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EXPERIMENT & STATION.

BULLETIN No. 39.

“Farm Irrigation.”—A. A. Mills.

“Orchard Irrigation.”—E. S. Richman.

MAY, 1895.

PRESS OF THE
SALT LAKE LITHOGRAPHING CO.

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AGRICULTURE

BULLETIN No. 39.

FARM IRRIGATION.

BY A. A. MILLS.

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The greater part of the matter given under the head "Farm Irrigation" is the result of five years' work. Some of the work reported gives the results obtained in fewer seasons. A great deal of the work was planned by Prof. J. W. Sanborn, formerly Director of the Station, while the remain-

der was planned by the writer. The writer, however, has had charge of every detail of all of the field work from the beginning. Some of the matter has been published before, while a goodly portion of it has never been reported. For this publication the figures have been gone over from the beginning in 1890, both by the writer and by the clerk, Mr. Dryden, or someone else. For the last three years of the five Mr. Dryden has kept the records of the experiments, which is no mean part of the work, being very laborious and very likely to error, unless great care is bestowed. The proof is read by both the clerk and the writer, and it is hoped that in this publication errors will be reduced to a minimum.

The future development of Utah depends almost wholly on her agriculture. Though it would appear that there is much other business carried on in Utah, it can be plainly seen that nearly all draw their very life blood from agriculture. The future development of agriculture depends largely on the more skillful and economic use of our water supply. It is to be hoped that the farmers of Utah will study our work on irrigation with the same diligence that the other Bulletins from the Station are studied, and test the results which they find most applicable to their wants.

The ground on which the experiments herein detailed were conducted, is upper bench or the "wash" from Logan canyon. Reference to the cuts given will show about what the land is for the first five feet in depth. It can readily be seen that it is ground which requires the maximum amount of water.

Amount of Water to Use, or the Duty of Water.

The attempt was made to get at this by the direct method of applying different amounts of water to the ground and noting the effect on crop yield. Along with this, drains were laid in the

soil about three and a half feet below the surface to find out the amount of water draining off where irrigation was excessive, and also to observe the effect on the fertility of the soil. These drains led into vaults lined with cement so as to be water-tight. The water that ran into the vaults was weighed out at each irrigation—a sample being taken for chemical analysis. Samples were also taken of the water as it ran to the plats. Small plats were used, and these were rotated from year to year. In table III the number of the plats is given for each year in order to show this rotation. As will be seen, the piece saturated four feet was on plat 20 in 1890; plat 19 in 1891; plat 18 in 1892; plat 17 in 1893; and plat 16 in 1894. This system of rotating the plats from year to year is the same for all the work, unless otherwise stated. The water was measured by allowing it to run through a hole of given diameter in an inch board under a three-inch head, for a given time.

The formula used in computing the flow is:

$$W = a \cdot 62 \sqrt{2gh}$$

In which W = cu. ft. of water per sec.

a = Area of hole in feet.

$\sqrt{2gh}$ = Velocity in ft. per sec.

g = Gravity = 32 ft.

h = Head = 3 inches or $\frac{1}{4}$ ft.

Though this method is not held to be infallible, it is thought to be accurate enough for comparative results. The attempt was made to keep the water at the proper head by an overflow. The greatest trouble was encountered from the grass, weeds and sticks that are carried along in a running stream. These would reduce the flow considerably by being sucked across the orifice, while there was little to cause the flow to increase from any cause whatever. So it is thought that the amounts of water given are somewhat larger than were actually applied. Taking an average for five years, however, the comparative results are thought to point strongly to the facts.

In table I the yields and the average inches of water applied are given under the different depths of saturation. Saturated

four feet deep, etc., means that at each irrigation the soil was saturated to the given depth in each case, and not that this amount of water was applied to the soil. It was estimated that the soil would take up 50 per cent. of its weight of water, but this estimate has been changed, for various reasons, and so table II is given, that the different amounts of water applied each year may be readily seen. Inches of water applied means that the ground was covered so many inches deep.

TABLE I.

PLATS 14 TO 20, INCLUSIVE.

Wheat—Yields, per acre; grain, bushels; straw, pounds.

YEAR	DRAINED										NOT DRAINED					
	Saturated 4 ft. deep		3½ feet deep		2½ feet deep		2 feet deep		1½ feet deep		¾ foot deep		Not Irrigated			
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw		
1890	12.95	987	22.09	1417	12.00	880	8.28	1103	10.10	766	.....	.....	2.15	289	.....	177
1891	19.05	2171	11.05	1623	13.15	1497	13.71	1120	15.81	1040	.....	.....	12.95	1394	.....	1234
1892	14.86	1051	12.57	1303	12.57	1874	24.00	3360	25.90	1989	.....	.....	6.86	731	.....	846
1893	5.71	457	6.10	320	13.34	800	14.86	1166	6.48	640	.....	526	.....	.....	.....	240
1894	14.09	1097	15.24	914	22.09	1531	12.38	1314	6.48	526	20.00	2114	.....	.....	.....	720
Average	13.33	1143	13.14	1115	14.63	1316	14.65	1613	12.95	992	12.28	1320	7.32	805	.....	643
Average lbs. of grain and straw.	1942.80		1903.40		2193.80		2492.00		1769.00		2056.80		1244.20			919.00
Av. in. water appl'd during season	50.86		41.08		34.3		26.82		20.96		7.8		.....			....

Size of all plats saturated, 2x3½ rods.

An acre of ground covered 26.82 inches, would require 26.82 acre-inches of water, which is equivalent to a cubic foot per second for 27 hours, nearly.

By reference to table I, it will be seen that the two-foot saturation gives the highest yield of grain and much the highest yield of grain and straw. More water than this was not only wasted, but a decrease in both grain and straw was brought about by its use. By reference to the cuts of plats 14 to 20, it will be seen the general conformation of the ground is such that a maximum amount of water would be required.

An acre-inch of water is that amount which will cover an acre one inch deep, and the acre-inch, or the acre-foot, the writer believes, is the best unit to use in irrigation. As the best results were obtained from that receiving water at the rate of 26.82 acre-inches, it may be well to state that this is equivalent to a cubic foot per second for ninety days, nearly, for eighty acres of ground; or forty-five days for forty acres, and twenty-two and a half days for twenty acres. The reader is referred to a discussion of these units further on.

Table II is inserted for those who may desire to study the matter in detail:

TABLE II.

PLATS 14 TO 20, INCLUSIVE.

Inches of water applied during season, with size of hole and time running:

SATURATION.	1890.		Inches of water	1891.		Inches of water	Size of hole	1892.		Inches of water	Size of hole	1893.		Inches of water	Size of hole	1894.		Inches of water	
	Hours	Mins.		Hours	Mins.			Hours	Mins.			Hours	Mins.						
Saturated 4 feet.....	58	45	61.1	2	51	24	62.9	2	38	1	46.5	2	34	15	41.9	2	34	15	41.9
" 3¼ "	70	.....	48.2	2	41	48	51.2	2	30	54	37.8	2	27	51	34.1	2	27	51	34.1
" 2½ "	20	33	39.3	2½	20	33	39.3	2½	21	11	40.5	2½	13	42	26.2	2½	13	42	26.2
" 2 "	16	30	31.5	2½	16	30	31.5	2½	15	13	29.1	2½	11	.....	21.0	2½	11	.....	21.0
" 1½ "	8	36	23.7	3	8	36	23.7	3	9	21	25.8	3	5	45	15.8	3	5	45	15.8
" ¾ " .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3	2	51	7.8	3	2	51	7.8

Time running and inches of water is the total for three irrigations.

Size of plats, 2x3½ rods.

As will be seen, the amount of water was decreased from year to year until 1894. This was on account of the fact that so much water could not be kept on the plats of highest saturation, though a small stream was left running on for parts of two or three days at a time. In 1892 the amount of water was increased on the different plats in order to get water to pass out through the drains.

In table III the amount of drainage-water, in pounds, is given for each season with the average amount of drainage and the average pounds of water applied.

TABLE III.
PLATS 14 TO 20, INCLUSIVE.
Drainage water in pounds per acre

	AVERAGE PER YEAR		1890		1891		1892		1893		1894	
SATURATION.	Pounds of water applied	Pounds of drainage water	Plat	Pounds of drainage water	Plat	Pounds of drainage water	Plat	Pounds of drainage water	Plat	Pounds of drainage water	Plat	Pounds of drainage water
Saturated 4 feet.....	500,587	3807	20	2121	19	6689	18	5792	17	2693	16	1742
“ 3¼ feet.....	404,427	2099	19	3998	18	2101	17	....	16	98	15	4297
“ 2½ feet.....	337,595	1626	18	3117	17	....	16	56	20	654	19	4301
“ 2 feet.....	263,974	893	17	487	16	....	20	766	19	408	18	2806
“ 1½ feet.....	206,298	748	16	....	20	....	19	720	18	2116	17	907
“ ¾ foot.....	76,771	....	..	....	..	....	..	....	15	....	20	....
Plat 20A—27.7 inches of water applied.....	272,636	2855	..	....	..	....	..	....	..	....	20A	2855

The numbers of the plats are given for each year, as the larger amounts of drainage seemed to follow certain plats rather than the heavier application of water. It will be seen that plats 18 and 19 gave much more drainage than other plats, while plat 16 allowed very little water to pass off in the drains. Reference to the cuts seems to show but very little difference in

the general make-up of these plats, except that the gravel and cobble stone of plat 16 are not quite so large as that of the other plats.

A statement of the analysis of this water is here furnished by the Chemical Department:

COMPOSITION OF WATER, (Applied and Drained.)

PARTS PER MILLION.

	Solids	Volatile Matter	Lime	Magnesia	Potash	Phosphoric Acid	Nitric Acid
Applied							
July 20.....	154.0	78.0	61.0	22.19	1.88	0.000	Trace
June 12, pt. 15, 16, 19	180.0	78.0	61.2	20.17	1.26	Trace	Trace
June 12, pt. 17, 18.	170.0	83.0	61.8	22.04	2.26	0.000	Trace
June 29, pt. 20A...	142.5	60.5	55.6	27.02	0.30	0.000	Trace
Average.....	161.6	74.9	57.9	22.8	1.42	0.000	Trace
Drained							
June 13.....							
Plat 15.....	302.0	148.0	68.6	25.44	4.60	1.01	6.30
" 16.....	237.0	92.0	64.0	25.50	4.78	1.33	4.20
" 17.....	178.0	72.0	65.0	23.80	10.80	Trace	5.00
" 18.....	184.0	90.0	42.0	21.12	9.00	Trace	6.10
" 19.....	293.0	148.0	81.6	58.93	19.47	2.07	5.00
June 29.							
Plat 20A	232.0	78.0	60.6	32.06	11.60	Heavy Trace	5.00
July 21.							
Plat 15.....	255.0	112.0	72.0	25.35	11.80	Heavy Trace	5.10
" 17.....	252.0	122.0	70.8	23.34	12.20	.069	5.00
" 18.....	271.0	100.0	71.0	31.40	12.60	Heavy Trace	4.50
" 19.....	218.0	88.0	48.0	28.53	7.80	Heavy Trace	5.20
Average Drainage Water.....	242.0	105.0	64.4	29.55	10.47	1.37	5.14
Average Comp. of Water Applied	161.6	74.9	57.9	22.80	1.42	0.000	Trace
Average Comp. of Water Drained	242.0	105.9	64.4	29.55	10.47	1.37	5.14

COMPOSITION OF RIVER AND DRAINAGE WATERS (Pounds per Acre.)

Plat	Satur. Depth.	Date	Solids	Volatile Matter	Lime	Magnesia	Potash	Phos- phoric Acid	Nitric Acid	Whole Weight of Water
15	3 1/4	6-12	Applied	201.60	158.10	52.12	3.25	Trace	Trace	2,584,235
		6-13	Drained.....	4.44	2.06	.76	.14	Trace	.19	29,988
	7-20 7-21		Retained.....	197.16	156.04	51.36	3.11	0.00	.19	2,554,247
			Applied	201.60	157.60	57.34	4.86	Trace	Trace	2,584,235
			Drained.....	5.33	3.43	1.21	.56	Trace	.24	47,611
			Retained....	196.27	154.17	56.13	4.30	0.00	.24	2,536,624
	AVERAGE FOR SEASON		{ Applied ...	201.60	157.85	54.73	4.06	.....	.....	2,584,235
			{ Drained....	4.88	2.74	.98	.35	.....	.21	38,799
			{ Retained ..	196.72	155.11	53.75	3.71	.....	.21	2,545,436
			{ Applied ...	604.80	473.55	164.19	12.18	.....	.63	7,752,705
			{ Retained..	590.16	465.33	161.25	11.13	.....	.63	7,636,308
17	1 1/2	6-12	Applied	99.16	73.83	26.33	2.70	Trace	Trace	1,194,648
		6-13	Drained.....	.78	.69	.26	.12	Trace	.05	10,880
	7-20 7-21		Retained.....	98.38	73.14	26.07	2.58	.....	.05	1,183,768
			Applied	93.18	72.87	26.51	2.24	Trace	Trace	1,194,648
			Drained.....	2.23	.63	.21	.11	Trace	.04	8,846
			Retained....	181.67	72.24	26.30	2.13	.....	.04	1,195,802
	AVERAGE FOR SEASON		{ Applied ...	96.17	73.35	26.42	2.47	.....	.....	1,194,648
			{ Drained....	.93	.66	.24	.12	.....	.04	9,863
			{ Retained ..	95.24	72.69	26.18	2.35	.....	.04	1,194,785
			{ Applied ...	288.51	220.05	79.26	7.41	.....	.....	3,583,944
			{ Retained ..	285.72	218.07	78.54	7.05	.....	.12	3,584,355

COMPOSITION OF RIVER AND DRAINAGE WATER (Pounds per Acre.)—Continued.

Plat	Depth.	Date	Solids	Volatile Matter	Lime	Magnesia	Potash	Phosphoric Acid	Nitric Acid	Whole Weight of Water
18	2	6-12	269.70	165.80	98.07	34.97	3.88	Trace	Trace	1,586,825
		6-13	2.00	.98	.46	.23	.10	Trace	.07	10,858
	7-20	Retained...	267.70	165.82	97.61	34.74	3.78	.....	.07	1,575,967
		Applied.....	244.30	123.80	96.80	35.23	2.98	Trace	Trace	1,586,825
		Drained.....	3.26	1.20	.85	.38	.15	Trace	.05	12,024
		Retained.....	241.04	122.60	96.95	34.85	2.83	.....	.05	1,574,801
	AVERAGE	{ Applied...	257.00	144.80	97.43	35.10	3.43	.....	.....	1,586,825
		{ Drained...	2.63	1.09	.66	.31	.13	.....	.05	11,441
		{ Retained..	254.37	143.71	96.77	34.79	3.30	.....	.05	1,575,384
		{ Applied..	771.00	434.40	292.29	105.30	10.29	.....	.....	4,760,475
19	2½	6-12	1688.00	366.50	287.60	94.78	5.92	Trace	Trace	4,699,222
		6-13	3.23	1.63	.90	.65	.21	.02	.06	11,016
	7-20	Retained.....	1684.77	364.87	286.70	94.13	5.71	.02	.06	4,688,206
		Applied.....	723.70	366.50	286.60	104.30	8.84	Trace	Trace	4,699,222
		Drained.....	11.55	4.67	2.50	1.50	.41	Trace	.28	53,005
		Retained.....	712.15	361.83	284.10	102.80	8.43	.....	.28	4,646,217
	AVERAGE	{ Applied...	1205.85	366.50	286.80	99.54	7.38	.....	.....	4,699,222
		{ Drained...	7.39	3.15	1.70	1.58	.31	.02	.....	32,010
		{ Retained..	1198.46	363.35	285.10	98.96	7.07	.02	.....	4,667,212
		{ Applied..	3617.55	1099.50	860.40	308.40	22.14	.....	.....	14,097,666
WHOLE SEASON		Retained..	3595.38	1090.05	855.30	296.88	21.21	.06	.....	14,001,636

COMPOSITION OF RIVER AND DRAINAGE WATERS (Pounds per Acre.)—Continued.

Plat	Satur. Depth	Date		Solids	Volatile Matter	Lime	Magnesia	Potash	Phos- phoric Acid	Nitric Acid	Whole Weight of Water
20A	...	6-29	Applied	298.10	126.60	116.10	56.52	6.27	Trace	Trace	2,092,126
		6-29	Drained	11.27	3.79	2.94	1.56	0.56	Trace	.24	48,560
		WHOLE SEASON	Retained	286.83	122.81	113.16	54.96	5.71	.....	.24	2,043,566
			App'ied	894.30	379.80	348.30	169.56	18.81	.....	.....	6,276,378
			Retained	860.49	368.43	339.48	164.88	17.13	.....	.72	6 130,698
16	4	6-12	Applied	1138.00	247.00	193.80	63.87	3.98	Trace	Trace	3,166,857
		6-13	Drained	6.70	2.60	1.81	.72	.14	Trace	.12	28,273
		WHOLE SEASON	Retained	1131.30	244.40	191.99	63.15	3.84	.....	.12	3,138,584
			Applied	3414.00	741.00	581.40	191.61	11.94	.....	.....	9,500,571
			Retained	3393.90	733.20	575.97	189.45	11.52	.....	.36	9,415,752

By reference to the figures furnished by the Chemical Department, it will be seen that there is a very small per cent. of the fertilizing material removed from the soil. Though, of course, the water is richer in plant food when it leaves the soil than when it was applied, so little of it passes off in the drains that the soil is richer in plant food after irrigation than before. This, too, is the case where the irrigation is excessive. Under all ordinary conditions the fertility of the soil is increased by irrigation.

As the ground on which these experiments are carried on is very poor and gravelly, a better part of the field was planted to wheat in 1894 and laid off in plats 2x4 rods. The results are given in table IV.

TABLE IV.

WEIGHT OF WHEAT AND STRAW PER ACRE, AND WATER APPLIED PER PLAT, 1894.

PLAT NO.		WATER APPLIED			YIELDS PER ACRE		Pounds of straw per bushel of grain	
		Size of hole Ins.	Time running		Inches applied to plat	Bushels of grain		Pounds of straw
			Hrs.	Min.				
Not drained	15A...	4	3	44	16.	34.17	4250	124
	16A...	3	9	57	24.	32.33	3360	104
	17A...	3	13	15	32.	37.00	3880	105
	18A...	3	16	33	40.	41.00	3640	89
	19A...	4	1	52	8.	25.00	2500	100
Drained.....20A...		2	25	51	27.7	34.00	2860	84

Inches applied to plat means that the plat was covered this deep during the season. The water was applied in three irrigations. An acre of ground covered 40 inches (3 $\frac{1}{2}$ feet) deep requires 40 acre-inches of water. This is equivalent to a cubic foot per second for 40 $\frac{1}{2}$ hours; or, for 80 acres a cubic foot per second for 134 $\frac{1}{2}$ days, nearly.

The ground of the plats given in table IV is about the same as that of plats 14 to 20 of table I, except that the stratum of clay soil (surface) is much more sandy. It will be seen that with one exception, that of plat 16A, the yield of wheat in-

creased uniformly as the amount of water applied was increased. The straw, however, reached its maximum yield with 16 inches of water applied. The surface soil being more sandy, it is evident that the water passed more rapidly through it, and the sub-soil had little, if any, power to hold and bring it back. Plat 20A was drained and the drainage water was weighed and analyzed in order to ascertain the power this soil had of holding either the water or the different fertilizing compounds held in the water, it having been analyzed before being applied.

This same saturation process was applied to timothy. The matter is given in convenient form in the following table:

TABLE V.
PLATS 40 TO 44, INCLUSIVE.
Yield of timothy per acre in pounds.

SATURATION	1891		1892		1893		1894		AVERAGE	
	Inches of water applied	Lbs. of hay	Inches of water applied	Lbs. of hay	Inches of water applied	Lbs. of hay	Inches of water applied	Lbs. of hay	Inches of water applied	Lbs. of hay
Saturated 4 feet.....	55.1	1740	36.7	1900	36.7	600	36.7	2600	41.3	1710
" 3¼ ".....	44.8	...	30.0	1400	30.0	600	30.0	1400	33.7	1133
" 2½ ".....	34.4	1020	23.0	2000	23.0	600	23.0	1400	25.8	1255
" 2 ".....	27.6	1280	18.2	1000	18.2	900	18.2	1500	20.5	1170
" 1½ ".....	21.0	1550	14.0	1300	14.0	500	14.0	3400	15.7	1687

Size of plats, 2x4 rods.

Inches of water applied, means that the ground was covered to this depth.

As will be seen by reference to table V, the highest average amount is from the plats receiving the greatest amount of water. However, the next highest amount is from plats receiving the least amount of water. The highest yield (1894), and lowest yield (1893), are also found on the plats receiving the least amount of water. There is very little uniformity in the yields, and so the inches of water applied are placed by the side of the yields for those who desire to study the matter in detail. As will be seen, timothy does very poorly on our soil, and this may have something to do with the apparently contradictory results.

In table VI is given the detailed statement of the water applied to those plats:

TABLE VI.

PLATS 40 TO 44, INCLUSIVE.

Inches of water applied to plat, with size of hole and time running.

SATURATION	1891.				1892.				1893.				1894.			
	Size of hole		Time running		Inches of water		Size of hole		Time running		Inches of water		Size of hole		Time running	
	In.	Hrs.	Min.		In.	Hrs.	Min.	In.	Hrs.	Min.	In.	Hrs.	Min.	In.	Hrs.	Min.
Saturated 4 feet	2	51	24	55.1	2	34	15	2	34	15	36.7	2	34	2	34	15
" 3¼ "	2	41	48	44.8	2	27	51	2	27	51	39.0	2	27	2	27	51
" 2½ "	2½	20	33	34.4	2½	13	42	2½	13	42	23.0	2½	13	2½	13	42
" 2 "	2½	16	30	27.6	2½	11	....	2½	11	....	18.2	2½	11	2½	11	....
" 1½ "	3	8	36	21.0	3	5	45	3	5	45	14.0	3	5	3	5	45

In 1893 plats 15A to 20A were laid off, and drains put in plat 20A to make a study of this question on a better part of the farm. The ground had been seeded to clover the previous year. Table VII gives the yields of the first crop of clover, and other matter:

TABLE VII.
YIELD OF FIRST CROP OF CLOVER, 1893.

PLAT.	Size of hole	Time running		In. applied to plat	Lbs. of hay per acre.
	In.	Hrs.	Min.		
Not drained: 15A.....	4	1	.....	4.2	2000
“ “ 16A.....	4	2	.....	8 4	1300
“ “ 17A.....	3	5	20	12.9	4000
“ “ 18A.....	3	7	6	18.1	2500
“ “ 19A.....	3	8	53	21.4	2500
Drained: 20A.....	.....	.....	.....	.....	.....

Size of plats. 2x4 rods.

Inches of water applied means that the ground was covered that many inches deep.

An acre of ground covered 12.9 inches would require 12.9 acre-inches, which is equivalent to a cubic foot per second for 13 hours, or for 80 acres a cubic foot per second for 43½ days, nearly.

In reviewing table VII it will be seen that only the weight of the first crop of clover is given. The second crop was not weighed, owing to a misunderstanding. So only the water used for this crop is given and not the water for the whole season. This was applied at one irrigation. As will be seen, the crop increased rapidly until 12.9 inches had been applied, after which there was a falling off. Up to this point, then, the water was beneficial; but an increase was worse than wasted, as the crop was decreased by it. This amount of water, too, was run on in 5 hours and 20 minutes, the water probably not covering any of the ground longer than one-half of this time. From this it is readily seen that the practice of allowing water to run on a piece for hours and hours, and often days at a time, must be very detrimental to crop growth.

Plats 15A to 20A are on ground that is under a regular six-year rotation. It will be seen that the yields are very much

higher, both in wheat and hay, than are the yields from the previous plats. It may be well to state here that on another part of the farm, but under this same rotation, one crop of timothy and clover, mixed, yielded, with but one irrigation, nearly three tons per acre in 1894. Judging from the water applied to plats 15A to 20A, it is estimated that this latter piece, consisting of about four acres, received water at the rate of about ten acre-inches, or that the ground was covered ten inches deep with water. This is an enormous amount of water to apply at once, three or four inches being about the average irrigation. Yet, as high as this may seem, it is far from being as much as is used in many sections of the Territory. Here in Cache Valley many of the people allow the water to run on the grass land from early spring till cutting time. This is *most* wasteful, as not only the water is wasted but the crop yield is very materially reduced, while it is likely that other men's crops are suffering for water.

It remains to indicate, by means of drawings which represent vertical sections of the plats, the nature of the soil. Plats 14 to 20, inclusive, on which part of the foregoing experiments were carried on, are here represented:

All of the cuts given represent a vertical section across the center of the plat named, one rod long and five feet deep. The clay soil on plats 14 to 20, inclusive, contains but little sand.

Dimensions in inches of three of the largest stones in clay soil	$\left\{ \begin{array}{l} 2 \times 3 \times 3\frac{1}{2} \\ 1\frac{1}{2} \times 2 \times 2\frac{1}{2} \\ 1 \times 1\frac{1}{2} \times 2 \end{array} \right.$
Dimensions in inches of three of the largest stones in white clay	$\left\{ \begin{array}{l} 2\frac{1}{2} \times 4 \times 5\frac{1}{2} \\ 2\frac{1}{4} \times 2\frac{1}{2} \times 3\frac{3}{4} \\ 1\frac{3}{4} \times 2 \times 3\frac{1}{2} \end{array} \right.$
Dimensions in inches of three of the largest cobbles in cement	$\left\{ \begin{array}{l} 5\frac{1}{4} \times 6\frac{1}{2} \times 9\frac{3}{4} \\ 4\frac{3}{4} \times 5\frac{1}{2} \times 8 \\ 4\frac{1}{4} \times 4\frac{1}{2} \times 8 \end{array} \right.$

Plat 15.

- Dimensions in inches of three of the largest stones in clay soil $\left\{ \begin{array}{l} 2 \times 2\frac{1}{4} \times 3\frac{3}{4} \\ 2 \times 2\frac{1}{2} \times 4 \\ 1\frac{3}{4} \times 2\frac{1}{4} \times 2\frac{3}{4} \end{array} \right.$
- Dimensions in inches of three of the largest stones in white clay $\left\{ \begin{array}{l} 2\frac{1}{2} \times 3\frac{3}{4} \times 4\frac{1}{2} \\ 2\frac{1}{2} \times 3 \times 4\frac{1}{4} \\ 1\frac{3}{4} \times 3\frac{1}{2} \times 5 \end{array} \right.$
- Dimensions in inches of three of the largest cobbles in cement $\left\{ \begin{array}{l} 5\frac{1}{2} \times 7\frac{1}{4} \times 10\frac{3}{4} \\ 4\frac{3}{4} \times 6\frac{3}{4} \times 10\frac{1}{2} \\ 3\frac{1}{2} \times 7 \times 8\frac{1}{2} \end{array} \right.$

Plat 16.

- Dimensions in inches of three of the largest stones in clay soil $\left\{ \begin{array}{l} 2\frac{1}{2} \times 3 \times 6\frac{1}{4} \\ 2\frac{1}{4} \times 3\frac{1}{2} \times 4\frac{1}{4} \\ 2 \times 5 \times 5\frac{3}{4} \end{array} \right.$
- Dimensions in inches of three of the largest stones in white clay $\left\{ \begin{array}{l} 4 \times 6\frac{1}{2} \times 9\frac{1}{4} \\ 3\frac{1}{4} \times 4\frac{1}{2} \times 8\frac{1}{2} \\ 3\frac{3}{4} \times 5\frac{1}{4} \times 7 \end{array} \right.$
- Dimensions in inches of three of the largest cobbles in cement $\left\{ \begin{array}{l} 6\frac{1}{2} \times 8\frac{3}{4} \times 9\frac{1}{2} \\ 5\frac{1}{2} \times 6\frac{1}{4} \times 8\frac{1}{4} \\ 5\frac{1}{4} \times 4\frac{3}{4} \times 9\frac{3}{4} \end{array} \right.$

Plat 17

Dimensions in inches of three of the largest stones in clay soil $\left\{ \begin{array}{l} 1\frac{1}{4} \times 2\frac{3}{4} \times 5 \\ 2 \times 3\frac{1}{4} \times 6\frac{1}{2} \\ 2\frac{1}{4} \times 3\frac{1}{4} \times 5\frac{1}{2} \end{array} \right.$

Dimensions in inches of three of the largest stones in white clay $\left\{ \begin{array}{l} 5\frac{1}{2} \times 8 \times 9\frac{1}{2} \\ 4\frac{3}{4} \times 7\frac{1}{2} \times 7\frac{3}{4} \\ 3\frac{1}{4} \times 5\frac{1}{2} \times 8\frac{3}{4} \end{array} \right.$

Dimensions in inches of three of the largest cobbles in cement $\left\{ \begin{array}{l} 8\frac{1}{4} \times 8\frac{1}{2} \times 14\frac{1}{2} \\ 5\frac{3}{4} \times 7\frac{1}{2} \times 11\frac{1}{2} \\ 5\frac{1}{4} \times 8 \times 11\frac{1}{2} \end{array} \right.$

Plat 18.

Dimensions in inches of three of the largest stones in clay soil $\left\{ \begin{array}{l} 2\frac{1}{2} \times 2\frac{3}{4} \times 5\frac{1}{4} \\ 1\frac{1}{2} \times 3\frac{1}{2} \times 4\frac{1}{4} \\ 1\frac{3}{4} \times 2\frac{1}{2} \times 4 \end{array} \right.$

Dimensions in inches of three of the largest stones in white clay $\left\{ \begin{array}{l} 4\frac{3}{4} \times 9 \times 10\frac{1}{4} \\ 6 \times 6\frac{3}{4} \times 14\frac{1}{4} \\ 4 \times 5\frac{1}{2} \times 9 \end{array} \right.$

Dimensions in inches of three of the largest cobbles in cement $\left\{ \begin{array}{l} 9\frac{1}{2} \times 10\frac{3}{4} \times 16\frac{1}{4} \\ 6\frac{1}{2} \times 7\frac{1}{4} \times 11 \\ 6 \times 7\frac{3}{4} \times 11\frac{3}{4} \end{array} \right.$

Plat 19.

Dimensions of three of the largest stones in clay soil } Very Fine

Dimensions in inches of three of the largest stones in loose gravel } $2\frac{3}{4} \times 3\frac{1}{2} \times 6\frac{3}{4}$
 $2 \times 2\frac{1}{2} \times 5\frac{1}{2}$
 $1\frac{1}{2} \times 2\frac{3}{4} \times 5\frac{1}{4}$

Dimensions in inches of three of the largest cobbles in cement } $9 \times 9\frac{1}{4} \times 11\frac{1}{2}$
 $6\frac{1}{2} \times 9\frac{1}{2} \times 11\frac{1}{4}$
 $6 \times 9\frac{3}{4} \times 10$

Plat 20

Dimensions of three of the largest stones in clay soil } Very Fine

Dimensions in inches of three of the largest cobbles in loose gravel } $3\frac{1}{4} \times 4\frac{1}{2} \times 5\frac{1}{2}$
 $2\frac{1}{4} \times 4\frac{3}{4} \times 6\frac{3}{4}$
 $1\frac{3}{4} \times 3 \times 5\frac{1}{4}$

Dimensions in inches of three of the largest cobbles in cement } $6\frac{1}{4} \times 9\frac{3}{4} \times 10\frac{1}{2}$
 $5 \times 7\frac{1}{2} \times 8\frac{1}{2}$
 $6\frac{1}{2} \times 7\frac{1}{4} \times 9\frac{3}{4}$

SUMMARY.

1. In clay soil the maximum yield of both wheat and straw was obtained by saturating the soil, approximately, 2 feet deep at each irrigation, or covering the ground with 26.82 inches of water during the season.

2. On this soil there was a decrease of crop where either a greater or less amount of water was used.

3. This maximum yield was brought about by the use of 26.82 acre-inches per acre, which is equivalent to a cubic foot per second for 27 hours, nearly.

4. Though the water that drains from the soil through excessive irrigation is richer in fertilizing material than when applied, the total amount of this material added to the soil by irrigation is more than that extracted.

5. On clay soil containing more sand the yield of grain (wheat) increased as the water increased up to 40 inches, while the maximum yield of straw was produced with 16 inches of water.

6. On clay soil containing little sand, timothy gave mixed results, though where the maximum amount of water, 41.3 inches, was used the yield was the greatest.

7. On clay soil containing more sand, the first crop of clover increased steadily and rapidly, from the use of 4.2 inches of water up to 12.9 inches. The application of 5.2 inches more water decreased the crop nearly one-half.

Frequency of Irrigation.

After determining the amount of water to use, the next thing of importance is to know how often to apply it. This we attempted to find out by the plat method. The results are grouped in convenient form in table VIII. With one

exception, all plats received the same amount of water during the season. This was brought about by the plat which was irrigated every three days, receiving but one-sixth of the water at each irrigation that the plat irrigated every eighteen days received. Each plat was irrigated at the beginning of the season at the same time, and in 1890 and 1892, the plat irrigated every eighteen days received water three times, while for the other seasons it received it but twice. The water was measured in the manner explained under the previous heading.

TABLE VIII.

PLATS 0 TO 6, INCLUSIVE.

Yield of wheat and straw per acre.

YEAR	IRRIGATED EVERY 3 DAYS		EVERY 6 DAYS		EVERY 9 DAYS		EVERY 12 DAYS		EVERY 15 DAYS		EVERY 18 DAYS		EVERY 6 DAYS	
	Grain		Grain		Grain		Grain		Grain		Grain		Grain	
	Bus.	Lbs.	Bus.	Lbs.	Bus.	Lbs.	Bus.	Lbs.	Bus.	Lbs.	Bus.	Lbs.	Bus.	Lbs.
1890.....	6.33	420	16.67	1300	9.50	730	16.00	1240	13.50	1090	12.50	1350	.....	.....
1891.....	14.00	660	8.67	2100	15.33	1780	18.33	2000	15.00	2140	5.50	570	18.00	2320
1892.....	11.67	1030	15.33	1380	21.00	1340	10.33	2680	16.00	1740	16.33	1620	15.00	1100
1893.....	20.50	1970	18.83	1670	18.17	1410	10.50	1670	5.67	460	5.33	780	23.33	2460
1894.....	17.00	1080	16.33	1220	11.67	1800	7.83	730	20.00	1500	6.33	1320	16.50	710
Average.....	13.90	1026	15.16	1550	15.13	1412	12.60	1664	14.03	1386	9.20	1128	13.21	1647
Average yield of grain and straw, pounds.....	1860.00		2459.60		2319.80		2420.00		2227.80		1680.00		2739.60	
Pounds of straw per bushel of grain.....	74.		102.		93.		132.		98.		122.		90.	
Average inches of water ap- plied.....	15.86		15.86		15.86		15.86		15.86		15.86		28.8*	

Size of plats, 2x4 rods.

That in the last column received twice as much water at each irrigation as did that in the second column.

In looking over table VIII it will be seen that upon the plats receiving the same amount of water, the highest yield of grain is with the irrigation every six days, while the highest yield of straw is with that irrigated every twelve days. The difference in yield of both grain and straw is very little between the six and the twelve-day periods. With periods of from six to fifteen days, the yields vary but little, while for that irrigated every three days and that irrigated only every eighteen days there is a decided falling off. For the eighteen-day period this falling off is in both grain and straw, while for the three-day period it is a falling off mostly of straw. Where the irrigation was every six days and the water doubled in amount the yield of grain was decidedly increased, while the yield of straw is not so great as with the twelve-day period with but half the water.

Table IX is inserted for those who may wish to study the matter in detail:

TABLE IX.

PLATS 0 TO 6, INCLUSIVE.

Inches of water applied during the seasons, with size of hole and time running at each irrigation.

IRRIGATION.	1890.			1891.			1892.			1893.			1894.		
	Size of hole	Time* running		Size of hole	Time* running		Size of hole	Time* running		Size of hole	Time* running		Size of hole	Time* running	
	Inches	Hours	Minutes	Inches	Hours	Minutes	Inches	Hours	Minutes	Inches	Hours	Minutes	Inches	Hours	Minutes
Irrigated every 3 days...	3	.....	30	21.7	3	21.7	3	.....	20	14.4	.....	30	14.4	.....	30
" " 6 " " " "	3	1	.....	21.7	3	21.7	3	.....	40	14.4	.....	.....	14.4	1	.....
" " 9 " " " "	3	1	30	21.7	3	21.7	3	1	.....	14.4	1	30	14.4	1	30
" " 12 " " " "	2½	2	52	21.7	3	21.7	3	1	20	14.4	2	30	14.4	2	30
" " 15 " " " "	2½	3	36	21.7	2½	21.7	3	1	40	14.4	2	30	14.4	2	30
" " 18 " " " "	2	6	45	21.7	2	21.7	3	2	.....	14.4	3	.....	14.4	3	.....
" " 6 " " " "	.....	.....	.....	.....	3	.....	3	1	40	28.8	2	.....	14.4	2	.....
															28.8

Size of plat, 2x4 rods.

In 1890 and 1892 the plat irrigated every 18 days was irrigated three times each season, while for the other seasons it was irrigated but twice.

*For each irrigation.

†During the season.

A cut of a vertical section, one rod long and five feet deep, is given of every other plat of this series, that the general characteristics of the soil may be seen. The cuts are of plats 1, 3 and 5.

Dimensions in inches of three of the largest stones in clay soil	$\left(\begin{array}{l} 4\frac{1}{4} \times 5 \times 7\frac{1}{2} \\ 2\frac{3}{4} \times 3\frac{1}{2} \times 6 \\ 2\frac{1}{2} \times 3\frac{1}{4} \times 6\frac{1}{4} \end{array} \right.$
Dimensions in inches of three of the largest stones in white clay	$\left(\begin{array}{l} 3 \times 5\frac{1}{2} \times 8\frac{3}{4} \\ 4 \times 4\frac{1}{4} \times 7\frac{1}{2} \\ 3\frac{3}{4} \times 4\frac{1}{4} \times 7\frac{3}{4} \end{array} \right.$
Dimensions in inches of three of the largest cobbles in cement	$\left(\begin{array}{l} 8 \times 8\frac{1}{2} \times 12\frac{1}{2} \\ 7\frac{1}{2} \times 8\frac{1}{2} \times 13 \\ 6\frac{1}{4} \times 7\frac{1}{2} \times 10\frac{3}{4} \end{array} \right.$

Dimensions in inches of three of the largest stones in clay soil	$\left(\begin{array}{l} 4\frac{1}{4} \times 5 \times 7\frac{1}{4} \\ 3\frac{1}{2} \times 5 \times 6\frac{3}{4} \\ 3\frac{3}{4} \times 4\frac{1}{2} \times 6 \end{array} \right.$
Dimensions in inches of three of the largest stones in white clay	$\left(\begin{array}{l} 3\frac{1}{2} \times 8\frac{1}{4} \times 13 \\ 5\frac{3}{4} \times 7 \times 12\frac{1}{2} \\ 5\frac{1}{2} \times 6\frac{1}{4} \times 9\frac{3}{4} \end{array} \right.$
Dimensions in inches of three of the largest cobbles in cement	$\left(\begin{array}{l} 6\frac{1}{2} \times 12\frac{1}{4} \times 14 \\ 5\frac{1}{4} \times 8\frac{1}{2} \times 15\frac{1}{4} \\ 5\frac{3}{4} \times 7 \times 12\frac{1}{2} \end{array} \right.$

Plat 5.

Dimensions in inches of three of the largest stones in clay soil { $2\frac{1}{2} \times 3\frac{1}{4} \times 5\frac{3}{4}$
 $2 \times 3\frac{1}{2} \times 4$
 $2\frac{1}{4} \times 3\frac{1}{4} \times 4$

Dimensions in inches of three of the largest stones in white clay { $5\frac{3}{4} \times 8 \times 13\frac{1}{4}$
 $5\frac{1}{4} \times 7\frac{1}{2} \times 12$
 $4\frac{1}{2} \times 6 \times 12\frac{1}{4}$

Dimensions in inches of three of the largest cobbles in cement { $7\frac{1}{2} \times 8\frac{3}{4} \times 14\frac{3}{4}$
 $6\frac{3}{4} \times 9 \times 13\frac{1}{2}$
 $4\frac{1}{2} \times 6 \times 12\frac{1}{4}$

To test this matter further, nine other plats were laid out on a better part of the farm, which is under a regular rotation. In 1894 the crop of the rotation on these plats was wheat, which followed the clover of the previous year. Five of these plats were given the same amount of water during the year, while four of them received the same amount of water at each irrigation. The matter is given in table X:

TABLE X.

PLATS 1A TO 5A AND 1B TO 4B, INCLUSIVE.

Yields of wheat and straw per acre, 1894.

PLAT No.	SIZE OF HOLE	*TIME RUNNING		Inches of water applied	GRAIN	STRAW	Pounds of straw per bushel of grain
		Hrs.	Min.				
Received the same amount of water during season.	Irrigated every 20 days: 1A....	4	2	31.9	47.83	4230	84
	" " 4 " 2A....	4	..	31.9	41.67	4600	110
	" " 8 " 3A....	4	1	31.9	47.67	5140	108
	" " 12 " 4A....	4	1	31.9	54.00	5160	96
	" " 16 " 5A....	4	2	31.9	52.00	4680	90
Received the same amount of water at each irrigation.	" " 20 " 1B....	4	1	12.8	37.00	3780	101
	" " 5 " 2B....	4	1	51.0	44.00	3760	85
	" " 10 " 3B....	4	1	25.5	39.67	3620	91
	" " 15 " 4B....	4	1	17.0	36.67	3000	81

Size of plats, 2x4 rods.

*At each irrigation.

†During the whole season.

An acre of ground covered 31.9 inches would require 31.9 acre-inches of water, which is equivalent to a cubic foot per second for 32 hours, nearly; or, for 80 acres a cubic foot per second for 107¼ days. Plats 1A and 1B were each irrigated three times.

By looking over table X it will be seen that where the same amount of water was used during the season the maximum yield of grain and straw was obtained by irrigating every twelve days. The yields of both grain and straw fell off uniformly where the time between the irrigations was either longer or shorter than this. The yields of these plats are exceptionally large for our poor ground, while the yields on plats 0 to 6, inclusive, are low. The two taken together, however, point strongly to the fact that irrigation should be about every two weeks for wheat on upper bench land underlaid with cement and gravel.

Where the same amount of water was used at each irrigation, the maximum amount of water gave the maximum yield of grain, while the minimum amount of water produced the maximum yield of straw. The yield of grain, too, was greatest where irrigation was carried on every four days, while irrigation every twenty days gave the largest yield of straw, so that it is hard to tell whether the difference was due to the different amounts of water, or to the different times between the irrigations.

This same line of work was also carried out with timothy and clover. For timothy, plats 23 to 29, inclusive, were used. These abut on to plats 0 to 6, inclusive, and have the same characteristics as do those last named. Table XI gives the matter in detail:

TABLE XI.

PLATS 23 TO 29, INCLUSIVE.

Weight of timothy per acre.

YEAR	Irrigated Every 3 days		Every 6 days		Every 9 days		Every 12 days		Every 15 days		Every 18 days		Every 6 days	
	Plat	Lbs. of hay	Plat	Lbs. of hay	Plat	Lbs. of hay	Plat	Lbs. of hay	Plat	Lbs. of hay	Plat	Lbs. of hay	Plat	Lbs. of hay.
1891.	28	1640	27	1980	26	2150	25	1840	24	1820	29	2050	....	.....
1892.	27	1000	26	1500	25	1406	24	1100	23	1500	28	900	29	1400
1893.	26	1000	25	900	24	700	23	1400	29	700	27	600	28	700
1894.	25	3400	24	2300	23	4809	29	2900	28	2400	26	3100	27	2600
Average ..	1760		1670		2264		1810		1605		1662		1567	
Average inches of water applied	12.6		12.6		12.6		12.6		12.6		12.6		25.2	

Size of plats, 2x4 rods.

That in the last column received double the amount of water at each irrigation that that in the second column received.

A glance at table XI will show that the plats irrigated every nine days gave the highest yield, with the plats irrigated every twelve days second. Doubling the amount of water and applying every six days decreased the yield.

In table XII the water applied is given in detail, for those who may desire to study it:

TABLE XII.

PLATS 23 TO 29, INCLUSIVE.

Inches of water applied during season, with size of hole and time running.

IRRIGATION	1891				1892				1893				1894			
	Size of hole		*Time running		In.	*Time running		In.	Size of hole	*Time running		In.	Size of hole	*Time running		In.
	In.	Hrs.	Min.	†In. of water applied		Hrs.	Min.			Hrs.	Min.			Hrs.	Min.	
Irrigated every 3 days	3	...	30	14.4	3	...	15	7.2	3	...	30	3	3	...	30	14.4
" " 6 "	3	1	...	14.4	3	...	30	7.2	3	...	...	3	3	1	...	14.4
" " 9 "	3	1	30	14.4	3	...	45	7.2	3	1	30	3	3	1	30	14.4
" " 12 "	3	2	...	14.4	3	1	...	7.2	3	2	...	3	3	2	...	14.4
" " 15 "	2 [‡]	3	36	14.4	3	1	15	7.2	3	2	30	3	3	2	30	14.4
" " 18 "	2	6	45	14.4	3	1	30	7.2	3	3	...	3	3	...	...	14.4
" " 6 "	3	2	...	28.8	3	1	...	14.4	3	2	...	3	3	2	...	28.8

Size of plats, 2x4 rods.

*For each irrigation.

†During the season.

To study this further, plats 1A to 5A and 1B to 4B were laid off, and are the same plats given in table X. The crop on this ground for 1893 was clover. The matter is grouped in table XIII.

TABLE XIII.

PLATS 1A TO 5A AND 1B TO 4B, INCLUSIVE.

Weight of clover hay, in pounds, per acre, 1893.

IRRIGATION.									
Size of hole	*Time running		†In. of water applied	First crop	Second crop	Total yield			
	Hrs.	Min.							
{ Same amount of water applied during season.	Irrigated every	4 days,	plat No. 1A	.....					
	"	"	"	2A	.....	6000			
	"	"	"	3A	.....	7300			
	"	"	"	4A	.....	7300			
	"	"	"	5A	.....	7460			
{ Same amount of water applied at each irrigation.	"	"	"	1B	.....	3590			
	"	"	"	2B	.....	6850			
	"	"	"	3B	.....	5600			
	"	"	"	4B	.....	4600			
	"	"	"	4B	.....	4000			

Size of plats, 2x4 rods.

*For each irrigation.

†During season.

As will be seen from table XIII, the plat irrigated every sixteen days, where the amount of water was the same during the season, gave the highest yield. Where the interval was increased but four days longer there was scarcely half a crop. This would suggest, then, that for clover the water should be put on within a few days of the right time, allowing the crop to go as long as possible without water and then irrigating quickly.

Where the same amount of water was applied at each irrigation, the maximum yield was obtained from that which received the maximum amount of water during the season, though the interval was but five days. From the foregoing, then, it would appear that timothy and clover do best watered not oftener than every nine days, and this may be extended to sixteen-day intervals. Cuts 1A, 2A and 3A are vertical sections of plats named. They show the general characteristics of the soil.

Plat 1 a.

Dimensions in inches of three of the largest stones in clay soil	{ Very Fine $2\frac{1}{4} \times 3\frac{1}{2} \times 5\frac{1}{2}$ $2 \times 3\frac{1}{2} \times 4\frac{1}{4}$ $1\frac{1}{4} \times 2\frac{3}{4} \times 4\frac{3}{4}$ $3\frac{1}{2} \times 6 \times 8\frac{3}{4}$ $2\frac{3}{4} \times 6\frac{1}{4} \times 8$ $2 \times 5\frac{1}{2} \times 7\frac{1}{2}$
Dimensions in inches of three of the largest stones in white clay	
Dimensions in inches of three of the largest cobbles in cement	

Plat 3 a.

Dimensions in inches of three of the largest stones in clay soil { $3 \times 3\frac{1}{2} \times 6\frac{1}{4}$
 $2\frac{1}{2} \times 3\frac{1}{4} \times 5\frac{3}{4}$
 $2 \times 2\frac{3}{4} \times 4\frac{1}{2}$

Dimensions in inches of three of the largest stones in sandy soil { $1\frac{3}{4} \times 3\frac{1}{4} \times 5\frac{1}{4}$
 $2 \times 3\frac{1}{2} \times 4\frac{3}{4}$
 $2\frac{1}{4} \times 3 \times 4\frac{1}{2}$

Dimensions in inches of three of the largest cobbles in cement { $5 \times 7\frac{3}{4} \times 10\frac{1}{2}$
 $4\frac{1}{4} \times 6\frac{3}{4} \times 8\frac{1}{2}$
 $4\frac{1}{4} \times 5\frac{3}{4} \times 9$

Plat 5 a.

Dimensions in inches of three of the largest stones in clay soil { Very Fine

Dimensions in inches of three of the largest stones in sandy soil { $4\frac{1}{2} \times 5\frac{3}{4} \times 9\frac{3}{4}$
 $5 \times 5\frac{1}{2} \times 8\frac{3}{4}$
 $4\frac{1}{4} \times 4\frac{1}{4} \times 9\frac{1}{2}$

Dimensions in inches of three of the largest cobbles in cement { $4\frac{1}{2} \times 6\frac{3}{4} \times 12\frac{1}{2}$
 $5 \times 5\frac{1}{2} \times 11\frac{1}{4}$
 $4\frac{1}{4} \times 6\frac{1}{4} \times 10\frac{1}{2}$

SUMMARY.

1. On poor, gravelly, clay soil the greatest yield of grain (wheat) was obtained by irrigating every six days, while the greatest yield of straw came from irrigating every twelve days.

2. There is very little difference in the total yields from plats irrigated every six, nine, twelve, or fifteen days respectively.

3. Where the water was doubled in amount and applied every six days, there was a decided gain in yield of grain, but not of straw.

4. On a better clay soil containing some sand, the maximum yield of both grain and straw was on the plat where water was applied every twelve days, the yields falling off uniformly where the interval was either increased or decreased.

5. On poor, gravelly, clay soil the highest yield of timothy was obtained from irrigating every nine days.

6. Where the water was doubled in amount and applied every six days the crop of timothy fell off nearly one-third.

7. On a better clay soil containing some sand the highest yield of clover came from irrigating every sixteen days, and only about one-half crop was procured by making the interval twenty days.

Number of Times and When to Irrigate.

Intimately connected with the previous subject is the number of times to irrigate and when to do this. To test this two sets of experiments were made—one with Spring wheat and one with Fall wheat. With Spring wheat nine plats were used. On three of them the grain was allowed to “burn” or suffer for water before the water was applied. The other six were irrigated from one to five times, the first three being irrigated from one to three times. The matter is given in table XIV, which is self-explanatory.

TABLE XIV.
PLATS 226 TO 234, INCLUSIVE.
Yields of wheat and straw.

IRRIGATIONS	1893					1894					AVERAGE		
	Yield per acre			Lbs. of straw of grain per bushel of	Yield per acre			Lbs. of straw of grain per bushel of	Yield per acre				
	Grain	Straw	Lbs.		Grain	Straw	Lbs.		Grain	Straw	Lbs.		
3 Irrigations, first applied after grain is "burnt".....	11.44		780	68	10.44	973	93	10.94	876	80			
2 " " applied when first and third above are.....	8.67		813	94	7.89	860	109	8.28	836	101			
1 " " after grain is "burnt".....	2.22		467	210	6.67	733	110	4.45	600	160			
1 " " " at first usual irrigation.....	1.56		108	69	18.44	1827	99	10.00	967	84			
2 " " " when first and third are of next.....	16.89		653	39	9.44	1566	166	13.16	1109	102			
3 " " " at usual times of irrigation....	11.56		1373	119	26.66	2267	85	19.11	1820	102			
4 " " " first applied at usual time of first irrigation....	11.44		980	86	7.33	1027	140	9.38	1003	113			
5 "													

In looking over table XIV it will be seen that the highest average yield and the highest single yield of grain (wheat) and straw came from the three irrigations. This shows, then, that by multiplying the irrigations both time and water are wasted and the crop decreased, and this, too, on our driest soils. In each case the crop increased in yield from one irrigation to three, when the maximum was reached. In each case, too, it will be seen that there is a decrease in crop where the grain was allowed to suffer before the water was applied. This all goes to show how important it is to irrigate just at the right time.

Below are given the dates on which the different plats were irrigated:

TABLE XV.
PLATS 226 TO 234, INCLUSIVE.
Dates of irrigating.

		1893.	1894.
		DATE.	DATE.
3	Irrigations, first applied after grain is "burnt" . .	June 28 July 13 " 25	June 25 July 14 " 26
2	" applied when 1st and 3d above are . .	June 28 July 25	June 25 July 26
1	" " after grain is "burnt"	June 28	June 25
1	" " at time of first usual irrigation . .	" 13	" 14
2	" " when 1st and 3d are of next . .	" 13 July 13	" 14 July 20
3	" " at usual time of irrigation . .	June 13 " 29 July 13	June 14 July 6 " 20
4	" first " " " " of first " . .	June 13 " 29 July 13 " 25	June 14 July 6 " 20 " 30
5	" " " " " " " " " " . .	June 13 " 22 " 29 July 13 " 25	June 14 " 26 July 6 " 20 " 30
3	" " at usual times of irrigation . .	June 13 " 29 July 13	June 14 July 6 " 20

One thing of importance in table XV is the fact that the irrigation began and ended at about the same time for both years. This, too, by depending wholly on observation of the crop. In later tables this point will be brought out, so as to show that within a few days of the same time each year irrigation should begin.

This has also been carried on with Fall wheat. Besides trying to find out the number of times to irrigate, we aimed to find out whether or not the water could be profitably used to irrigate Fall wheat just after it was sown in order to bring it up at once. The results are given in table XVI:

As will be seen from table XVI, fall irrigation, or irrigation the day after seeding, gives but a little more than three-fourths of a bushel than that not irrigated, not nearly enough to pay for the extra irrigation. The three irrigations for Fall wheat give about the same as for Spring wheat. The yield also increases from that not irrigated to that irrigated three times. The Spring wheat was our common wheat and the Fall wheat, Martin's Amber.

Table XVII gives the dates of irrigation:

TABLE XVII.
PLATS 280 TO 285, INCLUSIVE.
Dates of irrigation.

IRRIGATION				1892	1893	1894
Fall Wheat	{	1 Irrigation, Fall.....		*Sept. 25	†Sept. 9	‡Oct. 28
		No " ".....				
		1	" Spring...	June 3	June 12	June 2
		2	" " }	" 3	" 12	" 2
		2	" " }	" 27	" 27	" 27
Spring Wheat	{	3 " " }		" 3	" 12	" 2
		3 " " }		" 27	" 27	" 27
		3 " " }		July 12	July 19	July 7
		3 " " }		June 3	June 12	June 19
		3 " " }		" 27	" 27	July 7
		July 12	July 25	" 21		

*1891, †1892, ‡1893.

In 1892 and in 1894 the irrigation began at about the same date, while for the three seasons in succession, the second irrigation happened to come on the same date, June 27. This brings out the fact that the time of irrigating varies but little from year to year.

SUMMARY.

1. On poor, gravelly, clay soil with Spring wheat the maximum yield of both grain and straw came from irrigating three times.

2. There was a uniform increase in yield from one irrigation up to three irrigations, then a decrease from four and five irrigations.

3. By allowing the grain to become "burnt" before water was applied the yield decreased by nearly one-half, and this, too, whether the number of irrigations was one, two, or three.

4. This decrease in yield was brought about by deferring the first irrigation only about two weeks after the usual irrigation.

5. By irrigating Fall wheat just after seeding in the fall, and at no other time, there was but about three-fourths of a bushel per acre increase over no irrigation.

6. Irrigating Fall wheat but once in the spring gave an increase of more than 45 per cent. over that not irrigated.

7. The yields of Fall wheat steadily increased from that not irrigated up to that irrigated three times.

8. The Fall and the Spring wheat irrigated three times each, yielded practically the same.

Surface and Sub-Irrigation.

Much has been written and is written on this subject. The assertion is made and reiterated that sub-irrigation is far superior to surface irrigation, the idea being advanced that water reaching a plant's roots after having passed through the soil is much more effective in producing plant growth than that which reaches the plant from the surface; that water coming in contact with the stalks of plants is detrimental to plant growth. Applying water to the surface and having it come in contact with the stems and trunks is Nature's way of applying water as a rule, and could the rains be regulated in amount, I believe that we should all prefer Nature's way.

To find out the results and differences of these different methods, we began experiments in 1890 and have carried them on

for five years. For the first year there were laid out two plats on some of the very poorest ground on the farm. In one of these, trenches were dug and a cobble-rock drain laid in the trenches, so that the top of the drain was about ten inches under ground. These cobble-rock drains were carried for three years. In 1891 four plats were laid out on a more sandy and better part of the farm. In two of these plats were laid cement pipes. In each case the pipes or drains were put so that three of them would divide a two-rod plat in such a way that the seepage from each pipe would have to reach the same in each case, that the plat might be wholly soaked. This was brought about by running one pipe or drain down the centre of the plat and two others, one on either side of the centre one, and eleven feet from it. This would leave five and one-half feet for the water to soak each way from each pipe or drain that the whole ground may be soaked.

In the pipes, at intervals of eight feet, holes were made in which were inserted small wooden plugs, in which also holes were made—very small at first—but in 1893 these holes were enlarged by boring the plugs with a quarter-inch bit. Over each of these plugs there was placed an oyster can, inverted, so as to keep the soil from stopping the holes in the plugs.

On the plat in which the rock drain was laid, wheat was grown, the results being compared with a plat by the side of it not drained. On one of the plats in which the pipes were laid, wheat has been grown and on the other grass, each being compared with a plat by the side of it. The matter is given in table XVIII:

TABLE XVIII.

YIELDS OF WHEAT, STRAW, AND HAY PER ACRE.

DRAINS	SUB-IRRIGATION				*SURFACE IRRIGATION				SUB-IRRIGATION	*SURFACE IRRIGATION
	Wheat				Wheat				Grass	Grass
	Grain Bus.	Straw Lbs.	Lbs. of straw per bushel of grain	Total pounds of grain and straw	Grain Bus.	Straw Lbs.	Lbs. of straw per bushel of grain	Total pounds of grain and straw	Pounds of timothy	Pounds of timothy
1890, Rock drain.....	9.33	800	86	1360	12.67	880	69	1640	....	....
(Rock drain.....	15.50	1670	108	2600	15.50	1570	101	2500	....	....
1891 } Cement drain.....	13.33	1933	145	2733	17.78	2267	127	3334	....	....
(Rock drain.....	12.33	660	54	1400	15.00	1300	87	2200	....	....
1892 } Cement drain.....	15.11	1493	91	2400	18.89	1667	88	2800	2133	2400
1893, Cement drain.....	3.22	740	230	933	22.00	1547	70	2867	1867	4657
1894, " ".....	11.00	1273	116	1933	19.78	2813	142	4000	3067	4867
Average with rock drain.....	12.39	1043	83	1786	14.39	1250	86	2113	....	....
" " cement drain.....	10.66	1360	145	2000	19.61	2073	107	3250	2356	3975
" of all.....	11.40	1224	119	1908	17.37	1720	98	2763	....	....

*The plats surface-irrigated were not drained, but are compared with those drained as indicated.

A glance at table XVIII will show that the sub-irrigation is far behind the surface irrigation in yield of either grain, straw, or hay. Not only is the average yield less, but in every instance, save one (rock drain, 1891), the yield shows unfavorable to the sub-irrigation. It will be further seen that the rock drain did much better than did the more expensive cement tile, or pipe. The trouble with the sub-irrigation was evident. With the pipe the water seemed to move upward nearly as fast as it did in a lateral direction. The result was that right over the plug the ground was over-saturated, the water sometimes standing in pools, while three or four feet from the plugs the crop was suffering for water. As the water came out all along the rock drains the result was that more of the ground received water. But as with the pipes there was a line over each drain from one to two feet wide that was over-saturated, while half way between the drains the crops were burned up. From this it would appear that the water can not be distributed evenly enough to make a success of this kind of irrigation for general crop growth. Again, the system is very expensive, and from the point of practical agriculture it would seem that success would never be obtained. Farmers are, therefore, advised to introduce the system with great caution, if at all. However, it may be well for a trial to be made in more sandy soil, but only as an experiment at first.

SUMMARY.

1. On a poor clay soil containing gravel with the cobble-rock drain, or on a better clay soil containing some sand with the cement tile, the sub-irrigation was not so good as the surface.
2. The experiment covers ten trials, and in every trial but one the surface irrigation gave the highest yields.
3. During irrigation the soil immediately over the rock drains, or the plugs in the cement pipes, was over-saturated, while that between the drains or pipes and between the plugs in the pipes was very dry.
4. On our soil the system of sub-irrigation has proved an

utter failure for grain or grass. On soil containing more sand it may be possible, and is highly probable, that better results can be obtained.

5. The system is so expensive that it is doubtful whether it could ever be applied to general farming. The results are so discouraging that none are advised to put it in except on a small scale for trial.

Night and Day Irrigation.

As a rule, farmers hold that irrigation at night is much more effective than day irrigation; that water will go much farther at night than during the same time in the day. We have attempted to decide these questions by experiment. The results for wheat are given in table XIX. In 1890, but two plats were used, while for the remainder of the time there were three plats. The plats were rotated from year to year:

TABLE XIX.
YIELDS OF WHEAT AND STRAW PER ACRE.

YEAR.	DAY IRRIGATION.			NIGHT IRRIGATION.			DAY IRRIGATION.			NIGHT IRRIGATION.			AVERAGE DAY IRRIGATION.			AVERAGE NIGHT IRRIGATION.		
	Grain	Straw	Lbs. of straw per bushel of grain.	Grain	Straw	Lbs.	Grain	Straw	Lbs.	Grain	Straw	Lbs.	Grain	Straw	Lbs.	Grain	Straw	Lbs. of straw per bushel of grain.
	Bus.	Lbs.		Bus.	Lbs.		Bus.	Lbs.		Bus.	Lbs.		Bus.	Lbs.		Bus.	Lbs.	
1890.....	12.00	980	82	10.67	1460	137	12.33	1260	102	16.67	1600	96	12.00	980	82	10.67	1460	137
1891.....	13.00	1220	94	10.00	1300	130	16.67	1400	81	.....	.....	.....	12.33	1260	102	13.33	1450	113
1892.....	.....	.....	.....	14.33	1840	128	.....	.....	.....	.....	.....	.....	14.83	1310	89	14.33	1840	128
1893.....	.....	.....	.....	9.67	820	84	11.17	930	83	10.33	1080	105	11.17	930	83	10.00	950	94
1894.....	12.17	670	55	12.50	1350	108	19.17	1450	75	.....	.....	.....	15.67	1060	65	12.50	1350	108
Average	12.39	957	77	11.43	1354	116	14.84	1260	86	13.50	1340	100	13.20	1108	84	12.17	1410	116

As will be seen from table XIX, the average gives a little more than one bushel of grain per acre in favor of the day irrigation, while the yield of straw is higher for the night irrigation. The increase in straw may be the means of deceiving people into the belief that the crop is better, as many hold that the night irrigation is the better.

The same experiment is being carried on with timothy. Two plats are used and these are rotated from year to year. The results are given in table XX.

TABLE XX.
YIELDS OF TIMOTHY IN POUNDS PER ACRE.

IRRIGATIONS	1892	1893	1894	Average
Day irrigation.....	3400	2300	3400	3033
Night irrigation.....	2700	1700	1700	2033

As will be seen from table XX, the day irrigation increases the yield about one-half. From the fact that the straw increased with the night irrigation, we expected that the hay would increase likewise. But such was not the case. The only outward evidence we could see was that on the plats irrigated at night the water was not so evenly spread over the ground, and this we find very important. In every case the plats irrigated at night were irrigated soon after dark by a man who remained with the water to take care of it the same as in the day time.

SUMMARY.

1. For wheat the yield was the highest in grain from the day irrigation, while for straw it was highest with night irrigation.
2. With timothy there was a decided increase in yield by the day over the night irrigation.
3. The only physical effect noticeable was that the water did not seem to have been so well distributed at night.

Early and Usual Irrigation, and Early, Usual, and Late Irrigation.

The proper time to begin and to cease irrigation is a matter of some great importance. We have made an attempt to get at this by the usual plat method. A comparison of early and usual irrigation with both wheat and oats is given in table XXI:

TABLE XXI.

Yield of grain per acre, plats 7, 8, 9 and 10.

	EARLY IRRIGATION						USUAL IRRIGATION					
	Wheat			Oats			Wheat			Oats		
	Grain Bus.	Straw Lbs.	Lbs. of straw per bu. of grain	Grain Bus.	Straw Lbs.	Lbs. of straw per bu. of grain	Grain Bus.	Straw Lbs.	Lbs. of straw per bu. of grain	Grain Bus.	Straw Lbs.	Lbs. of straw per bu. of grain
1890	17.00	1330	78	.....	.....	.....	7.67	1240	162	.....	.....	.....
1891	6.67	1200	179	22.29	2020	91	14.67	1720	117	24.00	2060	86
1892	13.33	900	69	20.00	1700	85	10.33	1580	153	21.14	1460	66
1893	12.29	670	54	13.33	1000	75	17.14	1000	58	11.50	1110	96
1894	19.33	3840	198	20.00	1300	65	16.33	1020	62	18.57	650	30
Average	13.72	1588	115	18.90	1505	79	13.23	1312	110	18.80	1320	70
Average total pounds of straw and grain.....	2411.20			2166.50			2105.80			1978.00		
Average total of all, lbs.....	4577.70						4083.80					

By reference to table XXI, it will be seen that there is but a slight increase in grain with either oats or wheat by the early irrigation. On the other hand the straw in both cases is materially increased. A great many farmers are led into the belief that the crop is increased by early irrigation, whereas, it appears that it is only the straw that is increased to any extent.

Table XXII is inserted to show the time of beginning and ending of the irrigations:

TABLE XXII.
DATES OF FIRST AND LAST IRRIGATIONS, PLATS 7, 8, 9 AND 10.

IRRIGATIONS		1890	1891	1892	1893	1894
Early irrigation	Wheat {	First.....	May 11	May 23	June 5	May 28
	{	Last.....	July 2	July 7	July 25	July 23
	Oats.... {	First.....	May 11	May 23	June 5	May 28
	{	Last.....	July 11	July 7	July 25	July 23
Usual irrigation	Wheat.. {	First.....	June 8	June 1	June 19	June 16
	{	Last.....	July 2	July 7	July 25	July 23
	Oats.... {	First.....	June 8	June 1	June 19	June 16
	{	Last.....	July 11	July 7	July 25	July 23

Another series of plats was laid out. One plat was irrigated both early and late, another was irrigated at the usual time, and a third not irrigated at all. The results are given in table XXIII.

TABLE XXIII.
YIELDS OF WHEAT PER ACRE, PLATS II, 12 AND 13.

YEARS	EARLY AND LATE IRRIGATION				USUAL IRRIGATION				No IRRIGATION					
	Grain		Straw		Lbs. of straw per bushel of grain	Grain		Straw		Lbs. of straw per bushel of grain	Grain		Straw	
	Bus.		Lbs.			Bus.		Lbs.			Bus.		Lbs.	
1890.....	16.67		640		38	4.67	1120		241	1.75	135	77		
1891.....	11.67		1500		128	13.67	1480		108	6.83	1090	160		
1892.....	15.33		1480		97	15.30	1200		80	8.67	580	67		
1893.....	9.67		920		95	6.83	590		86	1.33	220	165		
1894.....	11.33		720		64	18.00	1520		85	4.83	510	106		
Average	12.93		1052		84	11.63	1182		120	4.68	507	115		
Average total pounds of grain and straw.....	1827.80					1879.80					787.80			

Table XXIII shows that by irrigating both early and late there was a gain of but little more than a bushel per acre. By reference to table XXI, one-half bushel of this, it will be seen, is due to the early irrigation. At best there is very little to be gained by beginning the irrigation very early or carrying it very late. By carrying the irrigation very late there is an actual loss of straw.

Table XXIV is inserted to show when the irrigation of each set began and ended.

TABLE XXIV.
PLATS 11, 12, AND 13.
Dates of first and last irrigations.

		1890.	1891.	1892.	1893.	1894.
Early and late irrigation	First	May 20	May 11	May 23	June 5	May 26
	Last	July 14	July 27	Aug. 1	Aug. 3	July 30
Usual irrigation	First	June 25	June 9	June 18	June 20	June 16
	Last	July 2	July 10	July 21	July 25	July 23

SUMMARY.

1. On very dry and gravelly clay soil there was but little increase in yield of grain, of either oats or wheat, less than half a bushel per acre, by early irrigation over usual irrigation.

2. With both crops, however, there was an increase of straw by the early irrigation.

3. By both early and late irrigation the yield of wheat was increased, but by only a little more than one bushel per acre.

4. In the latter case the yield of straw was decreased, due apparently to the late irrigation.

Fall and Spring Irrigation.

Prof. King, of Wisconsin, showed by his elaborate experiments, that a certain crop grown on a certain soil will leave that soil in a different condition as regards moisture, to that in which it would have been left by some other crop. He further showed that this influence lasted for more than one season, or, rather, that the effect was felt by the succeeding crop. This would go to show that the soil has great water-holding power, for the soil from which the water was not taken held it for the succeeding crop. For this reason it was thought possible to store water in the soil by irrigating in the fall when the water is running to waste, and an experiment was laid out at this Station to test this theory.

The matter is given in table XXV. The numbers of the plats are given to show that they have not been rotated. This is due to the fact that it was thought this would be necessary to properly carry out the experiment.

TABLE XXV.

YIELDS OF TIMOTHY AND WHEAT PER ACRE.

DATE	IRRIGATED FALL AND SPRING				IRRIGATED SPRING				IRRIGATED FALL AND SPRING				IRRIGATED SPRING			
	Plat No.	Wheat Lbs.	Straw Lbs.	Lbs. of straw per bu. of grain	Plat No.	Wheat		Straw Lbs.	Lbs. of straw per bu. of grain	Plat No.	Hay		Plat No.	Hay		Plat No.
						Bus.					Lbs.			Lbs.		
1891.....										38	2360		37	1760		.....
1892.....										38	1500		37	1000		.....
".....										39	1260		40	1400		.....
1893.....										38	1100		37	900		.....
".....										39	1100		40	600		.....
1894.....	37A	33.85	3500	103	38A	35.22	3828	109	109	38	1700		37	1300		.....
".....										39	1900		40	1500		.....
Average.....		33.85	3500	103	.....	35.22	3828	109	109	.....	1560		.....	1209		.....

The first crop of timothy was harvested in 1891. Plat 38 was watered in the fall of 1890, and every fall thereafter. Plat 39 was irrigated for the first time in the fall, during 1891, and every fall thereafter. As will be seen, there is an increase of hay by the fall irrigation. It appears by looking over the plats there is a better stand of grass on that fall irrigated, due likely to the fact that irrigation prevents some of the grass from dying during the dry fall months. But whether the increase is due to this, or to the fact that there is more moisture in the soil, it is hard to tell. There is an increase, however, of more than 28 per cent. This is worthy of experiment by anyone interested.

If the soil retained the water in such shape that the crop of the following year could use it, then it was thought that a grain crop could and would be benefited by fall irrigation. To test this matter, two half-acre plats were laid out, on a better part of the farm which is under a regular rotation. They are numbered 37A and 38A, and were planted Spring wheat. Plat 37A was irrigated in the fall of 1893, besides being irrigated at the same time, with the same amount of water, in the spring as was plat 38A. As will be seen by reference to table XXV, there is but little difference in yield of grain in the two plats, that little difference going against the fall irrigated. In straw the yield of that fall irrigated is very much decreased.

SUMMARY.

1. By irrigating timothy in the fall as well as during the growing season there was an increase in yield of over 28 per cent.

2. Whether this was due to the soil's retaining the moisture or whether due to the fact that more plants lived, thus giving a better stand, is not known.

3. With wheat there was a slight loss in yield of grain and a very noticeable loss in yield of straw, on the plat fall irrigated.

Methods of Irrigation.

In many of the European countries where the art of irrigation is much more developed than in this country, much labor is expended in fitting the ground for irrigation. Two principal methods are used for this purpose. One consists of many small ditches or laterals leading from a main ditch so that the water has to flood over the surface for a very small distance. By this means the water is evenly distributed over the ground at about the same time and to the same depth. Another method is to throw up a system of bed work, the beds being higher in the centre and sloping both ways. A ditch is made along the centre of each bed, large at the beginning and growing smaller as it advances. This allows the water to be distributed quite evenly over the whole ground at the same time. These methods, with others, are given in table XXVI, along with the results of each.

TABLE XXVI.
YIELDS OF TIMOTHY, IN POUNDS, PER ACRE.

YEAR.	Irrigated from one side	By laterals, run- ning from one side	Irrigated from one end	Flooded	From a ridge in centre, bed work
	Plat 123	Plat 124	Plat 152	Plat 153	Plat 154
1892.....	1685	3440	3556	2667	3400
1893.....	3463	4212	2578	3067	2933
1894.....	4961	6458	4177	5200	4533
Average.	3370	4703	3437	3645	3622

The plat "irrigated from one side" was irrigated by having the water flow continuously across the ground from one side of the plat, which was one and three-fourths rods wide, until the plat was irrigated. The plat irrigated "by laterals running from one side," was under the lateral system—the ground being laid off by a net-work of small ditches. The plat irrigated "from one end" was

irrigated by allowing the water to flow across a plat six rods long, continuously from one end until the whole plat was covered with water. The plat "flooded" had a ridge thrown up all around it, about one foot high—the whole plat being covered three or four inches deep with water, which was allowed to stand and soak in. The plat irrigated "from ridge in centre" was irrigated by the bed system, described above.

The water was measured, so that each plat received the same amount of water, which amounted, on an average, to about six inches at each irrigation.

As will be seen by reference to table XXVI, the lateral system gives much the highest yield. The system of flooding is next, while that irrigated by ridge in centre is very close to the flooding. That irrigated from the side or the end gives the lowest yield.

It will be observed that the system by which the ground was covered most evenly with water gave the best results. That in which great care was taken, by distributing the water by an extensive system of laterals, gives far the highest yields. It may be found profitable to extend and carry out this system and at best to distribute the water with more care than is generally bestowed.

Here in Utah, however, there are but two common systems, in vogue. One is the system of covering the ground with water, or simply flooding it, and the other is irrigation by furrows. Everything that can be planted in rows is so planted, and furrows plowed between the rows. With the small grains an instrument or machine is run through the field just after planting, leaving the ground in small furrows about a foot apart. When this machine is crudely made it is called a "go-devil," and the practice is called "go-deviling." With corn, potatoes, beets, etc., the furrow system of irrigation is practiced. We attempted to test the merits of the two systems by direct comparison of the yields by the two methods with both wheat and corn. The results with wheat are given in table XXVII.

TABLE XXVII.
YIELDS OF WHEAT PER ACRE.

METHOD OF IRRIGATION	Plat No.	Grain Bus.	Straw Lbs.	Lbs. of straw per bushel of grain.	AVERAGE.		
					Grain Bus.	Straw Lbs.	Lbs. of straw per bushel of grain.
Furrow, or "go- devil" irrigation..	108	15.56	1133	73	14.33	1140	80
	135	13.11	1147	87			
Flat or com'n flood'g syst'm of irrigat'n.	107	15.78	1320	84	17.67	1406	80
	136	19.56	1493	76			

As will be seen, the common flooding system gave an increased yield of more than 23 per cent. over that irrigated by the furrow or "go-devil" system. The yield of straw was also increased by flooding. This being the work of but one season it may be well to take the results with some caution. We are now intending to carry it forward with both Fall and Spring wheat.

Table XXVIII gives the results with corn.

TABLE XXVIII.
YIELDS OF CORN AND STOVER PER ACRE.

METHOD OF IRRIGATION	1891			1892			1893			1894			AVERAGE		
	Corn	Stover	Lbs. of stover per bushel of corn.	Corn	Stover	Lbs. of stover per bushel of corn.	Corn	Stover	Lbs. of stover per bushel of corn.	Corn	Stover	Lbs. of stover per bushel of corn.	Corn	Stover	Lbs. of stover per bushel of corn.
Furrow Irrigation	73.38	6173	84	45.90	3400	74	42.67	1800	42	48.57	2467	51	52.53	3460	63
Flooding "	64.57	6173	96	46.10	3400	74	52.38	2400	46	79.33	3200	40	60.59	3793	64

The furrow irrigation was that commonly in use. The corn was planted in hills and furrows run through one way and the water allowed to run through these furrows between the rows. In flooding, the corn was irrigated as is a level field of wheat by simply covering the entire surface with water.

A glance at table XXVIII shows that for every year, except 1891, there was an increase of yield in corn amounting in 1894 to more than 63 per cent. by the method of flooding over the furrow irrigation. The averages for the four years show an increase of more than 15 per cent. by flooding. The yield of stover was the same for the first two years by both systems, while for the last two years there was an increase by flooding, making for the average of the four years an increase of nearly 10 per cent. in the stover for the flooding over the furrow irrigation. The term "stover" is used to indicate that part of the plant left after the ears are taken off. The term "fodder" is more generally used here in Utah, but fodder should mean both stover and corn, or the plants cut and cured with the corn left on.

In connection with these experiments it may be well to call attention to one in this same line, made and reported by Prof. Richman, with potatoes. In summarizing Bulletin No. 20, of this Station, page 27, he says: "Irrigating potatoes by flooding gave better results than irrigating between the rows." Especial attention is called to these results in comparing the flooding and furrow systems. The latter system is so thoroughly established in Utah that farmers and gardeners, as a rule, consider it a folly to irrigate anything planted in rows by any other than the furrow system. The furrow system requires more time, more work, and more water than does the flooding system, while our experiments show that with wheat, corn, and potatoes, there is an increased yield by the flooding system. The great objection to the flooding system is that the ground bakes. This is easily overcome by cultivating as soon as the ground is dry enough. The furrow system of irrigation must of necessity be accompanied by the hilling system of cultivation.

With both corn and potatoes, as a rule, it is found that level cultivation is the better. Whether the decrease in yield is due to the furrow system of irrigation or whether it is due to the hilling system of cultivation, it is hard to decide. Be this as it may, there is a decrease in yield by the furrow system. In our general field of corn we use level cultivation, and irrigate the same as if irrigating a common wheat field, by laying off furrows along the high places, then flooding the ground. As soon as dry enough the cultivator is run over the ground, no crust being allowed to form. By this method, on our poor clay soil, we have raised as high as ninety bushels of corn to the acre, counting seventy pounds of ear corn to the bushel.

SUMMARY.

1. Of five different methods of distributing water on grass land, distributing by a net work of small ditches gave the best results.

2. The methods which distributed the water most evenly over the ground gave the highest yields.

3. There was an increase in yield of wheat of more than 23 per cent. by the common flooding system over the furrow or "go-devil" system. Result of duplicate plats for but one year.

4. With corn there was an increase of more than 15 per cent. by flooding over the furrow system.

5. The corn stover increased nearly 10 per cent. by the flooding system over the furrow system.

[5A. Prof. Richman at this Station found that "irrigating potatoes by flooding gave better results than irrigating between the rows."]

6. As the hilling method of cultivation is found to decrease the yield as compared with level cultivation, it is thought probable that this had as much to do with the results as did the different methods of irrigation.

7. By flooding fields of corn the same as wheat and cultivating the ground as soon as dry enough, we have reached a

yield of more than 90 bushels per acre of White Flint corn, the average for five years being 46.72 bushels per acre.

8. When the flooding system is practiced, it is thought that cultivation at just the proper time is very important.

General Remarks.

The drawings from which the cuts in this Bulletin are reproduced, were made by Mr. Joseph Nelson, a student of the College. A trench one rod long and five feet deep was dug in the centre of each of the plats, and the measurements of a vertical section were taken from this. The stratum of cement is very hard when dry, but is not impervious to water. Under the cement there is a loose gravel and cobble-rock for probably 200 feet in depth.

It is hardly necessary to add that such soil will require the maximum amount of water. Where the surface soil is a clay soil it required from 2 to $2\frac{1}{2}$ feet of water to produce the maximum yield of grain. Where the surface soil was somewhat sandy it required from 3 to $3\frac{1}{2}$ feet of water to produce the maximum yield. Good yields of clover and medium yields of other hay have been obtained by irrigating but from one to three times. With mixed hay the yields have been higher than that from some of the rich bottom lands, and this, too, with but few irrigations. A great deal of the rich bottom ground is being over-irrigated. The practice of allowing water to run on to grass from early spring to late fall cannot be too strongly condemned. As a rule, where land is irrigated at all, the irrigation is excessive. Corn is a crop that probably suffers most from over-irrigation. It is a tender plant and should never receive water until the leaves curl and fail to brighten up again during the night. Then it should never be soaked, not even on our driest soil.

Especial attention is called to the results of night and day-irrigation, and of the furrow and flooding systems.

Water Units.

In the different States and Territories there are different systems of measuring and dividing water. In many of the States the "miner's inch" is used. This probably is the poorest unit in use, as there are so many different "miner's inches," and each one must be reduced to some other unit more definite and easier to understand. For this reason it is to be hoped that the "miner's inch" may never come into vogue in Utah. Another unit is the second-foot, or the cubic foot per second—meaning that in a running stream a volume of water equivalent to a cubic foot will pass a given point in one second of time. When this unit is used it can be, and is, made either definite or indefinite. Wherever its use is attempted, it is both strange and unfortunate that it should be used as an indefinite unit. Water is divided by the cubic foot per second for the irrigating season. The irrigating season may last from 30 days to 150 days, Fall wheat doing well if irrigated in June only, while good pasture on high ground will do best if irrigated at intervals from May 15th to October 15th. When this unit is used, by making it a cubic foot per second for the irrigating season, it may vary as much as five or six hundred per cent., and at either extreme the water be used to the best advantage. This is somewhat modified, as it is now generally agreed that eighty days is the average irrigating season. If the second-foot is to be used, it should be made definite and fixed. This may readily be done by allowing a cubic foot per second for a given number of days. The second-foot, too, lacks simplicity. On the older ditches and canals much of the water is divided by the "irrigating stream," a man receiving this stream for a definite time. The trouble with this division is that the streams may vary much even when the best judgment is used.

A unit termed the acre-foot, is both simple and definite and exceedingly easy to apply. For this reason the writer believes that as a general unit to use in the division of water this is by far the best. The acre-foot may be defined as that

amount of water required to cover an acre one foot deep, and is equivalent to 43,560 cubic feet. Water sold at so much per acre-foot at once gives a definite amount and in such terms that any one can make application of them. For instance, if in a season a man has one and a half acre-feet of water for each acre of ground, he can easily see that this ground will be covered one and a half feet deep with water, or at three irrigations six inches of water may be applied at each irrigation. In dealing with the capacity of reservoirs, too, the acre-foot is very convenient. For example, if we have a reservoir with an area of twenty acres and an average depth of eighteen feet, it is a very easy matter to calculate that there are 360 acre-feet of water; and if it requires two feet of water to irrigate ground, 180 acres can be irrigated from such a reservoir. From any point of view, then, it would seem that the acre-foot is to be preferred.

GENERAL SUMMARY.

1. On gravelly clay soil, two feet of water were required to produce the best result with grain. Where the soil was more sandy three and a half feet were required. It is thought that an average of two feet will be required for most of the ground that is to be brought under irrigation in the future in Utah.

2. For wheat, clover, and timothy, it was found that the intervals between irrigations could vary from six to fifteen days, favoring an interval of twelve days. If the interval was shortened to three days or lengthened to eighteen days the results were quite disastrous.

3. With either Fall or Spring wheat the yield increased from one irrigation up to three. The Spring wheat decreased in yield when irrigated more than three times.

4. With either wheat or timothy, where either a cement tile or rock drain was used, sub-irrigation proved next to a complete failure, decreasing the yield of wheat by about 34 per cent.

5. Day irrigation gave better results than did night irrigation.

6. There was an increase of only about one-half bushel per acre for either early or for late irrigation over the usual time of irrigating.

7. There was an increase in the yield of timothy by irrigating in the fall, while the yield of wheat was slightly less from ground fall-irrigated.

8. In distributing water we found that the systems which distribute it with the greatest evenness over the surface gave the best results. It appears that our common systems may be greatly improved.

9. We have found at this Station that the yield of wheat, corn, and potatoes is decreased by the furrow system of irrigation as compared with the flooding system.

10. It is thought that much more of the ground, that is irrigated at all in Utah, is over-irrigated than under-irrigated.

11. The acre-foot being a simple and definite unit, is recommended for general adoption for the division of water for agricultural purposes.

Orchard and Vineyard Irrigation.

BY E. S. RICHMAN, HORTICULTURIST.

Orchard Irrigation.

The irrigation of orchards is now being watched very closely in all sections where irrigation is practiced. It is now more fully recognized that the welfare of an orchard does not depend upon the moisture that may be applied from time to time to the surface soil. In fact, some California orchardists have gone so far as to discard the irrigation of certain kinds of fruit altogether, relying entirely on the moisture stored in the soil during the winter months. But this seems to be carrying the matter almost too far. The most approved plan seems to be to irrigate as few times as is consistent, but to apply more water at each irrigation; enough should be applied at one time to reach down to the deeper roots. The amount would vary according to the size of the trees. Young trees—for the first two or three years—need watering oftener and less at a time than older ones, because the roots have not yet penetrated deeply into the soil. As the roots go deeper and deeper, more and more water needs to be applied in order to penetrate as deeply as they do. But as the roots penetrate deeper and deeper, they are able to supply the tree with moisture for longer periods of time without irrigation, providing the irrigation has been thorough enough to wet the lower strata of soil where the deep roots penetrate. I believe after the third year that two good irrigations are all that

are necessary for any of our fruit trees in Utah, unless they are carrying an exceptionally heavy crop of fruit. In that case three irrigations would probably be necessary.

In order to apply a sufficient amount of water to make two irrigations suffice, it is necessary to employ some means to confine the water in sufficient quantities to soak to the required depth. Just how much water should be applied to orchards I am unable to say with certainty, but hope to be able to give something more on the subject in the future. The amount applied to the Experiment Station orchard last year (1894) probably did not exceed fifteen inches for the two irrigations, and the orchard made a better growth and is in better condition than ever before. For two or three years a sufficient amount may be applied by running the water along the rows in furrows, but when the trees get so large that the roots penetrate deeply into the soil and the entire ground occupied by the roots needs irrigation, some more convenient and thorough method is needed. The method practiced in the Station orchard and many other places has been found to work with entire satisfaction. It is, briefly described, as follows:

Take two two-inch planks about fourteen inches wide and ten feet long, more or less. Place them on their edges in the form of the letter V, but leaving an opening at the point, of twelve to eighteen inches, nail 2x4 cross pieces to hold them firmly in place. Hitch a team to the broad end of this instrument, one horse to each plank, and drive between the rows of trees collecting the dirt into ridges. When the orchard is all gone over in this manner, cross ridges should be made, thus leaving the orchard blocked off in squares. The water is then turned in at the upper end and allowed to run to the lower end of the orchard. When the required amount of water has run into the lower square it is shut off and the second one filled, and so on back to the last or upper square. Each row of squares is treated in this manner. If a good-sized stream of water is used the irrigator can tell approximately how much water he is using by the depth in the squares about the trees. In order to irrigate

in this manner, the orchard must be free from other crops and kept well cultivated or the instrument used will not collect the dirt together for the ridges.

As soon as the ground is sufficiently dry after each irrigation, the ridges should be worked down and the soil thoroughly cultivated, in order to prevent evaporation and retain the moisture as long as possible.

It is claimed by some that the water should not come in direct contact with the base of the tree; this can be avoided by throwing some dirt around it. I am not certain, however, that the water will damage the bases of the trees. Many orange groves are irrigated in California without any protection for the trees and there appears to be no injury resulting from the practice.

Vineyard Irrigation.

SUB IRRIGATION VS. SURFACE IRRIGATION.

This experiment is described on page 177 of the Annual Report for 1893, and for the benefit of those not having the Annual, the following description is quoted from it:

"In order to convey the water along the row, tubing was made by using six-inch boards for the sides and four-inch boards for the top and bottom, the tube thus made being four inches square inside. A trench was dug along the row and the tubing so placed that the top was one foot from the surface, and the side next to the vines was one foot from them. In order to apply the water to the roots of each vine, two three-fourth-inch holes were bored in the tube just opposite the vines. These holes were protected from the dirt on the top and sides by boxing them in, leaving the bottom open for the free passage of the water.

"When it was desired to irrigate, the water was turned in and the pipes kept full until the ground began to show the effects of it on the surface. This usually took from one to two hours. The point where the water entered was from one to two feet above the outlets, so that there was some little pressure."

In 1892 only a slight difference was noticed in favor of sub-irrigation.

In 1893 the average weight of fruit per vine was:

Surface irrigation.....	3.36 pounds.
Sub-irrigation.....	4.50 "

In 1894 the yield was, per vine:

For surface irrigation.....	5.17 pounds.
For sub-irrigation.....	6.12 "

This gave an increase for sub-irrigation over surface irrigation in 1893 of nearly 34 per cent., and in 1894 an increase of over 18 per cent. Owing to the application of the water beneath the surface the roots are undoubtedly better supplied with moisture than when the water is applied to the surface. Then there is less evaporation in the case of sub-irrigation, because the top soil is left comparatively dry and does not become so compact as when the water is applied to the surface.

Further trial is needed to demonstrate whether it will be a financial success or not.

SUMMARY.

1. In orchard irrigation, two irrigations are thought to be sufficient if enough water is applied each time to reach the deep roots.

2. In vineyard irrigation, sub-irrigation has given more fruit per vine than surface irrigation.

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