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PROGRESS REPORT OF COOPERATIVE IRRIGATION EXPERIMENTS AT CALIFORNIA UNIVERSITY FARM, DAVIS, CAL., 1909–1912.

By S. H. Beckett,
Irrigation Engineer.

INTRODUCTION.

The experiments herein described were planned and carried out for the purpose of determining the water requirements of various standard crops. For the purpose a tract of 25 acres on the University farm at Davis was set aside by the college of agriculture. The work was planned and carried on by the irrigation investigations of the Office of Experiment Stations, in cooperation with the department of engineering of the State of California, the California Experiment Station furnishing seed and a part of the labor in return for the crops.

The University farm, comprising 779 acres, lies one-half mile west of the town of Davis. The soil, which is typical of that of a great portion of the Sacramento Valley, is classed as Yolo loam, described by the Bureau of Soils of this department, as follows:

> The surface soil of the Yolo loam consists of a dark-brown loam of light to rather heavy texture. The soil is usually free from gravel. Below a depth of 24 inches the subsoil is generally made up of strata of silty loam or sandy loam. At greater depths this rests on clay loam or clay. * * *
>
> Owing to the excellent drainage and comparatively open texture of this type it has proved to be well adapted to fruit, including peaches, almonds, prunes, and grapes. * * * While irrigation has not been in general use, it has been found to be beneficial to the tree and fruit where the lower strata of the soil lack the close texture and compactness necessary for the retention of moisture. It is one of the best general-purpose soils in the region and is adapted to a wide range of crops.[1]

The mean annual rainfall, although slightly below the average for the Sacramento Valley as a whole, amounts to 16.54 inches, the greater part of which comes in December, January, February, and March, while from May to October very little rain falls. A mean temperature of 77.9° F. is recorded for the month of July, the mean

[1] U. S. Dept. Agr., Bur. Soils, Field Operations, 1909, Eleventh Report, pp. 1657, 1658.

minimum of 47.6° F. occurring in January. The maximum temperature recorded is 112° F., and 16° F. has been registered as a minimum. These extremes are exceptional, however.

As a preliminary step in starting the experiments at Davis, a 12-inch well was sunk near the northeast corner of the tract and a 4-inch horizontal centrifugal pump, directly connected with a 7½-horsepower motor was installed, thus insuring a reliable water supply. Water was delivered to the various checks and field laterals through 8-inch galvanized-iron slip-joint pipe. When properly fitted together this was practically watertight, eliminating loss in transportation.

Before starting each irrigation the discharge from the pump was measured over an 18-inch Cippoletti weir, and the measurements were used in computing the amount of water applied.

IRRIGATION OF ALFALFA.

Operations were started in 1907, and in the fall of that year the major portion of the tract was leveled for alfalfa irrigation. Border, rectangular, and contour systems of checks were used, and at the time it was intended to rely upon the open-ditch system of the Yolo County Consolidated Water Co. for water. The accompanying sketch (fig. 1) shows the system of checks and ditches installed, the acreage of each check, and its number, which will be used in future designation.

During the whole of 1908 the land stood idle. Early in March, 1909, plats 1 to 28, 32, 33, 34, and the west half of 35, 36, and 37 were thoroughly disked, cross-disked, harrowed, and seeded to alfalfa, 20 pounds of Utah seed per acre being used. A grain drill, with alfalfa attachments, was used which placed the seed at a depth of about 1 to 1½ inches in the soil, in rows 6 inches apart. A good uniform stand was obtained, and by the middle of May a 3-inch to 4-inch growth had been made.

The following schedule for the season's irrigation was outlined and closely followed:

Schedule of irrigation, 1909.

Number of plat.	Number of irrigations.	Dates of irrigation.	Depth of water applied.
			Inches.
1 to 4	No irrigation		
5 to 9	1 early	June 5	15.0
32, 33	1 midseason	July 14	6.1
10 to 15	1 late	August 10	14.3
36	1 very late	September 9	10.6
20 to 23	1 early, 1 late	May 31	12.5
		August 10	15.4
24 to 28	2 late	July 14	7.8
		August 23	7.0
37	2 very late	August 1	9.4
		September 9	8.9
16 to 19	3 early	May 29	12.5
	3 midseason	July 13	7.2
	3 late	August 23	7.0

During the growing season the growth and condition of the crops were carefully observed, and at the end of the season the results were as stated below:

No irrigation.—At the end of November only about one-third of the stand seemed to be alive, and this had made not more than a 1 or 2 inch growth after it was first cut in June.

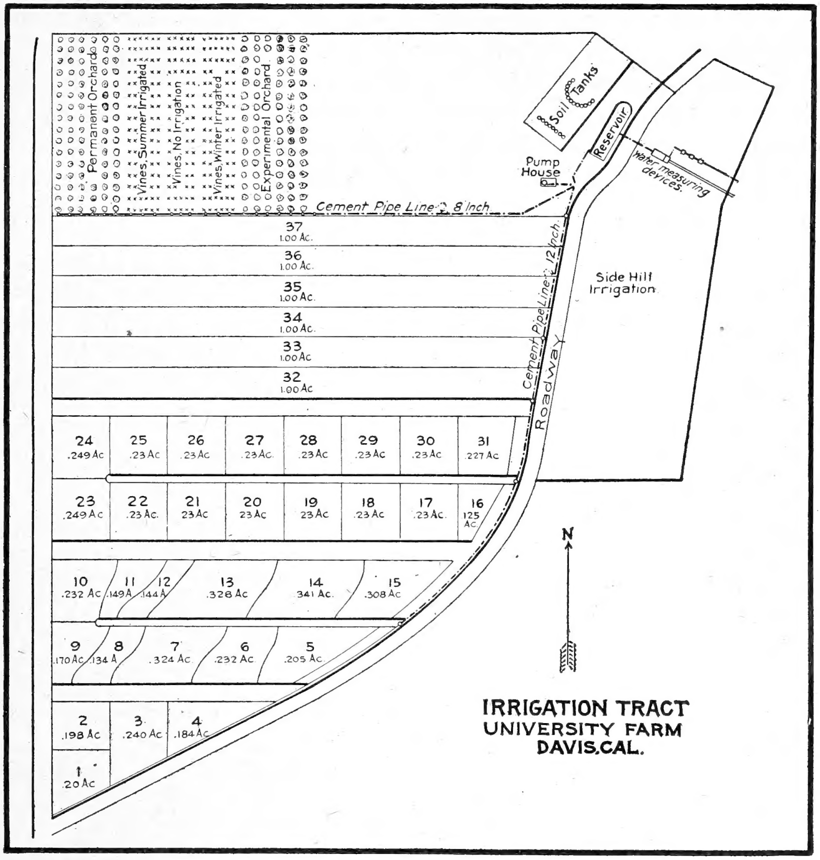

FIG. 1.—Irrigation tract, University farm, Davis, Cal.

One irrigation.—The alfalfa given one early irrigation showed practically no growth after the first cutting on May 14. Even after the heavy irrigation of June 5 it failed to make a substantial growth, and at the end of the season not more than one-half of it was alive. The explanation of this is that it was given too early an irrigation. The plats were irrigated before the roots had penetrated beyond the surface soil, and when this had dried out, following the first irrigation, the roots were stranded in a surface soil without sufficient moisture to forward the growth.

The midsummer irrigation of July 14 produced two very light crops and left the plants alive but growing very slowly at the end of the season. Before this first irrigation was applied the root system had time to penetrate well into the subsoil and receive full benefit from the irrigation after it was applied.

The late and very late irrigations both produced one fair crop besides the first light crop cut in May, and at the end of the season all of the alfalfa had shown a vigorous growth, with no apparent effects from the early drought, indications pointing toward a good yield in the spring.

Two irrigations.—In the plats given one early and one late irrigation only a 2-inch growth was shown between the cutting in the middle of June and the irrigation on August 10. Following the first irrigation the alfalfa made a slight growth, but it was not until after the second application that a substantial growth was made, which produced one fair cutting in September.

One midsummer and one late irrigation produced a fair cutting in September, followed by a second and much heavier crop early in November. At the time of this last cutting the stand was in very good condition, the plants being deep-rooted and sturdy.

Two late irrigations of 9.4 and 8.9 inches, respectively, applied August 1 and September 9, produced two good crops, the first on September 7 and the last November 12, and at the end of the season these plats had not only produced the heaviest first-season yields, but contained the hardiest and best appearing plants.

Three irrigations.—In these plats the first and heaviest irrigation, applied May 29, seemed to have little effect upon the stand aside from keeping it alive; but after the second application, on July 13, the growth was rapid; and following the third application of August 23 a heavy first-year crop was taken off October 12, and a second fair crop in November, and at the end of the season the plants seemed to be very well developed, indicating probable heavy yields the following spring.

Late in November plats 35, 36, and 37 were all given a very heavy early-winter irrigation. This was waste water pumped onto the plats during the testing out of the pumping plant, and, all told, the water applied must have amounted to a depth of about 18 inches. This seemed to have a remarkable effect upon the stand and was directly responsible for a heavy yield with small amounts of water the following summer.

Although no definite conclusions can be drawn from a single season's observations, nevertheless the results obtained point to the following facts:

(1) Without irrigation spring-sown alfalfa is uncertain in Sacramento Valley, and under conditions of normal rainfall and moderate

climate not more than one-half of the stand can be expected to survive through the summer.

(2) Heavy spring irrigations, when followed by long periods throughout the summer without water, did not benefit alfalfa. Examination of the root growth under these conditions shows that water applied to the little plants in the early spring produces a root growth outwardly along the surface of the soil rather than downward, and when this is followed by long dry periods, the soil drying out leaves the young plant stranded above the moisture zone. Far better results were obtained by delaying irrigation until the root growth was well established, and even until the little plants seemed to be stunted and suffering for moisture. Well-developed, deep-rooted plants mean heavier yields.

(3) Late and very late summer irrigations tend to produce sturdier plants and heavier yields the following summer.

(4) After the root growth is well established, the growth may then be forced by frequent and, if the soil will stand it, heavy irrigations.

DUTY OF WATER FOR ALFALFA, 1910, 1911, AND 1912.

The investigations during the first year's growth of the alfalfa had naturally destroyed the uniformity of the stand, making it necessary to reseed the whole area. Early in March the ground was thoroughly disked, cross-disked, and harrowed to a depth of 2 inches. It was then reseeded, 20 pounds of Utah seed per acre being drilled in at right angles to the seeding of the year before. This seed was brought up by the early spring rains and at the time of the first cutting on April 21 a very uniform stand covered the whole area.

The previous year's work had shown that the water supply from the ditch system was inadequate for experimental work, and the pumping plant was installed and used in all subsequent work, the ditch system being abandoned.

The following schedule for irrigation was outlined and followed on all but three of the checks in 1910 and 1911:

Schedule of irrigation of alfalfa, 1910 and 1911.

Number of plat.	Area.	Depth of water applied.	Schedule.
	Acres.	*Inches.*	
1, 2, 3, 4	0.822	....	No irrigation.
9, 10, 11	.536	....	Do.
8, 12	.293	12	6 inches after first and second cuttings.
7, 13	.652	24	8 after first, second, and third cuttings.
22, 23, 24, 25	.960	30	7½ after first, second, third, and fourth cuttings.
17, 18, 19, 28	.920	30	3¾ inches one week after first, second, third, and fourth cuttings; 3¾ inches before second, third, fourth, and fifth cuttings.
20, 21, 26, 27	.920	30	7½ inches one week before second, third, fourth, and fifth cuttings.
33	1.000	36	12 inches after first; 8 inches after second, third, and fourth cuttings.
6, 14	.573	36	9 inches after first, second, third, and fourth cuttings.
32	1.000	48	12 inches after first, second, third, and fourth cuttings.
5, 15	.513	48	Do.

A winter irrigation applied to checks 35, 36, and 37 produced a marked improvement in the stand which was carried over into the following season, producing much heavier yields. For this reason they were treated separately, the following schedule being used:

Schedule of irrigation of alfalfa, 1910 and 1911.

Number of plat.	Area.	Season of 1910.	Season of 1911.
	Acres.		
35	0.50	24 inches applied, 12 inches after first; 6 inches after second and third cuttings.	24 inches applied; 12 inches after first; 6 inches after second and third cuttings.
36	.50	30 inches applied; 12 inches after first; 6 inches after second, third, and fourth cuttings.	24 inches applied; 8 inches after second, third, and fourth cuttings.
37	.50	30 inches applied; 12 inches after first; 6 inches after second, third, and fourth cuttings.	24 inches applied; 6 inches after first, second, third, and fourth cuttings.

This work was continued during the season of 1912 but on a reduced area, rectangular checks 17 to 31 being devoted to the work. Application of equal amounts of water to these checks during 1910 and 1911 had produced a very uniform stand over the whole area, and the experiments were started in 1912 under very favorable conditions. Following is the schedule outlined and followed during the season:

Schedule of irrigation of alfalfa, 1912.

Number of plat.	Area.	Depth of water applied.	Schedule.
	Acres.	*Inches.*	
17, 30	0.46	....	No irrigation.
18, 29	.46	12	6 inches after first and second cuttings.
19, 28	.46	18	6 inches after first, second, and third cuttings.
20–27	.46	24	6 inches after first, second, third, and fourth cuttings.
21–26	.46	30	7½ inches after first, second, third, and fourth cuttings.
22–25	.46	36	9 inches after first, second, third, and fourth cuttings.
23–24	.50	48	12 inches after first, second, third, and fourth cuttings.
31	.23	60	12 inches after first, second, third, fourth, and fifth cuttings.

During each of the three seasons six crops of hay were cut. In harvesting, the general practice of cutting when about one-third of the alfalfa is in bloom was followed. The hay was generally raked the same day, shocked the day following, and hauled as soon as it was dry enough to be stacked without heating, never waiting until the leaves were dry enough to fall off when handled. The results of these experiments are given in the table following.

Summary of results of alfalfa irrigation investigations, 1910, 1911, and 1912.

Depth of water applied.	Yield in tons per acre.			Value of hay per acre at $7 per ton.			Cost of production.			Net profit per acre.		
	1910	1911	1912	1910	1911	1912	1910	1911	1912	1910	1911	1912
Inches.												
0	3.85	6.02	6.52	$26.95	$42.14	$38.64	$8.65	$13.50	$12.40	$18.30	$28.64	$26.24
12	4.75	7.52	6.51	33.25	52.64	45.57	13.40	19.60	17.35	19.85	33.04	28.22
18	......	......	7.02	......	......	49.14	......	......	19.85	......	......	29.29
24	6.00	8.38	8.32	42.00	58.66	58.24	18.90	24.20	24.10	23.10	34.46	34.14
30	7.53	9.61	9.43	52.71	67.27	66.31	23.15	27.85	27.35	29.56	39.42	38.96
36	7.58	9.33	9.38	53.00	65.31	65.66	24.15	28.05	28.10	28.91	37.26	37.56
48	8.45	9.64	8.87	59.15	67.48	62.09	27.80	30.25	28.80	31.35	37.23	33.29
60	......	......	10.04	......	......	70.20	......	......	33.65	......	......	36.63

NOTE.—Labor of production figured at $2.25 per ton. Water figured at $1.70 per acre-foot. Labor for irrigation figured at 50 cents per acre per irrigation. While the value of the hay is figured at $7 per ton for each of the three years 1910, 1911, and 1912, the local value in 1912 was $11 per ton.

The accompanying diagram (fig. 2) shows the average yields in tons per acre for the three years, with the corresponding depths of water applied, and figure 3 shows the average yield in tons per acre for each cutting from the unirrigated alfalfa and from the checks given 30 inches in four 7½-inch applications.

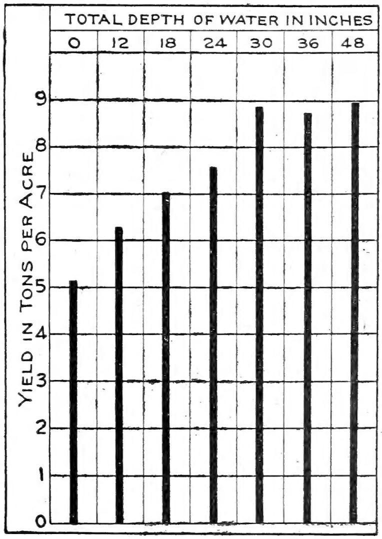

FIG. 2.—Average yield of alfalfa, 1910, 1911, and 1912, using different quantities of water.

The first diagram shows a very uniform increase in yield up to 30 inches of water applied, above which the increase is very small, and in the case of 36 inches applied a slight decrease is shown, although the maximum average yield was produced by a total of 48 inches applied in four 12-inch irrigations.

The first half of the diagram shown in figure 3 illustrates the gradual decrease in yield in each succeeding crop where no water is applied, showing the need of irrigation after the first crop has been removed. When this first half is compared with the other half of the diagram the result of irrigation is apparent. In each of the three seasons the maximum yield was produced in the third crop, probably because of more favorable growing conditions during June and the first part of July in which this crop was grown.

The results, although not absolutely conclusive, point to the following facts:

(1) In the open, well-drained soil, typical of that found in the floor of the Sacramento Valley, the general tendency is toward an increase in yield of alfalfa with the increased amounts of water applied up to at least 48 inches.

(2) There is a limit beyond which the increase in yield will not pay for increased cost of applying the water, and for such conditions as are found on the University farm this limit is in the neighborhood of 30 inches applied as a total for the season.

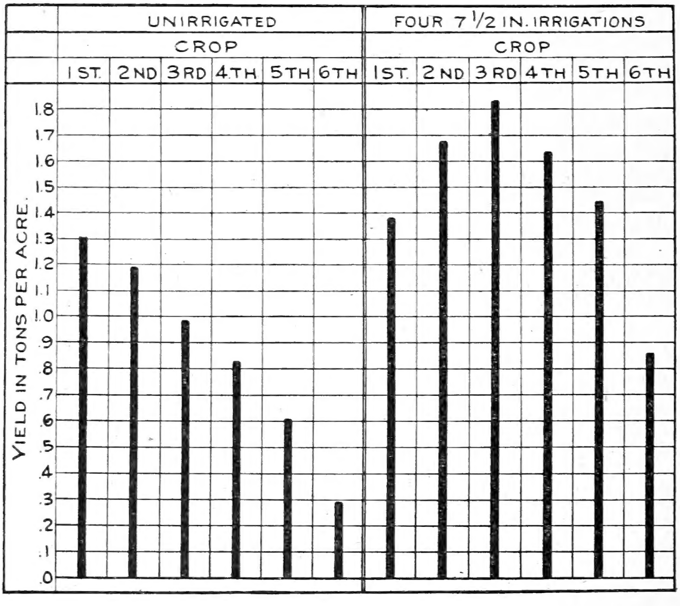

FIG. 3.—Comparative yield of unirrigated and irrigated alfalfa, by crops

In applying these conclusions to other localities, it is well to remember that local conditions are always the controlling factors. The character and condition of the soil, the climate, the rainfall, the length of the growing season, and the age of the alfalfa, all have their effect upon the yield, and each general locality will show different results and a different economic duty of water.

WHEN TO IRRIGATE ALFALFA.

In order to determine if possible at what stage of growth after cutting the water should be applied to produce the best results, checks 17 to 28, inclusive, were divided into three groups of four checks each, and during 1910 and 1911 they were treated in the following manner:

Group 1 (checks 22, 23, 24, and 25) received a total of 30 inches, applied in four 7½-inch irrigations, immediately following the first, second, third, and fourth cuttings.

Group 2 (checks 20, 21, 26, and 27) received a total of 30 inches in eight 3¾-inch irrigations, two irrigations being applied between cuttings, the first one week after cutting and the second two weeks later.

Group 3 (checks 18, 19, 28, and 29) received a total of 30 inches in four irrigations of 7½ inches each, applied just after cutting the second, third, fourth, and fifth crops.

The results obtained are shown in the following table:

Results from irrigating alfalfa at different stages of growth.

Number of group.	Schedule.	Total yield for season in tons per acre.		
		1910	1911	Average
1	Four 7½-inch irrigations applied immediately after cutting	7.53	9.61	8.57
2	Eight 3¾-inch irrigations applied in two irrigations between cuttings	8.24	9.91	9.08
3	Four 7½-inch irrigations applied just before cutting	7.97	8.95	8.46

Each of these seasons shows a small increase in yield to be produced by two irrigations between cuttings. This averages 0.5 ton per acre for the two seasons, and if the extra labor, such as laying the pipe and preparing for the irrigation, is considered, the small additional profit is consumed in labor, and from a financial standpoint no advantage is gained.

In heavy soils, subject to cracking after irrigation, frequent application of small amounts of water shows a decided advantage over the single irrigation between cuttings. It is true also, in light porous soils where the underground drainage is good and the moisture-holding capacity of the soil is small, that one heavy irrigation will not carry the crop through to a good yield and that a second application will produce good returns.

The groups 3 and 1, irrigated before and after cutting, show opposite results for the two seasons, irrigation before cutting showing the heaviest yield in 1910 and the lightest yield in 1911, but in each case the difference is so small that no conclusions can be drawn favoring either method. It was noticed, however, that toward the end of the season of 1911 the checks irrigated just before cutting had a very spotted appearance, the alfalfa standing at a very uneven height, and that after cutting, in spots the alfalfa was slow to start its new growth. A period of five days to a week always elapsed from the time of irrigation until the crop was cut. During this time the growing alfalfa was drawing heavily upon the moisture supply in the soil and in spots seemed to diminish it to such an extent that not enough remained to produce a vigorous growth in the plants after cutting.

IRRIGATION OF GRAIN, 1910, 1911, AND 1912.

During these three seasons the east halves of checks 35, 36, and 37, containing one-half acre each and 1½ acres of unleveled land lying north of check 37, were given over to experiments with irrigation of barley.

During 1909 checks 35, 36, and 37 were planted to sugar beets, which were irrigated, but the amounts of water added were small, and it is safe to assume had no effect upon the crops which followed in 1910. The unleveled area north of check 37 had been cropped to grain for a number of years previous to beginning the experiments, and was typical of much of the so-called "worn-out" land in the vicinity of the farm.

Season of 1910.—During the season of 1910 all plats were plowed in the early spring, harrowed, and drilled to barley on March 12, 85 pounds of seed per acre being used. The following irrigation schedule was planned and carried out.

Schedule of irrigation of barley, 1910.

Number of plat.	Number of irrigations.	Dates.	Depth applied.
			Inches.
Unleveled area	No irrigation		
35	One irrigation (flooded)	April 27	3.6
36	Two irrigations (shallow furrows)	...do May 17	3.6 2.6
37	Two irrigations (deep furrows)		

Plats 36 and 37 were furrowed immediately after seeding. The shallow furrows of plat 36 were made by a marker consisting of two 6 by 6 inch timbers, 2½ feet long, set on edge, 18 inches apart, and fastened parallel to each other by 2 by 4 inch cross strips. This was drawn over the surface parallel with the checks, making shallow furrows 18 inches apart and averaging 1½ inches deep. This method is practically the same as flooding, the furrows acting simply as guides for the water.

It was intended to irrigate plat 37 by subirrigation from deep furrows, but the method was not successful, and May 1 the check was plowed and seeded to cowpeas, which were turned under as green manure in the fall.

The dates of irrigating plats 35 and 36 depended entirely upon the condition of the crop, the water being added when it was thought it would produce the best results and in quantities sufficient to give the soil a good irrigation.

Season of 1911.—The experiment was repeated in 1911 on the same soil, following as nearly as possible the procedure of 1910, the land being spring plowed and seeded on March 20.

The following schedule was followed during the season:

Schedule of irrigation, 1911.

Number of plat.	Number of irrigations.	Date.	Depth applied.
			Inches.
Unleveled area—north half	None		
Unleveled area—south half	One	June 1	6.4
36	..do	May 13	4.3
37 [1]	..do	..do	6.0
35	Two	..do	4.3
		May 27	2.7

[1] Green manured.

Following the seeding the weather remained cold, and at the time of the first irrigation, on May 13, 54 days after seeding, the grain stood at an average height of only 6 inches. The second irrigation was applied to plat 35 just as it was coming into the head.

On June 1 the unleveled area was divided into two plats, and the south plat flooded to a depth of 6.4 inches. At this time the grain had just come into the head and was beginning to show indications of a lack of moisture. In irrigating the remaining plats (35, 36, and 37) the water was applied at a time when it was thought it would produce the best results.

Season of 1912.—Following the harvesting of the grain in 1911, checks 35, 36, and 37 were irrigated and plowed, and on July 22 planted to cowpeas of the Clay variety. Early in November these were turned under as green manure.

February 3, 1912, these checks, as well as the unleveled area to the north, were plowed, harrowed, and seeded, using the same variety of seed, quantity, and method of seeding as in the previous two years.

Schedule of irrigation, 1912.

Number of plat.	Number of irrigations.	Date.	Depth applied.
			Inches.
Unleveled area	None		
35 [1]	....do		
36 [1]	One	Apr. 24	7.35
37 [1]	Two	Apr. 17	12.00
		May 8	5.95

[1] Green manured.

It will be noticed that much heavier irrigations were applied here than in the other two seasons. In all cases sufficient water was added to give the soil a thorough wetting. The green manure seemed to produce a loose, porous soil which rapidly took up the water as it was applied. This condition will be noticed also in plat 37 of 1911, when 6.03 inches were added, as against 4.3 inches to the unmanured checks.

The following table shows the results obtained from the three seasons' work, and these are further illustrated in the diagram (fig. 4) in which the yields of grain in pounds per acre are platted, with the corresponding amounts of water applied.

Summary of results of barley irrigation, 1910, 1911, and 1912.

Season.	Rainfall for season.	Number of plat.	Number of irrigations.	Depth.	Yield per acre.		Value.	Cost of irrigation.
					Hay.	Grain.		
	Inches.			*Inches.*	*Pounds.*	*Pounds.*		
1910	11.90	Unleveled area	None		3,120	1,160	$17.40	
		35	One	3.6	3,440	1,480	22.20	$1.08
		36	Two	5.2	4,460	1,840	27.30	1.56
1911	23.18	Unleveled area (north half)	None		1,560	805	12.08	
		36	One early	4.3	2,040	1,108	16.62	1.29
		Unleveled area (south half)	One late	6.4	2,720	1,520	22.80	1.92
		35	Two	7.0	3,180	1,810	27.15	2.10
		37[1]	One early	6.0	3,740	2,146	32.19	1.80
1912	9.46	Unleveled area	None		680	345	5.18	
		35[1]	do		1,925	1,040	15.60	
		36[1]	One	7.35	2,480	1,280	19.20	2.20
		37[1]	Two	17.95	3,780	1,950	29.25	5.38

[1] Green manured.

NOTE.—Irrigation cost figured at 30 cents per acre-inch for marking furrows, power, and attendance. Grain values figured at $1.50 per hundred. Value of hay is disregarded.

Weather records taken over the entire period of the experiment show that these three years represented extremes in rainfall and general weather conditions. Nevertheless, under all of these varying conditions there is not one instance where the increase in yield did not more than pay for the cost of the water which produced it, the yield increasing with the increased amounts of water applied.

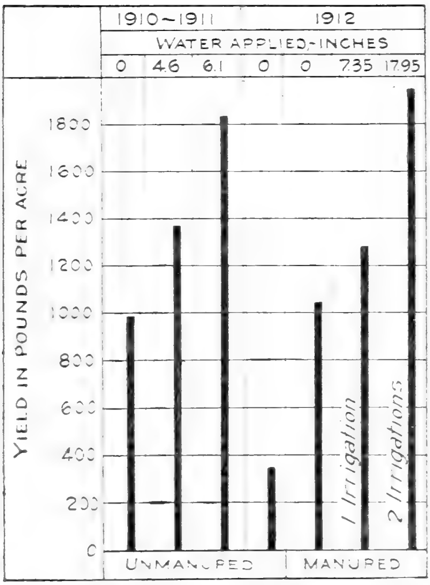

FIG. 4.—Yield of barley with different quantities of water, on manured and unmanured land.

It will be noted that in each of these seasons two irrigations, one of which was applied at about the time the grain came to a head or soon after, or one late irrigation, as in 1911, produced a heavy yield above the single early irrigation. In each of these three years strong, drying north winds occurred about the time the grain was in the dough. The unirrigated and early irrigated grain was badly pinched, while the presence of the moisture in the checks irrigated late seemed to prevent this, producing full, plump grain.

Were further conclusions to be drawn each season should be considered separately, but in each case inspection of the value column will show that for each of these three seasons irrigation of grain was made to pay.

IRRIGATION EXPERIMENTS WITH INDIAN AND EGYPTIAN CORN IN 1910 AND 1911.

For this work, which extended through 1910 and 1911, the 4-acre tract lying directly north of the west end of check 37 was used. During 1909 this tract was in sugar beets, and previous to that for a number of years it had been in grain.

In the spring of 1910 it was plowed twice—March 1 and April 9—harrowed, and cross-harrowed. On April 29 the west 2 acres were seeded to Yellow Dent Indian corn and the east half to Egyptian corn (white durra), a sorghum. In seeding a corn planter was used and the rows were placed 40 inches apart.

During the season of 1910 no definite time for irrigation was set or definite quantities assigned, both being controlled by the needs and conditions of the growing crops.

INDIAN CORN.

Immediately after planting the field was divided into four plats, the water being applied as shown in the following schedule:

Schedule of irrigation of Indian corn, 1910.

Number of plat.	Number of irrigations.	Date.	Depth applied.
			Inches.
1	None		
2	One	June 24	3.3
3	Two	..do....	3.3
		July 13	2.0
4	Three	May 26	4.4
		June 24	2.1
		July 13	1.5

Thorough cultivation followed each of these irrigations, and at all times the field was kept free from weeds. In the middle of August, when the corn was in the milk, it was cut, weighed, and fed green.

After the crop was removed the land was fall plowed, harrowed, and allowed to stand idle through the winter. The following March it was again plowed, harrowed, and seeded to "Yellow Flint" corn and the experiment of 1910 repeated. The area was divided into four plats, which received the following amounts of water during the growing season.

Schedule of irrigation of Indian corn, 1911.

Number of plat.	Number of irrigations.	Date.	Depth of water applied.	Status of corn.
			Inches.	
1	None			
2	One	June 22	2.3	Corn 20 inches high.
3	Two	June 21	2.2	Do.
		July 17	2.5	Corn coming in tassel.
4	Three	June 21	2.3	Corn 20 inches high.
		July 17	2.4	Corn coming in tassel.
		Aug. 8	2.4	Corn coming into the milk.

In each of these irrigations the furrow method was used, a small stream running in each furrow for a long period, thus avoiding flooding and, as in previous seasons, a thorough cultivation following each irrigation.

August 16 and 17 the corn was harvested, weighed, chopped, and stored for winter use.

The following table shows the results obtained for the two seasons:

Summary of results of irrigation of corn.

Season.	Number of plat.	Number of irrigations.	Depth.	Yield per acre.	Value at $2.50 per ton.	Cost of irrigation.
			Inches.	*Tons.*		
1910	1	None		6.85	$17.13	
	2	One	3.3	8.85	22.13	$1.50
	3	Two	5.3	10.05	25.13	2.60
	4	Three	8.0	10.45	26.13	3.90
1911	1	None		3.67	9.18	
	2	One	3.0	4.86	12.15	1.40
	3	Two	4.8	5.21	13.03	2.45
	4	Three	7.1	6.59	16.48	3.65

NOTE.—Cost of irrigation taken at 30 cents per acre-inch for water and application, plus 50 cents per acre per irrigation for furrowing.

The most noticeable feature in these results is the decrease in yield in 1911, when compared with the yield in 1910. This is due entirely to the character of the season. The late spring of 1911 was abnormally cold and very unfavorable to the production of a good yield, even in the presence of an abundance of moisture.

During 1910 one and two irrigations were applied to advantage, while the third irrigation just before harvesting produced an increase of but 0.4 ton per acre green weight, and was applied at a loss.

The season of 1911 shows light yields and small increases, and if interest on the investment in pumping machinery and cost of leveling the land be added to the cost of irrigation no financial gain would be realized.

EGYPTIAN CORN.

This investigation followed along the same lines as the investigations with Indian corn, the preparation of the land, time of seeding, and entire procedure being the same up until the time of the first irrigation. It was noticed, however, that the Egyptian corn (white durra) was much slower in coming up, and in the early stages of growth developed very slowly, especially during the cold spring weather of 1911.

The area originally was divided into three plats, No. 1 containing 0.9 acre; No. 2, 0.46 acre; and No. 3, 0.67 acre. About the middle of June it was seen that the yield from the unirrigated plat, No. 1, was going to be small, and it was then subdivided into plats 1–A, 1–B, and 1–C, of 0.3 acre each. Plat 1–A was not irrigated, plat 1–B received one irrigation, and plat 1–C two irrigations. Following are the dates of irrigation and the quantities of water applied:

Schedule of irrigation of Egyptian corn, 1910.

Number of plat.	Number of irrigations.	Date.	Depth.	Status of corn.
			Inches.	
1-A	None			
1-B	One	June 15	3.75	Corn 24 inches high.
1-C	Two	...do...	3.75	Do.
		July 14	1.75	Corn forming heads.
2	One	July 13	3.10	Do.
3	Two	May 28	3.25	Corn 4 inches high.
		July 14	2.10	Corn forming heads.

During 1911 the experiment was repeated on the same soil. The first seeding on April 18 was a failure, and only about one-fourth of a stand came up. The plat was replowed, harrowed, and reseeded May 13 and a good stand obtained. The area was then divided into four equal checks and the following irrigation schedule outlined:

Schedule of irrigation of Egyptian corn, 1911.

Number of plat.	Number of irrigations.	Date.	Depth.	Status of corn.
			Inches.	
1	None			
2	One	June 21	1.8	Corn 6 inches high.
3	Two	..do....	2.6	Do.
		July 18	2.0	First heads forming.
4	Three	June 22	2.3	Corn 6 inches high.
		July 18	1.9	First heads forming.
		Aug. 8	1.5	Corn in the dough.

In all irrigations the furrow method was practiced, the water being applied in alternate furrow spaces. A thorough cultivation followed each irrigation, and the whole area was kept free from weeds during both seasons.

In harvesting, which occurred the first of October, the heads were picked, hauled, and thrashed, and later the stalks were cut with a mowing machine.

The following table shows the results of the two seasons' work:

Summary of results of irrigation of Egyptian corn.

Season.	Number of plat.	Number of irrigations.	Depth.	Yield per acre.	Value at $1.50 per 100 pounds.	Cost of irrigation.
			Inches.	*Pounds.*		
1910	1-A	None		1,335	$20.03	
	1-B	One	3.75	2,670	40.05	$1.52
	1-C	Two	5.50	2,700	40.50	2.65
	2	One	3.10	2,510	37.65	1.43
	3	Two	5.35	3,340	50.10	2.60
1911	1	None		1,100	16.50	
	2	One	1.8	1,690	25.35	1.04
	3	Two	4.6	2,650	39.75	2.38
	4	Three	5.7	2,965	44.48	3.20

NOTE.—Cost of irrigation is taken as 30 cents per acre-inch for power and attendance, plus 50 cents per acre per irrigation for furrowing.

The accompanying diagram (fig. 5) shows the results for 1911, platted graphically, the yields with the corresponding amounts of water applied being shown.

With this crop, as with the Indian corn, a greater yield is produced in 1910, with less amounts of water applied, than in 1911, due entirely to a warmer spring and much more favorable growing season.

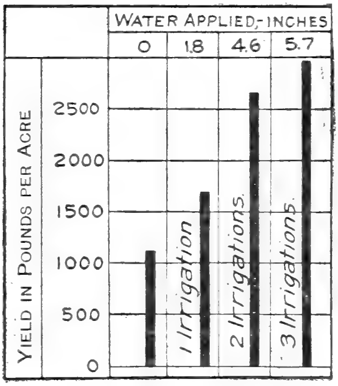

FIG. 5.—Yield of Egyptian corn with different quantities of water.

The results for 1910 show but a small variation in the yields from plats 1-B, 1-C, and 2, and a large increase in plat 3. This is due to the time of irrigation, plat 3 receiving one early and one midseason irrigation, the first applied before any effects of drought were shown, thus keeping more or less of a constant moisture percentage in the soil during the entire period of growth. In 1911 the yields increased quite uniformly with the increased amounts of water applied, until the third irrigation, when there was a slight falling off. When this last irrigation was applied the heads were fully formed and the grain ripening, and the only effect of this irrigation was probably in preventing any pinching or shrinking in the grain.

Inspection of the value column for each season shows that the irrigation of this crop may be made to pay, even if 6 per cent interest on an investment of $50 per acre for leveling the land and developing water be added to the cost of irrigation.

Here, as in the irrigation of other grain crops, no definite duty of water can be established. The amounts of water required and the time of irrigation will always vary with the season, and the intelligence of the irrigator along these lines is always going to be the controlling factor in success and failure or profit and loss. That the time of applying water is of as great importance as the quantity of water applied is shown plainly in 1910, in plat 1–C, where two irrigations followed in close succession and the increase in yield due to the second irrigation did not pay for the cost of the irrigation.

IRRIGATION AND CROP ROTATION EXPERIMENTS IN 1912.

It was decided in the fall of 1911 to turn under a part of the alfalfa as green manure, and in the spring of 1912 to start a crop rotation of grain, sugar beets, corn, and potatoes, following alfalfa, these crops to be investigated from an irrigation standpoint, showing the increase in yield, with the increased amounts of water applied. Comparison also was to be made with the returns obtained from the unfertilized soils in previous years.

Early in November, 1911, plats 1 to 15 and 32 to 37 were plowed to a depth of 8 inches with a two-gang plow. At this time the alfalfa had about a 6-inch top growth, and a good covering of green manure was turned under. Following this plowing the land was harrowed, cross-harrowed, and disked, leaving it in a finely pulverized condition to receive the winter rains.

On February 1, 1912, the land was replowed to a depth of 6 inches, harrowed, and cross-harrowed. Owing to the light winter rains the green manure had not thoroughly rotted, although the soil turned up in a fine, mellow condition, presenting the appearance of recently having been given a heavy application of rotted stable manure.

Owing to the checking system of plats 1 to 15, it was necessary to relevel them for furrow irrigation. This area was later seeded to sugar beets, Indian corn, and Egyptian corn.

GRAIN FOLLOWING ALFALFA.

Following the replowing and harrowing on February 1, the east halves of checks 32, 33, and 34 were seeded to 60-day oats, 75 pounds of seed per acre being planted. At the same time the west halves of these checks were seeded to Australian white wheat, at the rate of 85 pounds of seed per acre. All of the seed was drilled in, the drills running lengthwise with the checks, and a good stand came up on all of the checks.

The following plan of irrigation was outlined and carried out:

Schedule of irrigation of grain following alfalfa in 1912.

OATS.

Number of plat.	Number of irrigations.	Date.	Depth.	Status of oats.
			Inches.	
32	None			
33	One	April 9	13.2	Oats 12 inches high.
34	Two	April 13	13.2	Do.
		May 10	7.2	Oats heading out.

WHEAT.

Number of plat.	Number of irrigations.	Date.	Depth.	Status of wheat.
32	None			
33	One	April 25	10.00	Wheat 24 inches high.
34	Two	April 15	9.15	Wheat 18 inches high.
		May 9	8.40	Wheat coming into full head.

In each irrigation water was added at a time when it was thought that the best results would be obtained, and in no case was irrigation delayed until the crop was suffering for moisture. It will be noticed that in all cases large amounts of water were used. This was necessary in order to cover the checks completely and was due to the open, porous condition of the soil, the result of turning under the green manure.

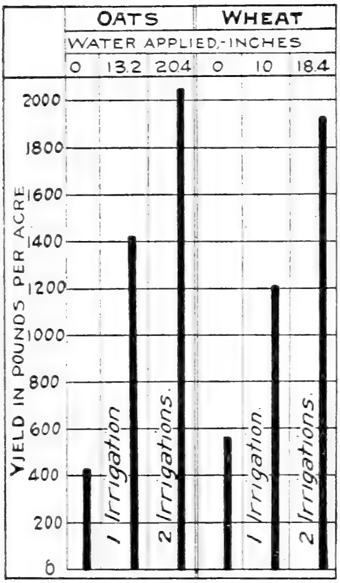

FIG. 6.—Yield of oats and wheat, with different quantities of water.

Early in June, just before harvesting, several days of heavy north wind occurred, badly shattering both crops, and it was estimated that 30 to 40 per cent of the grain was lost. This loss is not included in the table of yields. June 15 all plats were cut with a binder, stacked in the field, and later thrashed with a stationary thrasher.

The table following shows the yields in hay and grain in pounds per acre, the quantity of water applied, and the cost of irrigation. The accompanying diagram (fig. 6) shows the yields of grain platted with the corresponding amounts of water applied to each check.

Summary of results of oats and wheat irrigation.

Crop.	Number of plat.	Number of irrigations.	Depth.	Yield per acre.		Percentage of grain.	Grain value at $1.50 per 100 pounds.	Cost of irrigation.
				Hay.	Grain.			
			Inches.	*Pounds.*	*Pounds.*	*Per cent.*		
Oats	32	None		1,380	435	31.8	$6.53	
	33	One	13.2	4,900	1,420	28.0	21.30	$3.96
	34	Two	20.4	5,820	2,040	35.1	30.60	6.12
Wheat	32	None		1,730	560	32.4	8.40	
	33	One	10.0	3,920	1,210	30.9	18.15	3.00
	34	Two	18.4	6,300	1,935	30.8	29.03	5.52

NOTE.—Irrigation cost figured at 30 cents per acre-inch for power and attendance.

With the oats the single irrigation of 13.2 inches increased the yield 225 per cent, giving a gain in returns of $14.77 per acre, at a cost of $3.96 per acre for irrigation. Two irrigations, totaling 20.4 inches, increased the yield 370 per cent, with a gain of $24.07 per acre in grain value, at a total cost of $6.12 per acre for water and attendance during irrigation.

Figuring on the same basis with the wheat, one irrigation of 10 inches increased the yield 116 per cent, with a gain in returns of $9.55 per acre, at a total increased cost of $3 per acre. Two irrigations increased the yield 245 per cent, giving an increase in returns of $20.63 per acre, at a total expense of $5.52 per acre.

It will also be noted that in all cases the percentage of grain to hay remains about the same, showing the grain production to increase uniformly with the total weight of matter produced.

No definite conclusions can be drawn from this one season's work. A decided advantage, nevertheless, is shown in favor of irrigation. All of the water was applied at a financial gain, and an idea is obtained of what may be accomplished in years of light rainfall when conditions are unfavorable to dry-land farming.

SUGAR BEETS FOLLOWING ALFALFA.

Following the early spring preparation of checks 1 to 15, the land was replowed on February 22, then harrowed and cross-harrowed. The area was divided into seven plats, 5, 6, and 7 to be seeded early, and 1, 2, 3, and 4 seeded later. March 11 the first plats were seeded in drills 20 inches apart, 15 pounds of Wankaka seed per acre being used. March 27 the remaining checks were seeded in the same manner. Spacing, thinning, and hoeing followed when the beets were in the third and fourth leaf, and this was followed by a thorough cultivation.

The dates of irrigation depended upon the needs of the crop, and sufficient water was added to give the soil a thorough wetting. The furrow method of irrigation was practiced, the water being applied in alternate spaces between the rows, and as nearly as possible the water was confined to the furrows and kept away from the beets.

As long as the size of the beets permitted, thorough cultivation followed each irrigation, and all plats were kept free from weeds.

Following are the dates of irrigation and the amounts of water applied:

Schedule of irrigation of sugar beets in 1912.

Time of seeding.	Number of plat.	Number of irrigations.	Date.	Depth applied.
				Inches.
Early—Mar. 11	5	None		
	6	One	May 21	10.5
	7	Two	May 21	9.2
			June 21	4.4
Later—Mar. 27	1	None		
	2	One	May 24	6.12
	3	Two	May 26	6.12
			June 21	5.40
	4	Three	May 24	6.12
			June 21	5.40
			July 17	5.28

All plats were harvested the last of August, being plowed, topped, and sold in the field. At this time average samples were taken from each plat and tests made for sugar percentage and purity.

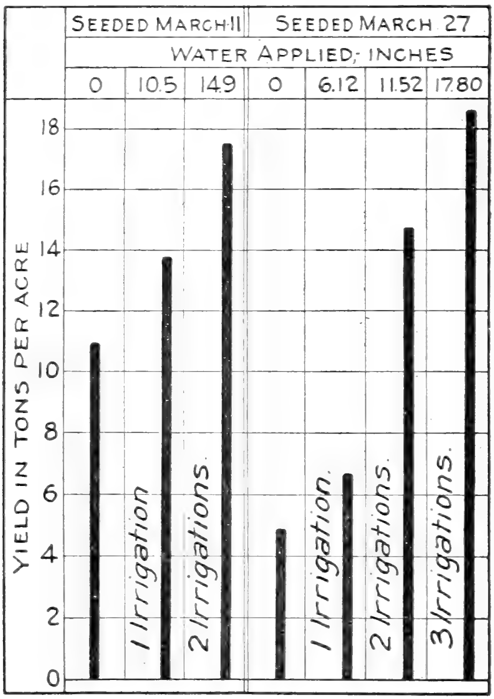

FIG. 7.—Yield of sugar beets, seeded at two periods and irrigated with different quantities of water.

The table following shows the results in yield, sugar percentages, purity, and net returns per acre. These results are illustrated in figure 7, the yields and corresponding amounts of water applied being shown.

Yield of sugar beets and perecntage of sugar content and purity.

Seeding.	Number of plat.	Number of irrigations.	Depth.	Sugar content.	Purity.	Yield per acre.	Value at $5 per ton.	Cost of irrigation.
			Inches.	*Per cent.*	*Per cent.*	*Tons.*		
Mar. 11	5	None	....	21.3	88.13	10.85	$54.25	....
	6	One	10.5	17.7	80.96	13.80	69.00	$4.10
	7	Two	14.9	16.5	81.44	17.50	87.50	5.81
Mar. 27	1	None	....	23.00	83.14	4.85	24.25	....
	2	One	6.12	20.10	83.75	6.70	33.50	2.38
	3	Two	11.52	17.25	83.89	14.75	73.75	4.49
	4	Three	17.80	16.85	89.91	18.60	93.00	6.94

In irrigating, continual attendance was necessary at a cost of 25 cents per acre-inch. Power cost 14 cents per acre-inch. The total cost is therefore 39 cents per acre-inch.

With the same number of irrigations heavier yields were obtained by early seeding than by late seeding. The results show an increase in yield of 6 tons per acre from the unirrigated plats in favor of the early planting, while the plats given one irrigation show an increase of 7.10 tons per acre. This is due entirely to the weather conditions following seeding. Between March 12 and 15, 1.13 inches of rain fell, giving the early seeding a vigorous start. Following this no more rain fell until April 10, and the late seeding was very slow in sprouting, some of the seed not coming up until the middle of April, after the early seeded plats had been thinned.

In general the sugar percentage decreased with the increased amounts of water added, although in every case this decrease was overbalanced by the increase in yield.

The time of irrigation and the quantity of water required will always depend upon the local conditions. This is shown very clearly in the yields from plats 2 and 3, on which a second irrigation of 5.4 inches, costing $2.10 per acre, increased the yield 120 per cent and the gross returns $40.25 per acre. Here, as in other irrigated crops, success or failure lies in the judgment of the irrigator in applying the water.

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