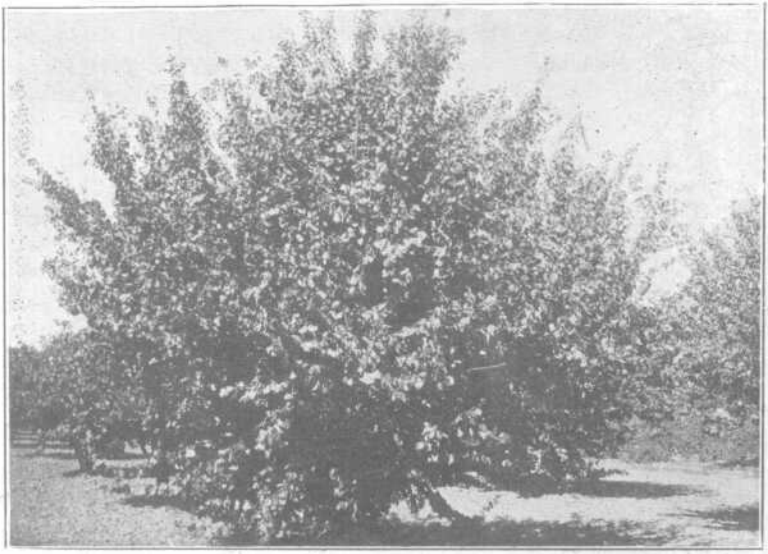
University of Arizona

Agricultural Experimental Station.

Bulletin No. 37.



OCTOBER CONDITION OF APRICOT TREES IRRIGATED DURING WINTER ONLY.

Winter Irrigation of Deciduous Orchards.

BY ALFRED J. McCLATCHIE.

Tucson, Arizona, May 25, 1901.

UNIVERSITY OF ARIZONA
AGRICULTURAL EXPERIMENT STATION

STATION STAFF

THE PRESIDENT OF THE UNIVERSITY . . . .
R. H. FORBES, M. S., . . . Director and Chemist
A. J. MCCLATCHIE, A. M., . . . Agriculturist and Horticulturist
G. H. TRUE, B. S., ... Animal Husbandry
DAVID GRIFFITHS, Ph. D., ... Botanist
W. W. SKINNER, M. S., ... Assistant Chemist
T. D. A. COCKERELL, ... Consulting Entomologist
S. M. WOODWARD, A. M., ... Consulting Meteorologist
W. O. HAYES, ... Clerk

The Bulletins of the Station are sent to all residents of Arizona applying for them.

Address,
THE EXPERIMENT STATION,
Tucson, Arizona.

CONTENTS

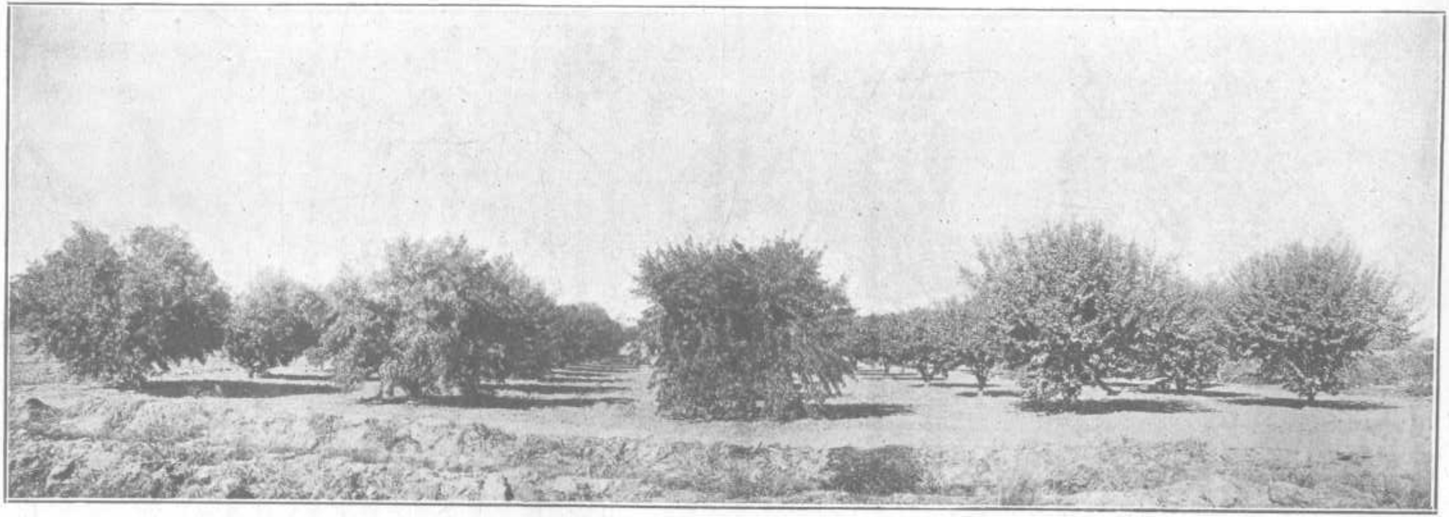


Fig. 1. Orchard used in making winter-irrigation experiments. Three rows on left side, peaches; the two rows on right side, apricots. Above photograph taken October 6th, 1900, seven months after last irrigation of the winter, and at the end of the most trying season of which there is a record at the Phoenix Weather Bureau.

WINTER IRRIGATION OF DECIDUOUS ORCHARDS.

By A. J. McClatchie.

INTRODUCTION.

During December, 1898, experiments were begun at the Station farm near Phoenix to test the effects of the irrigation of deciduous fruit trees during the winter months. The difference in opinion among orchardists as to the value of winter irrigation suggested the making of carefully conducted experiments along this line. The question as to how best to maintain orchards in a thrifty state under the somewhat trying conditions existing in the valleys of Arizona was one of much importance to the fruit interests of the territory. That those not familiar with the region may understand the bearing that the experiments outlined in this bulletin have upon our problems of orchard culture, some statements concerning the climatic conditions and the water supply of southern Arizona follow.

CLIMATIC CONDITIONS OF SOUTHERN ARIZONA.

Precipitation.

In the valleys the rainfall is usually so light that little of it reaches the roots of orchard trees. The soil is seldom wet to a depth of more than eight inches by one storm; and usually the rains are so infrequent that the soil becomes dried out between storms. Hence, in growing fruits, orchardists rely wholly upon irrigation, the supply for this purpose coming from the higher elevations.

In the mountains the precipitation is much greater, the fall of rain and snow being sufficient during a part of most years to cause a subsequent heavy flow in the streams that furnish water for irrigation. A large part of the water that falls in the mountains in the form of rain flows away within a few days or weeks. The remainder slowly percolates through the soil and rocks to the stream beds, thus maintaining a flow which, even though continuous, is not sufficient to supply with water the lands needing it. The water that falls as snow comes down to the valleys below more gradually, furnishing an increased supply for irrigation for one or two months.

While precipitation may occur at any time of the year, in most of southern Arizona, there are two seasons during which the fall is heavier than during the remainder of the year, and the consequent supply of irrigating water much greater. The greatest precipitation occurs from July to September, inclusive, the other rainy season occurring from December to February, inclusive The rain and snow falling in the mountains during the latter period usually furnish an increased supply of irrigating water until the end of March. From the latter month until July the rainfall is light and the supply of water usually gradually diminishes, becoming very low during June. The summer rains swell the streams and increase the supply of irrigating water temporarily. Then follow about three months during which the supply is again usually less than the demand, in many valleys of the territory. The following monthly averages of the rainfall recorded at the thirty-eight stations situated in the valleys of southern Arizona and in the watersheds furnishing them water for irrigation, and having a record of five or more years, will indicate how the rains are distributed throughout the year.

Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Total.*
1 14	0 74	0.64	0.35	0 26	0 21	1.83	2.22	1 05	0 73	0.72	1 13	10.98

Temperature and Relative Humidity.

The coolest months in southern Arizona are December and January, during which heavy frosts are frequent in most of the valleys. During February the weather becomes warm enough to start the buds of some deciduous trees, and by the end of March all are partially or wholly leaved out. The principal part of the growth is made during the three months that follow. During these three months the weather becomes increasingly warm, the maximum temperatures, by the latter part of June, ranging from 100° to 115° F. in the shade in most of the cultivated valleys. The relative humidity of the atmosphere decreases as the season advances and the temperatures rise, evaporation consequently becoming very rapid. During July, August and September the weather is as warm as, or warmer than, during June; but the humidity is temporarily increased from time to time by rains, and the weather is consequently less trying upon vegetation. From September to December the weather grows gradually cooler, and the relative humidity usually gradually increases.

The following averages of the monthly mean temperature and mean relative humidity at Phoenix for each month of the past five years will indicate the changes in the weather from season to season of the year, in the largest agricultural valley of the territory:

Monthly averages 1896-1900.	*Jan*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*
Mean temperatures	52	55	60	67	75	85	90	88	83	70	60	52
Mean relative humidity......	53	42	38	33	26	24	37	40	39	40	43	45

SUPPLY OF IRRIGATING WATER IN SALT RIVER VALLEY.

The variation in the supply of irrigating water from month to month of the year, in the Salt River valley, will be indicated by the following monthly averages of the flow of the Salt River during the past twelve years, based on available records.

The numbers express the flow in thousands of acre feet:

Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept*	*Oct.*	*Nov.*	*Dec.*	*Monthly mean*
171	306	175	92	55	27	37	65	52	65	60	104	101

The average rainfall at the six stations in the watershed of the Salt and its tributaries is, according to available records, as follows:

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1.84	1.46	1.57	0.81	0 64	0 30	2 27	2.57	1.20	0,95	1.08	1.90

It will be seen that although the rainfall is heavier during the summer than during the winter, the flow of the river is much greater during the latter season. The parched condition of the watershed and the rapidity of evaporation during the hot summer months are undoubtedly responsible for the failure of most of the rainfall of that season to reach the valleys below. The precipitation during July, August and September is one-sixth greater than that of December, January and February, yet during these three summer months the flow of the river is less than one-third what it is during the three winter months. Hence, during the months of December, January and February, an average of over three times as much water is available for irrigation as during the summer period of most abundant supply.

PREVALENT METHODS OF ORCHARDISTS.

The practice among orchardists, before the experiments were begun at the Station farm, had been (and to a considerable extent is yet in many parts of the Territory) to begin the irrigation of their orchards during February or March, about the time the development of the buds began, and irrigate about once a month until October, or as often as water could be obtained. During considerable of this period the amount of water available was usually inadequate to the demands of the trees, and orchards frequently suffered from drought. The methods of applying the water and the subsequent treatment of the orchards, varied very much. Some fruit-growers applied the water through temporary furrows about three feet apart, some through permanent ditches made between the rows of trees, and some by flooding the entire surface of the soil. In some cases an irrigation was followed by cultivation, as soon as the soil had dried sufficiently. In many cases orchards were seldom or never cultivated, some growers believing that the growth of weeds during summer was essential to the welfare of the trees, since they kept the soil cool and thus supposedly checked evaporation.

PURPOSE AND SCOPE OF THE EXPERIMENTS

Previous to beginning the experiments, there existed considerable difference of opinion among fruit-growers as to whether, under the trying climatic conditions of southern Arizona, the irrigation of an orchard during winter, when the trees were dormant, would materially lessen the amount of water that would need to be applied during the succeeding summer. It was thought by the writer that the question might be pretty definitely settled by experiments covering two or three years.

It is believed that sufficient data have been accumulated to warrant publishing the results in bulletin form. Besides keeping notes on the above-ground operations and conditions in the orchard, investigations have been made underground. The moisture content of the soil has been determined from time to time, and the changes caused by the application and by the withholding of water ascertained. Each phase of the subject, the above-ground and the underground, will be taken up chronologically.

ABOVE-GROUND OPERATIONS AND RESULTS.

DURING 1898-99.

The orchards upon the Station farm had been irrigated about once a month through the summer of 1898, water having been last applied about the middle of September. During the following winter all were irrigated more or less thoroughly, but one isolated orchard of about three-fourths of an acre was chosen for special treatment and observation. The orchard consists of three rows of peach trees and two rows of apricot trees, set 24 feet apart. It had been planted in 1892, and the trees had, therefore, been growing in their present situations seven seasons. The soil is a clayey loam.

Water was withheld from this small experimental orchard from September until January 9, when the frequent application of water began. The orchard was irrigated by the furrow system eight times, fresh furrows having been made with a turning plow twice during the winter. The last irrigation occurred March 29th to 31st.

As soon as the soil had dried sufficiently, it was harrowed crosswise the furrows to check evaporation from them. It was subsequently plowed deeply and harrowed thoroughly. During the two following months it was cultivated twice. It received no

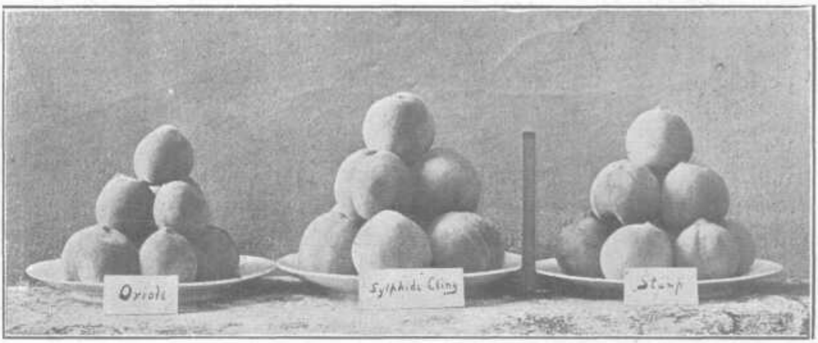


Fig. 2. Peaches grown in winter-irrigated orchard; harvested August 24, 1899, from heavily loaded trees.

irrigating water until June 24th, and no rain fell in the meantime. It was cultivated as soon after irrigation as the soil was sufficiently dry, and was cultivated once more during the summer.

The orchard remained in excellent condition throughout the season. The trees grew thriftily and maintained a vigorous appearance all summer. The young shoots on the peach trees were three to five feet long, and those on the apricot trees four to six feet long. The trees were well loaded with fruit that was larger than and of superior quality to that borne the previous year, when the orchard was irrigated frequently during the summer. The results of the season's experiment were satisfactory in every way.

The following monthly averages indicate the nature of the weather through the year 1899. The temperatures were recorded

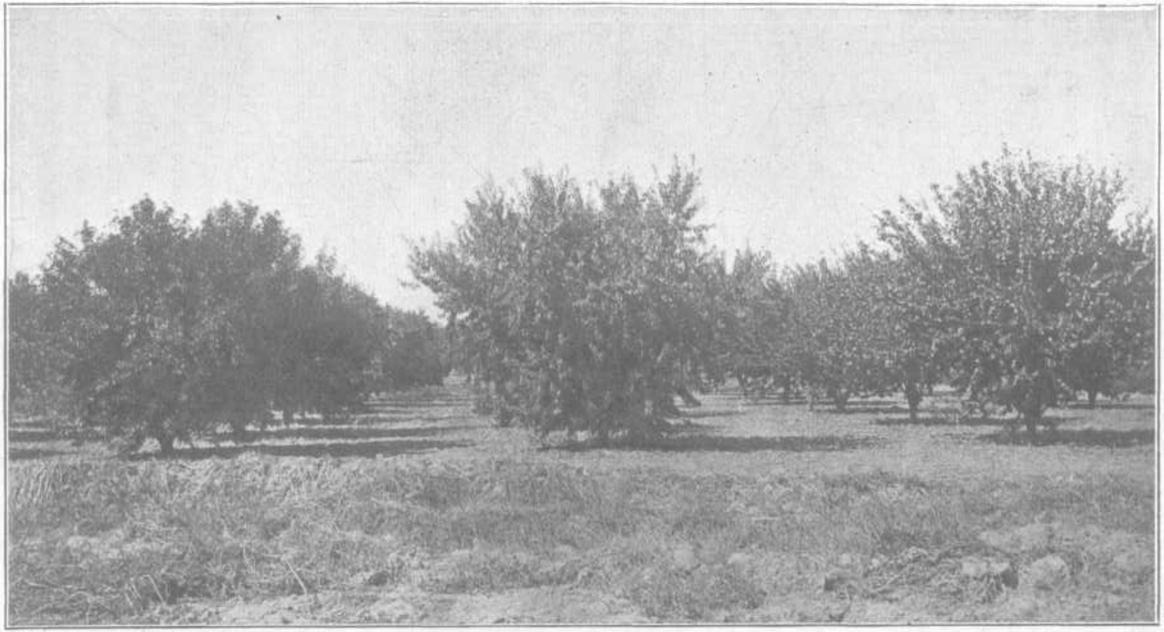


Fig 3. Winter-irrigated orchard as it appeared October 8, 1899.

at the farm, and the relative humidity determinations were made at the Phoenix Weather Bureau, two miles distant:

Temperature and humidity, 1899.	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May.*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
Mean minimum.	33	34	41	48	51	64	78	69	67	51	42	33
Mean maximum.	63	69	76	86	88	101	105	102	101	83	74	67
Mean rel. humidity	49	40	32	28	22	32	40	38	31	40	46	38

DURING 1899–1900.

The winter irrigation this season was begun December 16th. Water was applied about as rapidly as the soil would absorb it.

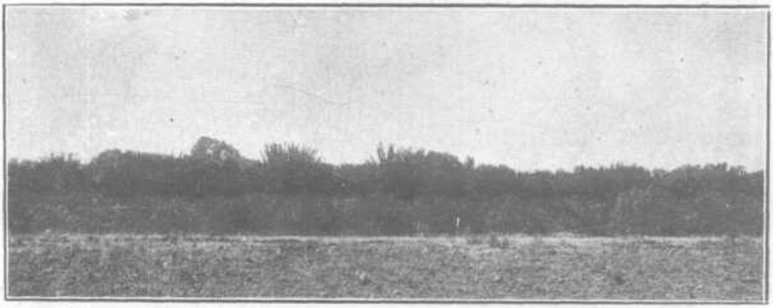


Fig 4. Winter irrigated vineyard and orchard, July, 1900.

until three feet in depth had been given the orchard. The last irrigation of the winter occurred March 5th.

As soon as the soil was dry enough, the orchard was plowed each way about a foot deep, harrowed thoroughly and left for the summer. After summer showers, a cultivator was run over the surface to break up the crust that formed. In this way an earth mulch six to eight inches deep was maintained. No water was applied for over eight months, during which period the rainfall was but two and one-half inches, divided among five rains.

As during the previous season, the trees remained in excellent condition throughout the summer. During May and June occurred the dryest hot period of which there is a record in the valley. At the end of it the orchard showed no signs of drought whatever, the peach trees having made a growth of about four feet, and the apricot trees a growth of three to six feet. During the dry, hot period mentioned above, the apricot trees matured a good crop of excellent fruit. Many of the peach trees remained unusually heavily loaded with fruit that matured during July and August, the quality being fully up to that of the previous year.

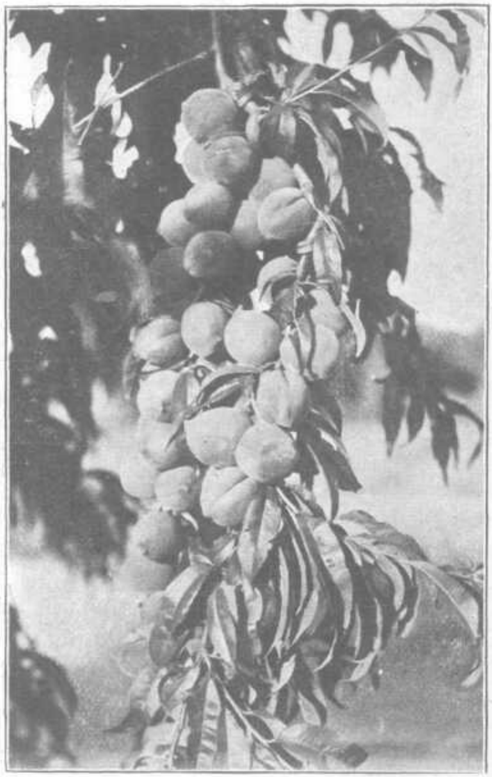


Fig. 5. Branch on peach tree, showing how heavily loaded some of the trees were July, 1900, in orchard irrigated during winter only.

Though the summer continued unusually dry (the mean relative humidity being the lowest recorded at the Weather Bureau at Phoenix), the trees maintained a vigorous appearance until November. Though having received no irrigating water for eight months, at the end of a season during which many orchards died, no thriftier or more vigorous orchard existed in the valley.

The following monthly averages will indicate the nature of the weather of 1900, the temperatures being those of the farm, and the relative humidity percentages those of the Weather Bureau

Temperature and humidity, 1900	Jan	Feb	Mar	Apr	May	Jan	July	Aug	Sept	Oct	Nov	Dec
Mean minimum. .	36	35	44	46	56	63	72	67	60	52	43	32
Mean maximum ..	70	68	82	77	95	104	105	102	100	85	76	70
Mean rel humidity	41	29	38	44	26	16	25	26	30	36	41	42

DURING 1900–1901

During the two previous years a green-manuring crop was grown in the other two orchards on the farm. Since it was found that the soil in these orchards would not only produce a heavy winter crop, but became thoroughly moistened to as great a depth as in the smaller orchard, the soil of which had been left bare, the latter was sown to clover *(Melilotus indica)* November 6. The seeding was followed by an irrigation, and water was applied frequently enough until March 29 to keep the crop growing well During this period water to the depth of four feet was applied. The green-manuring crop was turned under April 6. As shown by the accompanying illustration, the clover was twenty to thirty inches high, and very thick upon the ground. Judging by the amount applied the previous winter, the clover consumed, during the four months of its growth, about one foot more water than evaporated from the surface of the bare soil from December 16 to March 5, 1899.

DISCUSSION OF PRINCIPLES INVOLVED.

Reasons for Favorable Results.

The favorable results from the experiments outlined above were due to several factors. At first thought, it seems marvelous that trees not only could endure such dry, hot weather, but grow thriftily for eight months without their roots receiving any additional water in the meantime. But their ability to do this was simply the outcome of following natural laws.

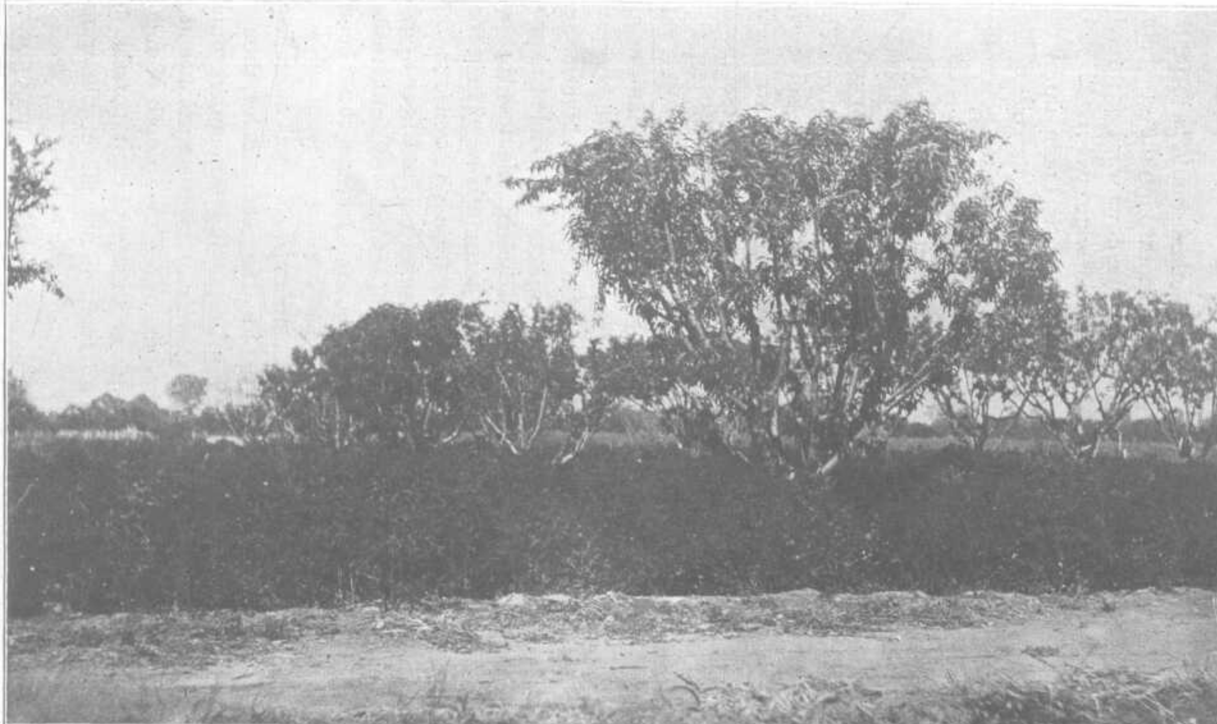


Fig. 6. Green-manuring crop of clover, showing growth reaching into limbs of trees of winter-irrigated orchard, April 2, 1900.

The chief aim of irrigation by any method should be to get the maximum amount of the water applied back through the crop being grown, and let the minimum amount escape downward or directly from the soil into the atmosphere. Only the water passing *through* a tree, for example, benefits it. That which is taken up by the roots and exhaled from the leaves is of service to the tree. The water that does not take this course does not benefit it. Another important point to be kept in mind in irrigating is that the entrance of air into the soil should not be interfered with while the plant is growing. The proper aeration of soil is very important. That the necessary biological and chemical processes may proceed properly in the soil, a constant supply of oxygen is essential. The method of irrigating trees that interferes least with the soil aeration is the desirable one. A consideration of the winter irrigation system, as outlined in the foregoing pages, will disclose that it answers the two above requirements.

During the winter the lower temperatures and the higher relative humidity cause evaporation to be much slower than during the remainder of the year. In applying water, therefore, comparatively little escapes into the atmosphere. The supply of water being greatest at that time of the year makes it possible to apply large amounts at short intervals, thus avoiding the loss that occurs if small amounts are applied at greater intervals. Then, too, the trees are dormant and the roots need little air; hence, no injury is done them by keeping the soil supermoistened, or by letting the surface bake to some extent. Consequently, cultivation after each irrigation is not necessary, much time thus being saved.

When the soil is of the proper character, the roots of orchard trees penetrate to great depths, enabling the trees to thrive, though the surface stratum be quite dry. In making the underground investigations in this orchard, roots were found in abundance at a depth of 12 to 16 feet, and many penetrated to a depth of more than 20 feet. This characteristic is what makes it possible to store in the soil, during winter, much, if not all of the water needed during the summer.

Trees make use of, and consequently need water much earlier than is commonly supposed. An examination made February

20th, 1900, revealed that at the depth of ten to sixteen feet, even, young roots three to six inches long had already grown. At this date there were few above-ground indications of growth, and it would not have been supposed by making a casual observation that the trees would make use of any water that might be applied While the air above-ground is still too cool to start the development of the buds, the roots far beneath the surface are making a growth that prepares the tree for the demand for water that the leaves will make later. Thus, if the trees have an abundance of water during the winter, the early root growth that will be made will enable them to make a rapid growth as soon as the air above-ground is warm enough to permit it. These facts account for the rapid and vigorous growth that the winter-irrigated orchard made in early spring, compared with those that had not been thus irrigated.

Effects of Summer Irrigations.

During the summer the climatic conditions and the demands of the trees are quite the reverse of those of the winter. The high temperatures and the low relative humidity cause such rapid evaporation that much of the water applied quickly escapes into the atmosphere The supply of water for irrigation being very low, It is not ordinarily possible to apply sufficient quantities of water to reach the deeply-seated roots of the tree. In summer a large percentage of the water applied escapes directly from the soil without passing through the trees. This is the case whether its surface is cultivated (as should be done) and the upper few inches loses all its moisture as a result; or the soil is left to bake (as should not be done) and not only the surface becomes dry and hard, but a large amount passes up from below through the baked soil.

Summer irrigations are ordinarily surface Irrigations. Only a comparatively small percentage of the water applied becomes available to the trees. While the surface may be wet, the roots below may be in comparatively dry soil. Furthermore, from the time that water is applied until a cultivation can take place, the soil is practically sealed air-tight. This exclusion of air, for the reasons stated above, retards the growth of the trees. Most of the cultivation that must follow each irrigation, in order to check evaporation and admit air, is obviated by applying the water during the winter, instead of during the summer.

Reasons for Cultivation and Weed Destruction.

After each summer shower the surface of the soil should be cultivated to break up the crust that forms, and thus check evaporation and permit the entrance of air. The conservation of moisture by cultivation is based on well-established principles. During a rainstorm or during irrigation, the water received by the soil moves downward. As soon as the supply from above ceases and the free water settles away, by capillary action the movement of the moisture in the soil sets in in the opposite direction, moving upward as well as downward. As the moisture reaches the surface, it passes off as vapor. Only by preventing the water reaching the surface can this evaporation be checked. The capillary action by which the water reaches the point where it evaporates can go on only in a closely packed soil furnishing the innumerable, minute, irregular tubes through which the water rises. To break up these tubes checks this upward movement. Cultivation not only breaks up the capillary tubes of the surface, but forms over the surface a mulch that prevents rapid evaporation. The moisture will then rise to the mulch, but cannot pass beyond it by capillary action, and evaporation thus proceeds much more slowly than if the moisture were permitted to follow the capillary tubes to the surface.

Samples of soil taken in an orchard during the summer of 1900 illustrate the foregoing. Most of the orchard had been thoroughly cultivated ; but a portion had been left uncultivated, and had become overgrown with weeds. A determination of the per cent of water in each of the five upper feet in each area May 23d showed that as a whole the upper five feet of soil in the cultivated area contained over a third more water than the upper five feet in the uncultivated area. But when only the available water in each is taken into consideration, the difference is much greater* Plants cannot remove all the water a soil contains. In such a soil as the above, at least five per cent would be left in it after the rootlets had removed all they had power to remove. Making this deduction, the soil in the cultivated area would be found to contain about twice as much available moisture as that in the uncultivated area. Or to make the statement in another form, the loss of water from the uncultivated area from March 5 to May 23 exceeded the loss from the cultivated area by the equivalent of over two inches of rainfall; and the loss during the entire summer would probably be about three times this amount. To replace this loss from a ten-acre field would necessitate the running of a stream of 2½ second feet (100 miner's inches) for about 30 hours.

In order to produce the best results the soil must be so cultivated, however, that it is not left broken up into large clods, that will permit the air to reach the underlying strata. The finer and looser the surface mulch the better, and in our arid region it needs to be deeper than elsewhere.

Weeds injure growing crops by appropriating the available plant food and by removing water from the soil. While a soil may be very fertile, there seldom is present enough plant food, in the form necessary for the use of plants, to support a crop of weeds and a crop of fruit. But weeds usually do the greatest injury by removing water from the soil. Not only do weeds require water for their increase in size, but water is continually evaporating from the surface of their leaves. While they may shade the surface of the soil so as to check evaporation there, the evaporation from their leaves is much more rapid than it would be from the surface of the unshaded soil, if it were properly cultivated.

One Summer Irrigation Considered Advisable.

If about the middle of the summer, water is available in abundance, it would probably be wise to give the orchard a thorough irrigation in as short a time as possible, and then follow the irrigation with a thorough plowing, as in the spring after the winter-irrigation ceases. But frequent summer irrigations are decidedly not advisable under our conditions, where the soil is fairly deep and retentive of moisture.

UNDERGROUND INVESTIGATIONS.

DURING 1899.

Ten days after the last irrigation, samples of each foot of the soil from the surface to ground-water were taken for the purpose of determining the moisture content. By that time the surface applications had settled away, but as will be seen from the results of the determinations, the water of the entire soil had not yet had time to come to an equilibrium.

The upper five feet proved to be a clayey loam, the next foot a mixture of loam and gravel, the seventh to the thirteenth, inclusive, gravel of varying coarseness, the fourteenth foot gravel and clay, the fifteenth foot gravel, the sixteenth foot gravel and clay, the seventeenth to the thirty-first, inclusive, fine clay, and the three feet below this a mixture of clay and gravel. Free water was encountered at a depth of 34 feet.

In the upper loam stratum soil samples could be bored out with an auger, but it was not found practicable to bore through the gravel below the loam. Hence it was necessary to excavate to a depth of 16 feet, and take the samples of the gravel from the side of the excavation. Through the remainder of the distance the samples were obtained by boring with a two-inch auger. The boring was stopped at the 34th foot by the gravel encountered.

In taking the samples, roots were encountered in abundance at a depth of 14 to 16 feet, and one peach root was followed into the 20th foot, showing that water to this depth at least would be available to the trees. The 20-foot root went down almost perpendicularly, starting 18 feet from the base of the tree.

June 18th, samples of each foot of the soil to a depth of 34 feet were again taken. Samples were also taken September 30th and December 10th.

DURING 1900.

March 12th of this year, a week after the last irrigation of the orchard, samples of each foot of the soil were taken from the surface to a depth of 33 feet for the purpose of determining the moisture content, as during the previous year For the purpose of determining how much moisture would be lost during the summer, by evaporation of water from the surface of the soil without passing through the trees, the space surrounded by four trees was covered with roofing tin.

No samples of the soil were taken until October 9th. At this time it was found that, with the exception of the upper six inches, the soil under the roofing tin was as dry as in the uncovered area. Rootlets had formed in great numbers in the surface foot, from which they were almost entirely absent in the uncovered portion of the orchard.

TABLE I. RESULTS OF MOISTURE CONTENT DETERMINATIONS.

The accompanying table gives the results of the determinations from the soil samples taken during the summers of 1899 and 1900.

The "weight per cubic foot" is the weight of the soil completely dry. In order to ascertain the degree to which the soil was saturated, it was necessary to determine the "maximum water capacity" given in the second column of the table. The percentages of moisture in the samples were determined by the usual method of weighing them before and after being completely dried in an oven kept at a temperature of 230° F.

Number of foot.	Character of Soil.	Weight per cubic foot.	Maximum water capacity.	April, '99. Water content.	April, '99. Degree of saturation.	June, '99. Water content.	June, '99. Degree of saturation.	Sept. '99. Water content.	Sept. '99. Degree of saturation.	Dec. '99. Water content.	Dec. '99. Degree of saturation.	March, '00. Water content.	March, '00. Degree of saturation.	Oct. '00. Water content.	Oct. '00. Degree of saturation.	Number of foot.
		lbs.	%	%	%	%	%	%	%	%	%	%	%	%	%	
1	Clayey loam	76.4	37.8	15.1	40.0	4.2	11.1	3.2	8	4.2	8.4	15.0	40.0	4.0	10.5	1
2	" "	78.2	37.6	17.6	46.7	6.3	16.7	4.0	11	4.0	11.0	17.5	[illegible]	5.0	13.2	2
3	" "	77.5	37.5	17.4	46.4	8.4	22.4	5.6	14	7.5	12.0	16.0	[illegible]	7.3	19.4	3
4	" "	73.3	[illegible]	[illegible]	55.0	10.0	27.4	7.4	20	7.0	19.1	20.0	54.8	7.4	20.2	4
5	" "	75.5	[illegible]	[illegible]	52.6	11.0	28.9	8.2	21	[illegible]	19.7	20.0	52.6	[illegible]	17.8	5
6	Loam and gravel	83.0	[illegible]	9.7	48.7	6.2	31.1	5.0	25	[illegible]	12.0	10.4	50.0	2.8	14.0	6
7	Coarse gravel	111.0	[illegible]	[illegible]	50.4	1.6	12.8	1.5	12	2.5	12.0	6.5	51.2	2.0	16.0	7
8	Gravel	96.5	[illegible]	8.4	44.4	3.0	15.8	2.6	13	2.5	13.1	[illegible]	44.7	2.8	14.7	8
9	"	96.0	[illegible]	7.4	37.0	3.4	17.0	3.2	16	[illegible]	14.0	7.0	[illegible]	3.6	18.0	9
10	"	97.0	[illegible]	4.5	27.1	3.4	20.4	3.3	20	[illegible]	13.2	5.0	[illegible]	2.9	17.8	10
11	"	96.8	[illegible]	[illegible]	39.4	3.4	19.9	3.2	18	[illegible]	17.4	7.0	[illegible]	3.6	20.9	11
12	"	98.0	27.2	4.7	22.1	3.0	14.1	3.0	14	[illegible]	13.2	5.0	[illegible]	3.0	[illegible]	12
13	"	102.4	21.6	4.7	21.0	2.7	11.9	2.6	11	[illegible]	12.5	[illegible]	22.1	3.0	13.2	13
14	Clay and gravel	87.4	32.0	17.3	57.6	16.0	53.3	15.0	50	[illegible]	46.6	[illegible]	[illegible]	15.0	50.0	14
15	Gravel	97.3	[illegible]	8.6	35.1	5.1	20.8	4.2	17	4.1	12.6	[illegible]	35.1	3.0	[illegible]	15
16	Gravel and clay	80.8	44.1	[illegible]	71.4	22.2	52.7	20.0	47	[illegible]	47.5	30.0	[illegible]	[illegible]	49.5	16
17	Clay	74.0	62.8	[illegible]	60.5	30.1	49.5	27.5	45	20.9	46.1	[illegible]	[illegible]	[illegible]	48.4	17
18	"	73.3	[illegible]	[illegible]	55.7	23.3	42.7	23.0	42	27.0	45.8	[illegible]	57.2	26.1	48.0	18
19	"	77.0	44.4	[illegible]	55.7	22.0	45.4	21.1	41	25.8	45.2	[illegible]	56.2	22.7	47.0	19
20	"	74.5	52.2	24.5	46.9	21.7	41.5	21.0	40	21.8	41.7	[illegible]	47.1	24.2	46.5	20
21	"	76.0	[illegible]	19.3	38.6	18.9	[illegible]	20.0	40	21.6	41.2	[illegible]	[illegible]	22.0	44.0	21
22	"	76.5	49.6	17.6	35.5	19.4	[illegible]	20.0	40	20.4	41.1	[illegible]	[illegible]	21.6	43.5	22
23	"	75.8	51.1	17.3	33.6	20.3	[illegible]	21.0	40	20.9	41.0	[illegible]	[illegible]	21.8	42.2	23
24	"	78.0	45.1	14.4	31.9	15.5	[illegible]	17.5	38	[illegible]	38.6	[illegible]	[illegible]	19.0	42.2	24
25	"	78.4	41.1	[illegible]	27.5	12.3	29.9	13.8	33	12.8	31.1	[illegible]	[illegible]	17.1	41.8	25
26	"	76.0	45.1	15.6	34.5	13.8	[illegible]	14.5	32	14.6	32.4	[illegible]	[illegible]	[illegible]	41.5	26
27	"	75.2	47.0	19.0	40.4	16.8	[illegible]	16.9	35	17.0	36.1	[illegible]	[illegible]	19.6	41.4	27
28	"	75.0	44.6	22.1	49.5	16.8	[illegible]	20.0	42	20.0	44.8	[illegible]	[illegible]	[illegible]	49.3	28
29	"	73.2	45.0	23.4	52.0	19.7	43.7	21.0	46	21.0	46.6	[illegible]	[illegible]	[illegible]	52.9	29
30	"	75.8	45.4	25.2	55.5	22.3	[illegible]	22.5	49.5	22.1	48.9	[illegible]	[illegible]	24.1	53.0	30
31	"	74.0	45.2	26.2	57.9	25.1	[illegible]	25.1	55.2	25.0	55.3	[illegible]	55.7	25.0	55.3	31
32	Sand and gravel	81.5	[illegible]	[illegible]	65.6	23.5	[illegible]	28.3	63.0	22.3	62.7	23.4	[illegible]	23.0	62.9	32
33	" "	79.0	[illegible]	[illegible]	74.4	28.5	[illegible]	28.4	69.1	28.0	68.1	28.4	[illegible]	28.0	68.1	33
34	" "	80.0	40.0	[illegible]	88.0	....	....	....	....	....	....	....	....	....	....	34

Conditions found April 12, 1899.

Since the capacity of a soil to hold water depends upon its fineness, the maximum water capacity will, other things being equal, vary inversely as with the size of the soil particles. Also, the coarser a soil, the heavier a given dry quantity of it is, as a rule. Hence, as is to be expected, it will be observed that the maximum water capacity percentages vary inversely as the weights per cubic foot, in most cases. For example, the foot composed of the coarsest matter—the seventh—was the heaviest, and was capable of holding the least water; while the higher percentages of water capacity are found in the soils that are the lightest when dry.

That the ability of a soil to retain water depends upon its fineness also, is well illustrated by the determinations given in Table I. During even the two weeks intervening between the last irrigation of the winter, in 1899, and the taking of the samples March 12th, the gravel had evidently lost a much greater percentage of the water it was capable of holding than the finer soil above and below it. The absence of water in gravel lying next to fine clay is especially noticeable. In the case of the stratum of gravel between the 14th and 16th foot, the degree of saturation was very different from that of the strata on either side, causing the turns in the moisture lines in Figs. 7 and 8, as will be seen, to be very abrupt. It would seem that the finer soils acted like a sponge in absorbing the moisture from the coarser ones. The determinations given could not be explained on the ground of percolation alone, for if only the latter were taking place, in the samples taken March 12th, the gravel just above the clayey 14th foot for example, would be moister than that farther above.

When the fine soil below the 15th foot is reached the changes in moisture from foot to foot are more gradual and regular. The clay just below the stratum of gravel was very wet at the time of taking the first set of samples, April 12th, 1899, due evidently to the fact that it had received water from the gravel above more

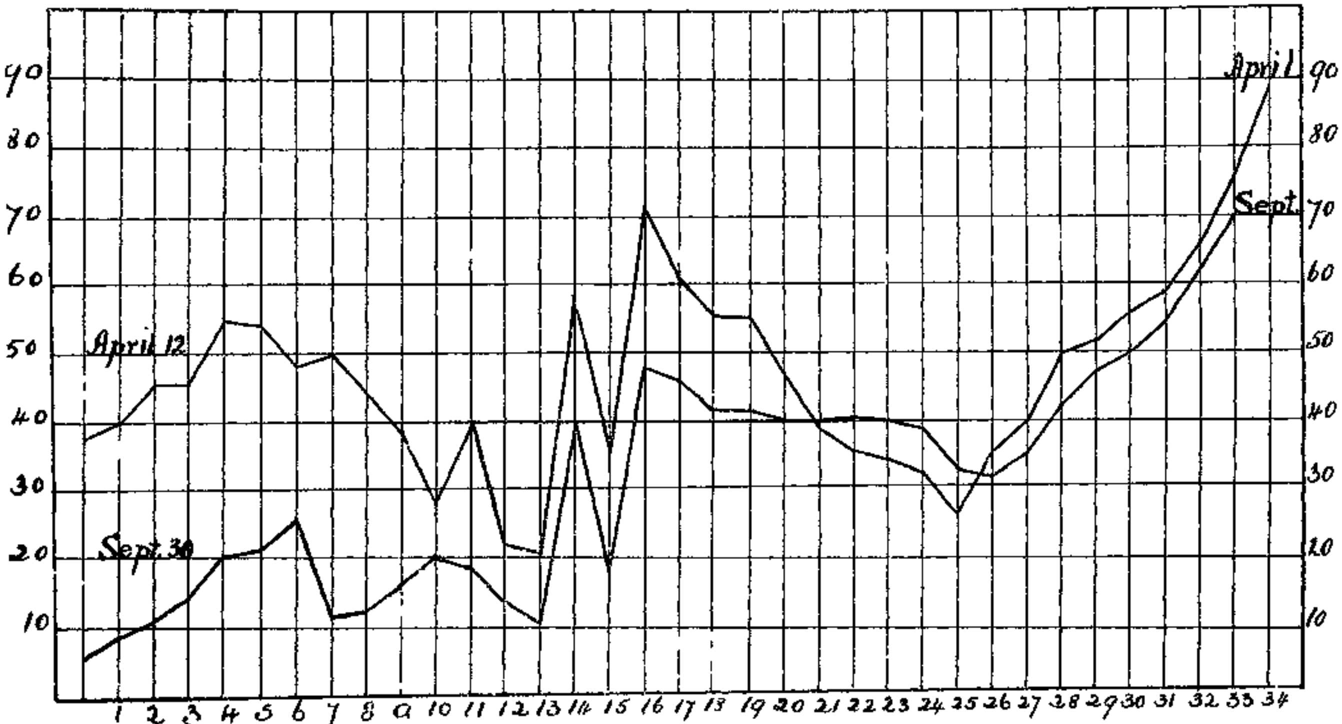


Fig. 7. Diagram showing moisture content of soil in the winter-irrigated orchard, at the beginning and at end of summer of 1899 Numbers at sides express percentages of saturation, and those at the bottom give the depth of the respective feet.

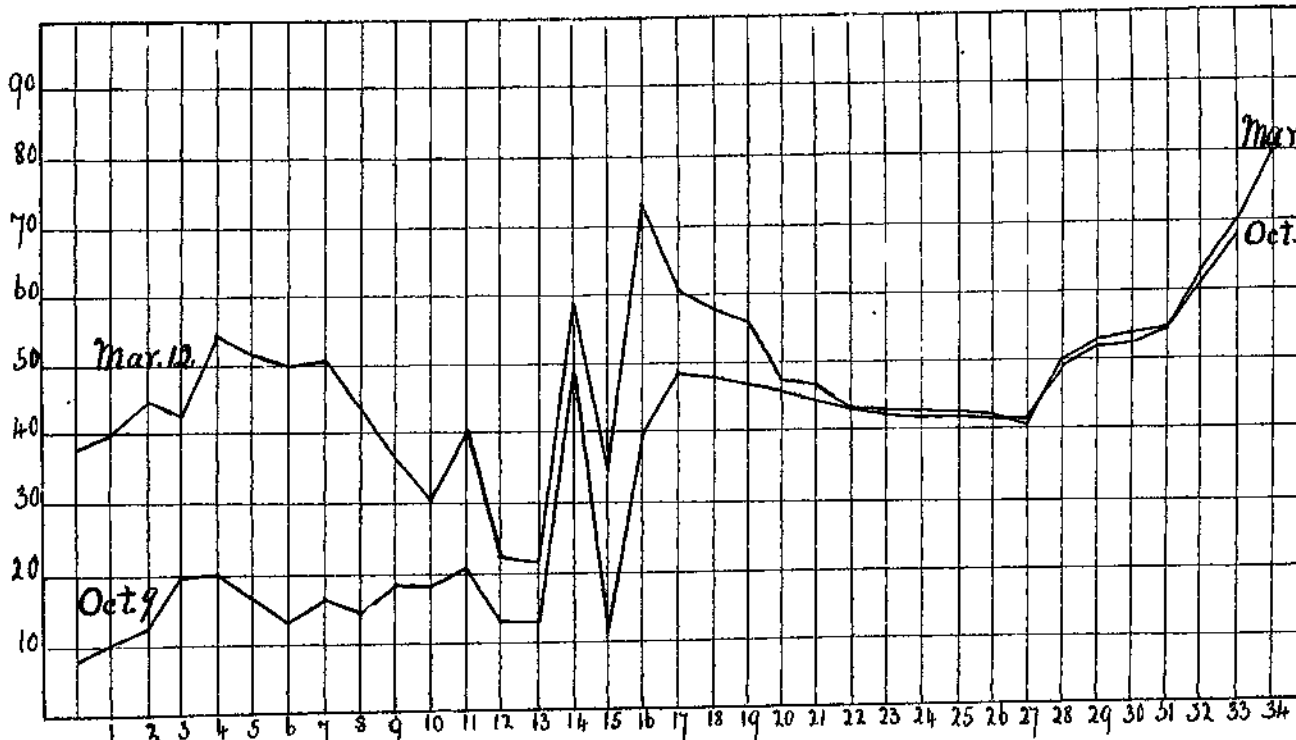


Fig 8 Diagram showing moisture content of soil in orchard irrigated only during winter, at beginning and at end of summer of 1900 Side numbers give percentages of saturation, and those at the bottom the depth.

rapidly than it could percolate downward. From the 16th to the 25th foot the percentage of moisture gradually decreased. The fact that the 25th foot contained the least water of any foot of the clay soil indicates that the soil down to just above that region had been reached by the irrigating water, the latter having percolated through the gravel into the first eight feet of clay.

Below the 25th foot the moisture content was apparently affected by the ground water nine feet below. It will be observed that the increase in the degree of saturation is quite gradual, however, and that in passing downward wet soil is not encountered suddenly, as is commonly supposed. The increase in wetness is, to be sure, more marked in the last three feet above ground water. The degree of saturation of the 34th foot is given as 88 per cent. This, it will be understood, applies to the mixed sample of soil taken from between a plane tying 33 feet below the surface, and a plane lying 34 feet below. At 34 feet from the surface the soil was saturated with water, and the degree of saturation would be expressed by 100 per cent. The regularity of the changes in the degree of saturation compared with the changes in the actual moisture content, in passing downward, is quite noticeable, illustrating the importance of determining the former, in making soil investigations.

Table of Losses and Gains.

For the purpose of showing the loss or gain in the moisture content of the respective feet, and the total loss from the orchard, Table II was computed from Table I. As it seemed evident that only or principally the tipper 25 feet were affected by surface operations and conditions, the computations are given for only that depth. The percentages given in Table II are the differences between corresponding percentages of moisture for the two dates being compared; and the pounds are the products of the respective weights per cubic foot and the above differences.

TABLE II.

Losses and gains in the moisture content of each of the upper 25 feet, between dates of taking soil samples, from April, 1899, to April, 1901:

Number of foot	April 12 to June 18. Loss per cubic foot %	ft	Jun. 18 to Sept. 10. Loss per cubic foot %	ft	April 12 to Dec. 10. Loss per cubic foot %	ft	Dec. 10 to March 12. Gain per cubic foot %	ft	March 12 to Oct. 9. Loss per cubic foot %	ft	Oct. 9 to April 12. Gain per cubic foot %	ft	Number of foot
1	10.9	8.0	1.0	0.7	11.9	9.1	11 8	9 0	11,0	8.4	8 4	6 4	1
2	11.3	8 7	2 3	1.8	UJ.fi	10.6	13 0	10 2	12 0	9.4	14 7	11 0	2
3	9 0	6.9	2.8	2 2	12.9	10.0	12 0	9 3	9 2	7 1	10 S	8 3	3
4	10.1	7.3	2 6	1.8	13 1	9.6	13 0	9 5	12.6	9 1	10 5	7 8	4
5	9.0	6.7	2.8	2 1	12 5	9.4	12 5	9 4	13 2	10 0	11 7	8.8	5
6	3.5	2.9	1 2	0 9	7 3	6 0	7.6	6.3	7 2	5 9	7 2	5 9	6
7	4.7	5 2	0.1	0.1	4 8	5.3	4 9	5 i	4 4	4 9	4 4	4 9	7
8	5.4	5.3	0.4	0 4	5.9	5.7	6.0	5 8	5 7	5 5	5 7	5 5	8
9	4.0	3 8	0 2	0 2	4.6	4.4	4 5	4 3	3 7	3 5	3.7	H 5	9
10	1.1	1 1	0.1	0.1	2.3	2.2	2 8	2 7	2 1	2 0	2 1	2 0	10
11	3 4	3.3	0 1	0.1	3.8	3.9	4.0	3,9	3.4	3 3	3 4	3 3	11
12	1.7	1.7	0.0	0.0	1 9	1 9	2.2	2 2	2.0	2 0	2 0	2 0	12
13	2.0	2 0	0.1	0 1	1 9	1.9	2 2	2 2	2 0	2.0	2.0	2 0	13
14	1 3	1 1	1 0	0 9	3.3	2.9	3 6	3.2	2 6	2 2	2 8	2 4	14
15	3.5	3 4	0 9	0.8	5 5	5.3	5 5	0.8	5 6	5 4	5 8	5 6	15
16	7 9	6 4	2 2	1.7	10 1	8 0	10 0	8 8	9.2	9 3	11.3	9 8	16
17	6 7	4 9	2.6	2 0	8 9	6.6	9.1	6 8	7 8	5 8	6 2	4 6	17
18	4 1	3 0	3 3	2.5	5 4	4 0	5.8	4 5	5 1	3 7	7.4	5 5	18
19	4 8	3 7	1.4	1.2	5.0	S 9	6.0	4 7	4.5	3.5	3 5	2.8	19
20	2.8	2.1	0 7	0 5	2.7	2 0	2.8	2 1	0.4	0 3	0.8	0 tt	20
	Total loss	87.5	Total loss	20 1	Total loss	112.8							
	Gain per cubic foot		Gain per cubic foot		Gain per cubic foot								
21	0.0	0.5	0 1	0 1	1.3	1.0	2.5	1.9	1.3	1 0	2.0	1 5	21
22	1.8	1.3	0.6	0 4	2 8	2 1	1.4	1.0	2.0	1.5	1 3	1.0	22
23	3 0	2 1	0.0	0 0	3.6	2.7	1 2	0.9	0 5	0.4	1.8	1.0	23
24	1 1	0.9	2 0	1.8	3.1	2 4	2.0	1.8	0.5	0.4	1 0	0.9	24
25	1 0	0.8	1.5	1.2	1 5	1.2	4.7	3 8	0 4	0.3	0 8	0.9	25
	Total gain	5.6	Total gain	3.5	Total gain	9.4							
	Net loss	81.9	Net loss	16.6	Net loss	103.4	Total gain	125.0	Total loss	108.8	Total gain	108.4	

Changes from April 12 to June 18.

The set of samples taken June 18, 1899, showed that marked changes had taken place in the moisture content of the respective feet of the different soil strata. The greatest change was in the upper five feet, this part of the soil having lost over half of the water it contained April 12. This great change was due, evidently, to several factors—evaporation, percolation, and the use of water by the trees. The stratum above the gravel is the only one that could lose water by capillary action and evaporation. There was probably no great amount of percolation from this stratum after taking the first set of samples, April 12, as two weeks had already intervened since irrigation ceased. The greatest loss of water was undoubtedly from its use by the trees, as the surface mulch was intended to, and probably did, prevent the rapid loss of water from below the first foot. The four feet lying between the first and the sixth foot contain a much larger number of roots and rootlets than any stratum below, and the withdrawal of water by the trees would be much more rapid from this stratum than from any other. Furthermore, the trees made nearly all their growth between April 12th and June 18th. Hence it is not surprising that during this period the upper five feet lost over half the water contained upon the former date.

The next greatest change occurred in the upper two feet of the clay below the gravel, the water that had been received from the gravel above more rapidly than it could percolate downward, having had time to settle. Where part of it went will be indicated by a reference to the tables and to Fig. 7, which show that between the 20th and the 26th foot the moisture content actually increased during the summer. By Table II it will be seen that the net loss of water from each column of 25 feet, from April 12 to June 18, was approximately 82 pounds—equal to a layer of water a little over 15 inches deep. Of this amount the upper five feet lost over 50 pounds, or nearly two-thirds of the total.

Changes from June to September.

During the three and one-third months that intervened between the taking of the samples June 18 and September 30, the loss of water was comparatively—at first thought surprisingly—small. The total loss from the 25 feet was but a little over a fifth of what it was during the previous two and one-fifth months, or an equivalent of only about three inches in depth. The irrigating water applied June 24 did not affect the above results, as only three-fifths of the orchard was irrigated at that date, and the samples were taken from the unirrigated portion. Neither could the 4.76 inches of rain that fell in the interval affect the moisture content below the upper six inches, as it fell in twelve different showers, less than an inch falling during any one day. The only effect of these summer showers upon the soil, in the vicinity of Phoenix, is to wet a few inches of the surface that dries out within a few hours or days. There is thus formed a crust that not only promotes capillary action and the consequent loss of water that was already present, but excludes air from the subsoil. Even the part of the orchard irrigated received little benefit from the water applied, as the soil was wet to a depth of only about 15 to 18 inches, and was as dry as before irrigation within three weeks thereafter.

When Trees Use the Most Water,

The great comparative loss of water during the months of spring and early summer indicate that this is the period when orchard trees naturally use, and consequently need, the major part of their water supply. During this period of rapid growth, therefore, water should be available in abundance. But by reference to the data given in the introduction, it will be seen that during this period the supply of irrigating water is usually low. The above facts, disclosed by the moisture determinations, emphasize very strongly the importance of filling the subsoil with water during the winter, when the supply is comparatively abundant.

Losses of Water During Entire Season.

From September 30 to December 10 there was little change in the moisture content, the total loss from the 25-foot column of soil being but about five pounds. As the trees remained in excellent condition until they shed their leaves in November, all the water they needed was evidently available. The total loss during the season equaled a depth of about 20 inches of water over the orchard, of which about 80 per cent was lost during the first three months, about 16 per cent the next three months, and only about 4 per cent the last three months.

It seems to be a warrantable conclusion from the facts discussed above that the loss of water from the leaves of orchard trees is comparatively light after the trees have made their growth, the amount exhaled (and consequently the amount needed) gradually diminishing as the summer season advances. As indicated by the investigation of underground conditions (mentioned on page 219) deciduous orchard trees in our climate begin using water early in February. From this date until about the end of June the amount used evidently gradually increases, and after the latter date evidently gradually diminishes. These facts indicate plainly that much of the water should be applied as soon after the first of January as possible.

Effects of Changes in Level of Ground Water.

It will be observed by referring to Table I that during the summer of 1899 the stratum below the 25th foot lost considerable moisture, notwithstanding the fact that the 5-foot stratum above gained moisture during the same period. This was evidently due to the lowering of the level of the ground water, as the water in all of the wells of the region fell during this season. The comparatively light rainfall both in the valleys and in the mountains during the preceding one and one-half years was undoubtedly the cause of this fall in the level of the ground water. On account of the coarse gravel encountered in the 34th foot, it was impracticable to bore to ground water after June, 1899. But if this could have been done, it would probably have been ascertained that at the same distance from the water level the conditions would have been practically the same at the end of the season as at the beginning, the water of the stratum above having simply settled and adjusted itself to the changing position of the ground water. During the winter of 1899–0 the lower eight feet gained a little in moisture as the water level raised slightly, and lost a little again during the succeeding summer, as the war

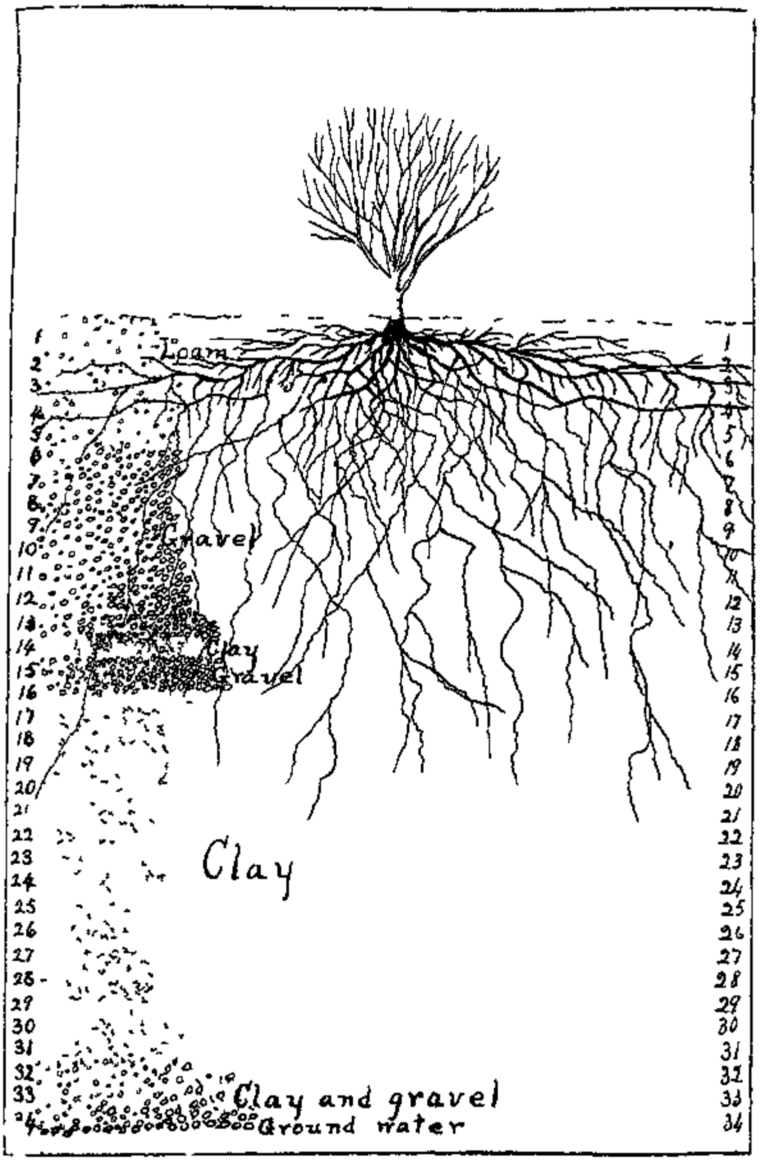


Fig 9 Showing diagramatically the different soil strata from the surface to ground water in the winter irrigated orchard and the root system of one of the trees
Scale one inch to eight feet

ter level fell. Thus, it seems that the upper stratum to a depth of about 25 feet was influenced by above-ground operations and conditions, while the soil below was influenced only or principally by the changes in the ground water level. Investigations after the heavier precipitation of the past winter will throw additional light on this subject.

Gain in Water During Winter 1899–1900.

During the winter of 1899-1900 each 25-foot column gained 125 pounds, or an equivalent of two feet of water. The gain being greater than the loss during the preceding summer, the soil at the end of the irrigating season, March 12th, was moister than at the same time the previous spring. This gain is one foot less than the depth given on a preceding page as to the amount applied. This does not mean that a foot of the water applied was lost by evaporation and percolation during the winter. For it is to be remembered that it was ascertained during the winter of 1899 that the growth of rootlets begins early in February. The production of these rootlets, the rise of sap in the tree, the swelling of the flower and leaf buds, and the putting forth of bloom and early leaves (as had some of these trees when the samples were taken) all mean the withdrawal of water from the soil.

Loss of Water During Summer of 1900.

It will be observed that the total loss of moisture between March 9th and October 8th was a little greater than that given for the previous summer. This was undoubtedly due to the fact that the samples were taken earlier in the growing season than they were the previous spring. Experiments were planned and inaugurated during the spring of 1900 to ascertain how much of the total loss of moisture would be due to withdrawal by the trees, and how much would escape directly from the soil. But it developed that the methods pursued were not adequate. As has been stated, one space between four trees was covered with an air-tight sheet of metal bordered with four-inch strips that were sunk into the soil. The purpose of this was to prevent the escape of moisture directly from the soil in that section. It happened also, that a few of the trees near the center of the orchard had died when young, leaving a vacant space for the center of which it was thought no moisture would be withdrawn by the trees.

When the samples were taken from the covered area October 9th it proved, as has been stated previously, that the surrounding trees had put out additional rootlets and caused all the soil, with the exception of a few surface inches, to be as dry as that of the adjacent uncovered area. While the soil samples from the vacant space showed the presence of considerably more moisture than in the part occupied by trees, a little reflection resulted in the conclusion that no definite calculations could be based on the results, as it was not known during what part of the summer am particular portion of the losses occurred, in either section. It seemed evident that the comparative losses should have been determined, from week to week, since moisture that trees (had they been present) might have withdrawn from the upper five or six feet early in the season, would be lost from the vacant area, by capillary action and evaporation, during a later part of the summer. Samples should have been taken also from the covered area at least once a month, in order to determine the comparative changes that were occurring. It is hoped that experiments now under way in this orchard will bring results that will throw some light at least upon this problem as to how much water orchard trees use under the conditions existing in the vicinity of Phoenix.

Moisture Content Changes of 1899 Compared with those of 1900.

By reference to Tables I and II, and to Figs. 8 and 9, it will be seen that each foot of the 25-foot column lost moisture during the summer of 1900, instead of the stratum between the 20th and the 26th foot, gaining, as was the case the previous year. As Fig. 8 shows diagrammatically, the decrease in moisture content was quite regular from the 16th to the 26th foot. This difference between what occurred during the summer of 1899 and what occurred during the summer of 1900 was undoubtedly due to the fact that the comparatively dry stratum encountered between the 20th and the 26th foot, April 1899, had become about as moist as it could remain. In other words, this stratum was, at the beginning of the summer of 1900, so moist that it could retain no additional water permanently. Its degree of saturation was about the same as that of the surface stratum of loam. If any water escaped the tree roots of the 16th, 17th, 18th and 19th feet (where the soil was so moist at the beginning of the season) and percolated downwards, it had evidently passed on through this formerly dry stratum into the soil below. Continued heavy irrigation of this orchard during the winter may finally so fill all the soil with moisture from the 15th foot to ground water that at the end of succeeding summers the increase in the degree of saturation will be regular from the 15th foot downward. The line on a diagram representing this condition would then be an inclined one, approximately, straight, instead of curved or angular as are the lines representing the past conditions.

Amount of Water Needed by an Orchard.

The set of samples taken April 12, 1901, showed that (as will be seen by referring to Table II) the gain during the past winter was just about the same as the loss during the previous summer—between 108 and 109 pounds per 25-foot column, or an equivalent of approximately 21 inches of water over the orchard. This evidently indicates about how much water should be left deposited, henceforth, at the end of each winter, in this underground bank, that the individuals depending upon the deposit for a living may not suffer during the summer.

The difference between the amount applied during the winter (48 inches) and the gain in soil moisture (21 inches) represents the evaporation from the soil, the amount used and exhaled by the trees, and the amount used and exhaled by the clover grown in the orchard for a green-manuring crop. The latter, judging by the amount needed to grow similar crops during the winter, probably withdrew from the soil fully 20 inches of water. The amount lost by evaporation from the soil surface was probably slight, as the soil was covered with the growth of clover most of the period.

The above amount (four feet) probably represents quite accurately the amount that need be applied to deciduous orchards in the warm valleys of southern Arizona to grow a heavy green-manuring crop, and at the same time store enough water in the soil to carry the orchard through the hottest and dryest summers. Judging by observations, and by consultation with orchardists, this amount is frequently applied during the summer to maintain the orchard alone, with no better results than were secured last summer by winter irrigation alone.

SUMMARY AND CONCLUSIONS.

1. Fruits can be grown in the valleys of southern Arizona only by irrigation, the supply of water for which coming from the higher elevations where precipitation is much heavier.

2. The heaviest rainfall is during mid-summer, but the largest supply of irrigating water is during the winter, the supply during the latter period being over three times what it is during the former.

3. The general practice previous to beginning the experiments was to irrigate orchards once or twice a month, from February or March until October, the belief being quite general that under the trying summer conditions of the region winter irrigation was of little value, or at least entirely inadequate.

4. The purpose of the experiments was to determine how much summer irrigation might be rendered unnecessary by the liberal application of water during winter when the supply was comparatively abundant.

5. During the first year of the experiment the orchard was irrigated eight times from January 9 to March 30, 1899, followed by thorough plowing and summer cultivation. The only water applied during the summer was a small amount to three-fifths of the orchard June 24.

6. The climatic conditions of the growing season of 1899 were somewhat more unfavorable than usual, the rainfall being about normal, the relative humidity some below normal, and the temperature above normal.

7. The orchard remained in excellent condition throughout the summer of 1899, making a vigorous growth and bearing a heavy crop of fruit of superior quality.

8. During the second year of the experiment the orchard received three feet of water from December 16 to March 5, 1900. Following the irrigation, the orchard was plowed about a foot deep; by thorough cultivation, a mulch of 6 to 8 inches of loose soil was maintained throughout the summer.

9. The weather of the eight months following March 5, 1900, during which the orchard received no water, was very trying upon all vegetation, the rainfall being considerably below the average, the relative humidity below (part of the time very much below) the normal, and the temperature above the normal.

10. The condition of the orchard at the end of this trying season of 1900 was most excellent, the trees having made a vigorous growth, and at no time having shown the effects of the drought.

11. During the third year of the experiment a green-manuring crop of clover was grown in the experimental orchard (as had been done in the other orchards of the farm for two previous years), and four feet of water applied from November 6 to March 29. A heavy crop of clover was turned under April 6, 1901.

12. The excellent condition of the winter-irrigated and summer-cultivated orchard at the end of trying seasons was due to the fact that by this treatment a maximum amount of the irrigating water is stored in the soil and returns through the trees, due to the more abundant supply of water during winter, to comparatively slow evaporation while the water is being applied, and to efficacy of the surface earth-mulch that can be maintained throughout the summer,

13. The water of summer irrigations, upon account of the insufficient supply and rapid evaporation, does not ordinarily reach deep-seated roots and return through the trees, but irrigations cause a baking of the surface and a growth of weeds that make extra cultivation necessary.

14. The surface earth-mulch (which can be secured only by cultivation) conserves the moisture stored in soil by checking capillary action, and by preventing evaporation from all the soil except the mulch itself; and it also permits air to enter the subsoil freely.

15. The results of the underground investigations illustrated, among other things, the superior ability of fine soils to absorb and retain moisture, and the inability of coarse soils lying next to fine soil to long retain much water.

16. The moisture content of the upper 25 feet of soil was effected appreciably by above-ground operations and local climatic conditions.

17. The ground water evidently affects the moisture content of clay eight or ten feet above it, the per cent of water in the respective feet of that stratum decreasing as the water level falls, and increasing as the water level rises.

18. Growth of rootlets begins on deciduous trees, in our climate, about a month before there are indications of growth above-ground.

19. The set of samples taken June, 1899, showed that about 15 inches of water had been lost from the upper 25 feet (of which the upper five feet lost about eight inches), and that from the 16th and 17th feet considerable water had percolated into the drier soil below.

20. From June 18 to September 30 there was a loss of but a little over three inches of water from the upper 25 feet, of which the upper five feet lost a little over two inches.

21. The total loss of water from the upper 25 feet, during the spring, summer and autumn of 1899 was about 20 inches, of which about 80 per cent was lost the first three months, about 16 per cent the next three, and only about 4 per cent the last three months.

22. Deciduous orchards use and need the major part of the water supply during spring and early summer, which need can best be supplied in most of southern Arizona by filling the subsoil with water during winter.

23. The amount of water needed by a deciduous orchard to keep it in good condition in southern Arizona from March to November is about 21 inches, which can be stored in the soil by the application of about three feet during winter.

24. The amount that need be applied to grow a green-manuring crop and store enough water in the soil to carry a deciduous orchard through the summer is about four feet.

25. Deep winter irrigation followed by thorough summer cultivation is better for deciduous orchards in southern Arizona than the frequent application of small amounts of water during the growing" season.