, in 1919*

Date of irrigating up and subsequent irrigations	Row No.[1]	Rural New Yorker				Peerless			
		Percentage of germination	Acre yields			Percentage of germination	Acre yields		
			Primes	Culls	Total		Primes	Culls	Total
			Bushels	*Bushels*	*Bushels*		*Bushels*	*Bushels*	*Bushels*
Irrigated up June 18; subsequent irrigations Aug. 14 and 26	1	83.3	155.5	22	177.5	87.3	141.5	35	176.5
	2	79.9	156.5	21	177.5	85.8	145	36	181
	3	80.4	141	21	162	88.2	161	40	201
	4	82.4	162	21	183	83.3	143	41.5	184.5
Average		81.5	153.8	21.3	175	86.2	147.6	38.1	185.8
Irrigated up June 23, subsequent irrigations Aug. 14 and 26	1	69.6	92.5	20	112.5	63.2	93	30	123
	2	67.2	72	14	86	64.2	104	33	137
	3	64.7	96	21.5	117.5	66.7	111.5	38.5	150
	4	66.7	76.5	21	97.5	63.7	112	35.5	147.5
Average		67.1	84.3	19.1	103.4	64.5	105.1	34.3	139.4
Irrigated up June 18; subsequent irrigations July 19, Aug. 1, 14, and 26	1	94.1	237	17.5	254.5	87.8	274	71.5	345.5
	2	93.1	254	15	269	86.3	200	61	261
	3	92.2	250	18.5	268.5	83.3	247	60	307
	4	94.1	240	17	257	88.7	192.5	39	231.5
Do	1	84.3	206	12	218	90.7	202	56	258
	2	86.3	211.5	15.5	227	83.3	194	53.5	247.5
	3	86.8	216	12	228	83.8	205	61.5	266.5
	4	83.8	200	10.5	210.5	85.3	206	49	255
Average		89.3	226.8	14.8	241.6	86.2	215.1	56.4	271.5

[1] Each row was one-sixtieth of an acre in area.

TABLE 6.—*Relative germination and yield from plots of Rural New Yorker potatoes irrigated up and those not irrigated up, in 1922*

Dates of irrigation	Row No.[1]	Irrigated up June 16				Not irrigated up			
		Percentage of germination	Acre yields			Percentage of germination	Acre yields		
			Primes	Culls	Total		Primes	Culls	Total
			Bushels	*Bushels*	*Bushels*		*Bushels*	*Bushels*	*Bushels*
Plot 1: July 6, 12, 19, 26; Aug. 2, 9, 16, and 23	1	97	345.5	27	372.5	88.3	274	20	294
	2	97.8	363.5	29	392.5	73.9	261.5	17	278.5
	3	98.7	348	28.5	376.5	91.3	261.5	17.5	279
	4	95.7	360	31	391	89.1	283	30	313
	5	95.2	352	31	383	87.8	292	24	316
	6	93.5	358	31	389	88.3	280	35	315
	7	90.9	339	23.5	362.5	89.6	273	24	297
	8	94.4	359.5	23	382.5	90	283.5	19.5	303
Plot 2: Aug. 30, Sept. 7 and 13	1	93.9	389	25	414	81.3	277	21.5	298.5
	2	93	342.5	28	370.5	78.3	287	14	301
	3	96.1	336.5	29.5	366	83.5	269	19.5	288.5
	4	98.7	374	26	400	81.7	282	18.5	300.5
	5	96.5	373	19.5	392.5	82.6	284.5	23	307.5
	6	97.4	355	27	382	83.5	265	17	282
	7	97.4	350	23	373	81.7	255.5	21	276.5
	8	95.7	362	27	389	84.4	281	21	302
Average		95.7	356.7	26.8	383.5	84.7	275.6	21.4	297

[1] Each row was one-sixtieth of an acre in area.

Comparison of the figures presented in Table 7 shows that a 95.70 per cent stand was obtained where the land was irrigated before plowing. The plots that were not irrigated were planted June 2 and irrigated up June 7. These plots produced but 60.30 per cent of a stand. The rows were 484 feet long, the lower 200 feet being poorly drained.

Immediately following the irrigating up, or before the work was quite completed, 0.70 of an inch of rain fell in a very short period of time. Water ran down the rows, flooding the lower 200 feet, and it was on this poorly drained portion of the field that the seed rotted and a very poor germination was obtained. On June 12, 0.23 of an inch of rain fell; on June 14, 0.16 of an inch, and on June 15 1.18 inches was recorded at the station. These heavy rains and the water applied while irrigating up, together with the poor drainage conditions, puddled the soil and resulted in very unfavorable germinating conditions. On the upper end of the rows where there was good drainage a very good stand was obtained.

TABLE 7.—*Relative germination and yield of Rural New Yorker potatoes from land irrigated before plowing and that irrigated after planting in 1925*

Dates of irrigation	Row No.	Irrigated before plowing				Irrigated after planting			
		Percentage of germination	Estimated acre yields			Percentage of germination	Estimated acre yields		
			Primes	Culls	Total		Primes	Culls	Total
			Bushels	*Bushels*	*Bushels*		*Bushels*	*Bushels*	*Bushels*
Plot 1: July 9 and 16	1	98	312.5	19	331.5	65	272	13.5	285.5
	2	95.6	303	23.5	326.5	63.7	227.3	18.3	245.5
	2	97.1	309	18.5	327.5	64.2	229	15.8	244.8
	4	92.2	326.5	15	341.5	65.4	234.3	9	243.3
	5	93.1	288.5	16	304.5	------	------	------	------
	6	97.1	308	21.5	329.5	------	------	------	------
	7	97.1	297	21	318	------	------	------	------
	8	97.6	309.5	22.5	332	------	------	------	------
Plot 2: Aug. 5, 24, and 31	1	95.6	279.5	20	299.5	51.5	246	11	257
	2	97.1	290	18.5	308.5	53.4	261.3	16	277.3
	3	92.2	304.5	18	322.5	55.4	234	10.5	244.5
	4	92.2	299	10.5	309.5	63.7	280.5	19	299.5
	5	97.1	331	22	353	------	------	------	------
	6	96.1	293.5	18	311.5	------	------	------	------
	7	96.6	296	19.5	315.5	------	------	------	------
	8	96.1	299.5	23	322.5	------	------	------	------
Average	------	95.7	302.9	19.2	322.1	60.3	248.1	14.1	262.2

In 1926 the irrigating-up experiment consisted of four plots of four rows each, the rows being 484 feet long. The plots were planted with whole seed. Two of the plots were irrigated up June 14, and two were not irrigated up. One of each of the two plots received four irrigations during the month of August and one on September 3. Except for the fact that one of these plots was irrigated up, they were handled in exactly the same manner during the remainder of the season. The germination on the plot that was irrigated up was 96.30 per cent and gave a total yield of 435.90 bushels per acre; the plot irrigated on the same dates but not irrigated up gave 91.80 per cent of a stand and 411.31 bushels per acre total yield, or 24.57 bushels less than the plot that was irrigated up. The other two plots of this experiment received two irrigations in July, four in August, with the

last irrigation September 3. One of these plots was irrigated up June 14, and the other was not irrigated up. The plot that was irrigated up produced 96.50 per cent of a stand, while that which was not gave a germination of 91.60 per cent. The plot irrigated up produced 446.10 bushels of primes and 36.80 bushels of culls per acre, or a total production of 482.90 bushels; the plot that was not irrigated up produced 394.70 bushels of primes and 36.70 bushels of culls, a total yield of 431.40 bushels per acre, or 51.56 bushels less than the plot that was irrigated up after planting. (Table 8.)

The germination of the plots that were irrigated up was 96.30 per cent for one and 96.50 for the other. The germination of the plots that were not irrigated up was 91.80 and 91.60 per cent, respectively. It is evident that in 1926 there was sufficient moisture in the soil to sprout a large percentage of the seed planted without irrigating up. However, irrigating after planting improved the stand and also increased the yield.

TABLE 8.—*Relative germination and yield of Rural New Yorker potatoes from plots irrigated up and those which were not irrigated up, in 1926*

Dates of irrigation	Row No.[1]	Irrigated up June 14				Not irrigated up			
		Percentage of germination	Estimated acre yields			Percentage of germination	Estimated acre yields		
			Primes	Culls	Total		Primes	Culls	Total
			Bushels	*Bushels*	*Bushels*		*Bushels*	*Bushels*	*Bushels*
Plot 1: Aug. 2, 12, 19, 26; Sept. 3	1	97.4	433.3	38	471.3	90.9	373.8	36.5	410.3
	2	96.5	389.5	23	412.5	91.7	383.5	32	415.5
	3	95.7	438.5	42.8	481.3	92	398.5	28.8	427.3
	4	95.7	350.5	28	378.5	92.6	359.5	32.8	392.3
Average		96.3	402.9	32.9	435.9	91.8	378.8	32.5	411.3
Plot 2: July 30; Aug. 12, 19, 26; Sept. 3	1	97.8	465	35	500	92.6	381	38.5	419.5
	2	96.1	448.3	31	479.3	91.7	410	28	438
	3	95.2	466.5	42.3	508.8	90.9	383.5	40.8	424.3
	4	96.7	404.8	39	443.8	91.3	404.3	39.5	443.8
Average		96.5	446.1	36.8	482.9	91.6	394.7	36.7	431.4

[1] Each row was one-thirtieth of an acre in area.

LIGHT COMPARED WITH HEAVY IRRIGATION

In studying the effect of light and heavy applications of water on yield, no attempt was made to measure the water applied with each irrigation or the total applied to each plot during the growing season, because the quantity of water required to produce a crop of potatoes in one location could not be given as a standard for irrigation, inasmuch as the amount will vary with seasonal conditions and with the variation in type of surface and subsoil. The plots receiving light and heavy applications of water were planted, cultivated, irrigated, and in every way handled in the same manner except in the quantity of water supplied with each irrigation, these being governed by the condition of the soil in the row. Where light applications were made the water was allowed to run until the soil in the row under the hills became moist; or sufficient water was added at frequent intervals to enable the plants to make a continuous and vigorous growth. The

plots given heavy applications with each watering were irrigated until the soil was fairly well saturated around the tubers before the water was shut off, thus simulating the soil-moisture conditions produced by the average irrigator with every irrigation. This water was applied to determine whether the additional water would give an increase in yield, and not to what extent water could be added without having an injurious effect on quality or yield. On comparing the figures for 1924, it will be noted that the average total yields in bushels per acre of plots on which the light and the heavy applications of water were made are practically the same (Table 9).

TABLE 9.—*Relative yields of Rural New Yorker potatoes from light and heavy applications of water, in 1924*

Dates of irrigation	Row No.[1]	Light applications						Heavy applications					
		Number of hills	Number of tubers		Acre yields			Number of hills	Number of tubers		Acre yields		
			Primes	Culls	Primes	Culls	Total		Primes	Culls	Primes	Culls	Total
					Bush.	*Bush.*	*Bush.*				*Bush.*	*Bush.*	*Bush.*
Plot 1: July 14, 23; Aug. 4, 11, 18, 25; Sept. 1	1	224			360. 5	14	374. 5	224			376	16	392
	2	225	762	189	387	17. 5	404. 5	220	667	294	360	27	387
	3	224			375. 5	25	400. 5	222			342. 5	19	361. 5
	4	224			386	14	400	220	641	208	349	26	375
	5	224			384	22. 5	406. 5	220			367	21. 5	388. 5
	6	223	774	189	379. 5	16	395. 5	222			354	22. 5	376. 5
	7	224			384	21	405	223			362. 5	22	384 5
	8	224			384	21	405	224			377	20. 5	397. 5
Plot 2: July 14, 23; Aug. 4, 11, 18, 25; Sept. 1	1	224			350	17	367	224			351	20	371
	2	223	678	167	336	20	356	224	708	155	361. 5	14	375. 5
	3	224			350. 5	21	371. 5	225			341	22	363
	4	220	645	187	341	15. 5	356. 5	224	687	190	369. 5	13	382. 5
	5	218			345. 5	26	371. 5	220			361	27. 5	388. 5
	6	224			356	13	369	224			363	16. 5	379. 5
	7	225			352	21	373	224			363. 5	21. 5	385
	8	221			348. 5	20	368. 5	221			382	15. 5	397. 5
Average		232. 2	714. 8	183	363. 8	19	382. 8	222. 6	675. 8	211. 8	361. 3	20. 3	381. 6

[1] Each row was one-sixtieth of an acre in area.

Although possibly twice the quantity of water was added to the heavily irrigated plots in 1925, the yields were again very similar, the difference of 8.50 bushels per acre being in favor of the heavy irrigations. (Table 10.)

It will be noted that in 1926 there was very little difference in yield between the plots receiving the heavy irrigation and those receiving the light applications of water. (Table 11.)

For the three years the average yields of the plots receiving the light and the heavy applications of water are practically the same, being for the plots receiving light applications of water 352.64 bushels of primes and 23.32 bushels of culls, or a total of 375.96 bushels per acre. The plots receiving the heavy application of water with each irrigation gave an average yield of 351.67 bushels of primes and 23.59 bushels of culls, or a total of 375.26 bushels per acre. It will be noted that for the 3-year average there was a difference in total yield of less than 1 bushel per acre with the two methods of irrigation. (See fig. 10.)

TABLE 10.—*Relative yields of Rural New Yorker potatoes from light and heavy applications of water in 1925*

Dates of irrigation	Row No.[1]	Light applications						Heavy applications					
		Number of hills	Number of tubers		Acre yields			Number of hills	Number of tubers		Acre yields		
			Primes	Culls	Primes	Culls	Total		Primes	Culls	Primes	Culls	Total
					Bush.	*Bush.*	*Bush.*				*Bush.*	*Bush.*	*Bush.*
Plot 1: July 15; Aug. 3 and 24	1	265			272	13.5	285.5	240			211	13.5	224.5
	2	260	680	347	227.3	18.3	245.5	242	752	185	237.3	16	253.3
	3	262			229	15.8	244.8	244			230.5	15.5	246
	4	267			234.3	9	243.3	248			241.3	14.5	255.8
Plot 2: Sept. 1	1	210			246	11	257	260			279	13.3	292.3
	2	218	710	185	261.3	16	277.3	254	776	126	276.3	13.5	289.8
	3	226			234	10.5	244.5	252			304	13.3	317.3
	4	260			280.5	19	299.5	240			271	15.5	286.5
Average		246	695	266	248.1	14.1	262.2	247.5	764	155.5	256.3	14.4	270.7

[1] Each row was one-thirtieth of an acre in area.

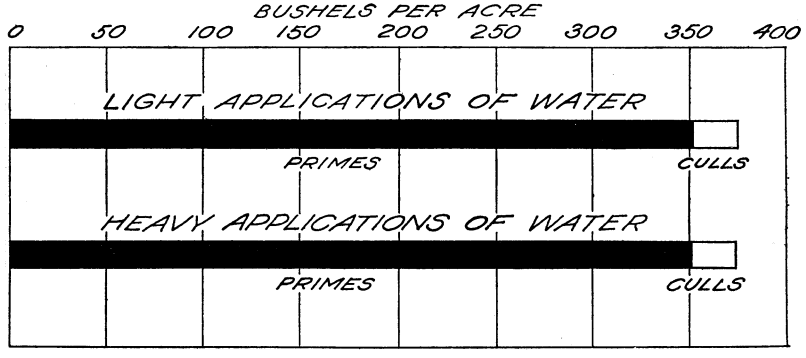

FIGURE 10.—Three years' average yields, in bushels per acre, from light and heavy applications of water on potatoes of the Rural New Yorker variety

TABLE 11.—*Relative yields of Rural New Yorker potatoes from light and heavy applications of irrigation water in 1926*

Dates of irrigation	Row No.	Light applications						Heavy applications					
		Number of hills	Number of tubers		Acre yields			Number of hills	Number of tubers		Acre yields		
			Primes	Culls	Primes	Culls	Total		Primes	Culls	Primes	Culls	Total
					Bush.	*Bush.*	*Bush.*				*Bush.*	*Bush.*	*Bush.*
July 16, 30; Aug. 12, 19, 26; Sept. 3	1	450			465	35	500	444			402	23.3	425.3
	2	442	1,642	348	448.3	31	479.3	442	1,866	824	492	40	532
	3	438			466.5	42.3	508.8	444			464.5	48	512.5
	4	445			404.8	39	443.8	436			391.3	33.3	424.5
Average		443.8			446.2	36.8	483	441.5			437.5	36.1	473.6

LITERATURE CITED

(1) BARK, D. H.
1916. EXPERIMENTS ON THE ECONOMICAL USE OF IRRIGATION WATER IN IDAHO. U. S. Dept. Agr. Bul. 339, 57 p., illus.
(2) CLARK, C. F.
1921. REPORT OF POTATO INVESTIGATIONS. Colo. Agr. Expt. Sta. Bul. 261, 34 p., illus.
(3) FARRELL, F. D.
1911. WORK OF THE GOODING SUBSTATION. Idaho Country Life 4(9): 13–15, 19.
(4) FLEMING, B. P.
1902. THE EFFECT OF DIFFERENT AMOUNTS OF WATER USED IN IRRIGATION UPON THE YIELD OF POTATOES. Wyo. Agr. Expt. Sta. Rpt. (1901/02)12:31–34.
(5) ———
1905. DUTY OF WATER. Wyo. Agr. Expt. Sta Bul. 67, 20 p.
(6) HARRIS, F. S.
1917. THE IRRIGATION OF POTATOES. Utah Agr. Expt. Sta. Bul. 157, 20 p., illus.
(7) ——— and PITMAN, D. W.
1923. IRRIGATION EXPERIMENTS WITH POTATOES. Utah Agr. Expt. Sta. Bul. 187, 14 p., illus.
(8) ISRAELSEN, O. W., and WINSOR, L. M.
1922. THE NET DUTY OF WATER IN SEVIER VALLEY. Utah Agr. Expt. Sta. Bul. 182, 36 p., illus.
(9) KNIGHT, C. S., and HARDMAN, G.
1919. IRRIGATION OF FIELD CROPS IN NEVADA. Nev. Agr. Expt. Sta. Bul. 96, 42 p., illus.
(10) KNORR, F.
1914. EXPERIMENTS WITH CROPS UNDER FALL IRRIGATION AT THE SCOTTSBLUFF RECLAMATION PROJECT EXPERIMENT FARM. U. S. Dept. Agr. Bul. 133, 17 p., illus.
(11) ———
1915. MANAGEMENT OF IRRIGATED LAND. Nebr. Agr. Expt. Sta. Bul. 152, 24 p., illus.
(12) MARTIN, D. G.
1911. EIGHTH BIENNIAL REPORT OF THE STATE ENGINEER TO THE GOVERNOR OF IDAHO. 1909–1910. 367 p., illus. Boise, Idaho.
(13) POWERS, W. L., and JOHNSTON, W. W.
1920. IRRIGATION OF POTATOES. Oreg. Agr. Expt. Sta. Bul. 173, 28 p., illus.
(14) RICHMAN, E. S.
1894. IRRIGATION OF POTATOES. Utah Agr. Expt. Sta. Rpt. (1893)4: 179–180.
(15) UNITED STATES BUREAU OF THE CENSUS.
1922. FOURTEENTH CENSUS OF THE UNITED STATES TAKEN IN THE YEAR 1920. V. 5. AGRICULTURE. Washington, D. C.
(16) WELCH, J. S.
1914. IRRIGATION PRACTICE. Idaho Agr. Expt. Sta. Bul. 78, 27 p., illus.
(17) WIDTSOE, J. A.
1902. IRRIGATION INVESTIGATIONS IN 1901. Utah Agr. Expt. Sta. Bul. 80, p. 62–199, illus.
(18) ———
1903. THE RIGHT WAY TO IRRIGATE. Utah Agr. Expt. Sta. Bul. 86, p. 53–101, illus.
(19) ——— and MERRILL, L. A.
1912. THE YIELDS OF CROPS WITH DIFFERENT QUANTITIES OF IRRIGATION WATER. Utah Agr. Expt. Sta. Bul. 117, p. 69–119, illus.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

September 11, 1929

Secretary of Agriculture	ARTHUR M. HYDE.
Assistant Secretary	R. W. DUNLAP.
Director of Scientific Work	A. F. WOODS.
Director of Regulatory Work	WALTER G. CAMPBELL.
Director of Extension Work	C. W. WARBURTON.
Director of Personnel and Business Administration.	W. W. STOCKBERGER.
Director of Information	M. S. EISENHOWER.
Solicitor	R. W. WILLIAMS.
Weather Bureau	CHARLES F. MARVIN, *Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Bureau of Dairy Industry	O. E. REED, *Chief.*
Bureau of Plant Industry	WILLIAM A. TAYLOR, *Chief.*
Forest Service	R. Y. STUART, *Chief.*
Bureau of Chemistry and Soils	H. G. KNIGHT, *Chief.*
Bureau of Entomology	C. L. MARLATT, *Chief.*
Bureau of Biological Survey	PAUL G. REDINGTON, *Chief.*
Bureau of Public Roads	THOMAS H. MACDONALD, *Chief.*
Bureau of Agricultural Economics	NILS A. OLSEN, *Chief.*
Bureau of Home Economics	LOUISE STANLEY, *Chief.*
Plant Quarantine and Control Administration.	C. L. MARLATT, *Chief.*
Grain Futures Administration	J. W. T. DUVEL, *Chief.*
Food, Drug, and Insecticide Administration	WALTER G. CAMPBELL, *Director of Regulatory Work, in Charge.*
Office of Experiment Stations	E. W. ALLEN, *Chief.*
Office of Cooperative Extension Work	C. B. SMITH, *Chief.*
Library	CLARIBEL R. BARNETT, *Librarian.*

This bulletin is a contribution from

Bureau of Plant Industry	WILLIAM A. TAYLOR, *Chief.*
Office of Horticultural Crops and Diseases	E. C. AUCHTER, *Principal Horticulturist, in Charge.*

U. S. GOVERNMENT PRINTING OFFICE: 1929

For sale by the Superintendent of Documents, Washington, D. C. - - - - - Price 5 cents