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CITRUS CULTURAL METHODS IN SOUTHERN CALIFORNIA

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Citrus fruits

Fruit-culture—California

"CITRUS CULTURAL METHODS IN SOUTHERN CALIFORNIA"

By

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CITRUS CULTURAL METHODS IN SOUTHERN CALIFORNIA

INTRODUCTION

It is proposed to give some facts and figures in this thesis concerning the growing of citrus crops in Southern California. The Corona and Riverside districts will be most in evidence as the writer has had more personal experience there. Other colonies to which reference may be made or at any rate where observations were taken are: San Bernardino, Rialto, Redlands, Uplands, Pomona, LaVerne, Whittier, Santa Paula, Sespe, Orange, Santa Anna, Anaheim and Villa Park.

More particular attention will be paid to the use of water and fertilizers on a ranch at Corona, California, known as "The Chase Plantation". A system of irrigation using permanent basins and one using furrows will be treated. The use of fertilizers in basins and buried in furrows will also be discussed. Before entering upon this, however, a few words on general conditions prevailing in that section will not be amiss.

GENERAL CONDITIONS: FRUIT GROWN

The citrus fruits grown are Navel and Valencia oranges, together with a small acreage of St. Michaels, Mediterranean Sweets, Bloods, and Seedling Sweets; Eureka and Lisbon lemons; Marsh grapefruit and some Tangerines. A table appended shows that in California the acreage of citrus crops has increased from 84,997 in 1904 to 214,651 in 1915 and the production ffom 23,729 cars in 1902-03 to approximately 40,000 cars in 1915, which, however, is not the high-water-mark in production.

The Navel orange has been grown in California since the first importation of two trees in 1873. It is a native of Brazil. In 1916 California shipped approximately 22,500 cars of this delicious seedless fruit. *

The Valencia orange came into California from various sources about 1876, and is no doubt a native of the Mediterranean countries. It produces about 8,500 carloads per year.

The Marsh grapefruit is a variety introduced from Florida about 1890.# The annual production is about 300 cars but promises to become much more.

Other varieties of oranges mentioned above may total close to 1,500 cars annually. The acreage of sweet seedlings is becoming less.

In 1917 -18 California shipped 5,823 carloads of lemons which was 71% of a crop.** The varieties were mostly Eurekas and Lisbons with a limited number of Villa Francas.

The Navel orange blossoms in April and the fruit is mature enough to begin harvesting about January 1st. The fruit hangs well and pickings are often continued until June. Valencias blossom about the same time as Navels or a little later and are ready to pick by the next June, the harvesting continuing until as late as November 1st. Grapefruit is picked beginning in May or June. It is not of good quality much before June. Lemons are blossoming throughout the year.

* U. S. D. A. Bul. #623 - A. D. Shamel; U.S.D.A. Bul. #624.
\# U. S. D. A. Bul. #697 - A.D. Shamel.
** Report of California Fruit Exchange, 1918.

There are periods, however, of heavy blooming. The heaviest picking is done during late winter and early spring. This is more true of the Lisbon variety than of the Eureka, which can be induced to produce summer lemons to quite an extent. Lemons are of the best keeping quality when grown to full size while still green then picked and cured to the well known bright yellow in special curing rooms. It is desired to keep a crew continuously picking lemons going over the trees every four or six weeks and cutting off all fruits which come up to a designated size regardless of color.

This, in a brief way, mentions the principal citrus fruits and their season. It will be noted that the fact that oranges will hang so well after ripening and that lemons are a year-round crop makes the growing of citrus quite dependable and stable so far as a long marketing season can influence to that end.

CLIMATIC AND SOIL CONDITIONS

Climate varies in southern California very much according to location, altitude,distance from the ocean, winds, etc. Up on the mountain slopes there may be apples and cherries, and down just below the foothills orange groves; perhaps further out in the valley, peaches and apricots; and finally grain ranches. The interior valleys have a hotter, drier climate than sections close to the sea, hence, the oranges in some of the central valleys ripen before they do in other places much farther south. It is a semi-arid country and has the attendant characteristic of hot days and succeeding nights of considerable coolness. This great variation from day to night causes the

feeling of suffering from cold after sundown although in reality a long way from freezing. There is much frost hazard, however, from about December 1st until March 1st and sometimes even outside these dates. The citrus fruits can stand about 28° without much injury unless of long duration; below that causes loss of fruit. Lemons are more susceptible than oranges. Many groves are completely equipped with smudge pots, reservoirs, and tanks to fight the frost hazard. Some ranches have been known to light the pots as many as forty times during the winter. The higher groves are the least affected, of course, by the ordinary cold night. At times of severe cold accompanied by high winds the higher altitudes do not protect.

During the winter of 1912-13 the temperature went down to below 20° F, and during June 1917 it went up to 117° F. in the shade. These figures are given to show the possible extremes. The picture of a record page showing climatic variations is interesting as a chronicle of actual climate at Corona for one year.

Rainfall varies from year to year; sometimes being only 7 or 8 inches and sometimes up to 15 inches or more. The precipitation may occur over a period from November 1st to May 1st. It not uncommonly is heaviest in some one or two months of that period.

Humidity in the Corona and Riverside districts is variable to a great degree. Records kept with a hydrograph and regularly checked with a sling pyschrometer show amazing fluctuation. During a twenty-four hour period the relative humidity sometimes varies from 100% to below 20%. When these

low periods are in connection with high wind velocity the moisture lost is very great. The high winds are erratic. They usually bring much dust from the desert regions but are not "northers" in the sense of being very cold.

Soil varies much in the citrus district. There are sandy sections and others of black adobe. Some are like brown loam and at Redlands the soil, as the name indicates, is quite reddish. At Corona the groves are planted on a gently sloping "mesa" land of decomposed porphory rock coming from the Santa Anna mountains on the south and extending for some miles toward the Santa Anna River. The soil is made up of strata of adobe and gravel. Consequently there are streaks of almost impervious soil and streaks of coarse material which allows water to seep away with ease. The adobe contains gravel stones with square edges and corners. It cuts steel tilling-tools and machinery out very quickly.

Remember that this being a semi-arid country and originally covered with sage brush and other shrubs of like nature no accumulation of humus was ever present. Hence, after many years of farming with grain crops and selling these crops off the land, it becomes very poor indeed; at least it is very devoid of vegetable matter and nitrogen. Now recall also that on such soil groves of oranges and lemons were planted and carried along for years with clean cultivation both summer and winter. Could there be much left as a soil except a mineral mass of poor physical texture for plant growth?

With this incomplete discussion of conditions, the next step will be to describe the operations and equipment used in obtaining information given in the following pages.

Much of the work done as a regular ranch operation was in cooperation with the Bureau of Plant Industry, Office of Bio-Physical investigations.

-- STUDY METHODS --

IRRIGATION

The problem was how much and how to apply water to citrus trees during the dry season. The usual method is to run the water down furrows between the trees. Most of the studies made, however, were with a permanent basin around the tree into which water of varying amounts could be run. These basins varied in size, shape, and nearness to tree trunk in different parts of the grove.

The fitst year's work was done by the U. S. Department of Agriculture, who stationed a man (Mr. J. W. McLane) of the Office of Bio-Physical Investigations, to take charge. It seemed so vital an undertaking that a laboratory was established and the work made a regular ranch operation for the next two years. Beginning with the second year the proceedure was as follows:

Climate: A hydrograph and thermograph were used to record humidity and temperature respectively. These were furnished by the Office of Horticultural Investigations, A. D. Shamel in charge. The wind velocity was secured by a wind meter which gave the total velocity over any period. It was read each twenty-four hours. A rain guage was used to secure daily rainfall.

Moisture Testing: Samples of soil were taken with a soil tube to depth of four feet. During a part of the time the foot samples were determined separately. Two borings were secured at each tree selected and from two to four were sampled on each plot before and after every irrigation. Samples were taken also at regular intervals during the rainy season. The soil borings were put into numbered tin cans and records made on cards for the purpose. The soil was then weighed very accurately on balances and record made on same card. After drying for 24 hours at 220°F in an automatic electric oven, it was again weighed and record made. The loss, of course, was moisture, and the percent was figured using the dry sample as the basis. The average of the two samples at one tree was given as that tree's soil moisture and the average of all trees tested in a plot was the soil moisture for that particular plot.

The figures thus secured were entered from the cards on a large sheet of cross-section paper having space for all the thirty-seven plots. Dates were always shown. From this sheet the data was transferred into a large book of cross-section paper having a leaf for each plot and space sufficient for five years record. It was entered in this book in form of graphs. The line was unbroken and the high and low points indicated the moisture content when tested. As the dates throughout the year were across the top, a glance would indicate when such sample was taken as well as length of interval between irrigations. A picture of a page of this book gives some idea of its make-up. On one page of this book each year's record of temperature, relative humidity, rainfall, and wind-velocity was recorded in a graphic or pictorial way. For each plot the office of soil investigations at Riverside make determination of the wilting coefficient and moisture equivalent. These percents were run in as permanent lines on each page representing a plot. The moisture equivalent line was made in green ink and the wilting coefficient as a red line. Those interested in knowing more about these standard determinations are referred to Bulletin No. 230, Bureau of Plant Industry, and Bulletin No. 284, Bureau of Plant Industry.

METHODS WITH FERTILIZERS

To get information on value of various mulches a plot was laid out containing 21 rows of about 50 trees each and four different available materials used as mulch. Detail of plan will be given under review of results.

Ammonium Sulphate was applied to marked rows in varying amounts to determine efficiency. The total soluble nitrates contained in the soil samples taken for moisture studies were determined by the colorimeter method during 1918 to first learn the amount present,and second to learn the movement or loss of nitrate due to any cause as the action of water or the consumption by the trees.

The use of manure in furrows and buried with soil was started in 1918. One example of this had been demonstrated some few years previous by A. D. Shamel of the U. S. Department of Agriculture, and the method was being employed by some other growers.

DISCUSSION OF IRRIGATION RESULTS

The Permanent Basin vs. The Furrow System

Some disadvantages inherent in a system using furrows led to the adoption of the permanent basin plan. Where water is run down a furrow, it must be run slowly to avoid washing, hence the upper end gets water for a longer period with consequent over soaking to a great depth. Frequent cultivation in connection with furrows leads to excessive decomposition of nitrogenous substance and resultant poor thrift of trees.

The basin was expected to remedy this to quite an extent by allowing the requisite amount of water to be added which would keep up a good moisture content down to a depth penetrated by the roots. Also the mulch would do away with most of the cultivation and a humus content be built up.

Temporary basins are not a new thing. They are made each irrigation period and then destroyed by cultivation. To make them a ridging machine is run each way half way between the rows of trees; hence, the entire surface of the soil is flooded when the water is run in.

Permanent basins as made on the proposition under discussion did not cover the entire land surface, but the rows between trees in one direction were open to cultivation or crop growth as desired. Much experimenting was done to find out the size and shape of basin desirable. It is quite imperative to have the bottom of the basin level, and on a grade of approximately 5% ~~and~~ this becomes quite a problem. Most of the work of constructing the basin was done by man labor, using two pronged picks, shovels, and large plantation hoes.

It was assumed that a basin should equal the spread of the tree in diameter at least. A mulch of manure or bean straw from 3" to 6" in depth was always kept to keep the soil from cracking and forming crusts as well as adding plant food.

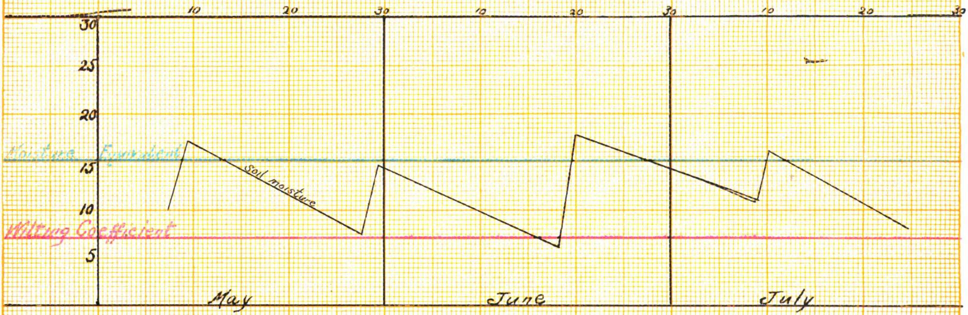
At first portable galvanized pipe was used to run the water to the basins from the head canal. This pipe was carried from row to row across a block. Owing to breakages and high cost of pipe, as well as slowness of operation, this scheme was given up and water run in furrows. From six to fifteen furrows were handled by one irrigator as follows:

Gates were opened in canal and about $1\frac{1}{2}$ to 2 inches of water allowed to run in each furrow. The furrow was opened into each of the first basins in all the rows in question. As soon as the depth required had run in, the entrance was filled with soil and the water proceeded down to the next basin below. Thus the irrigator was kept moving back and forth over the area changing the flow. On an average the water ran into each basin about 15 minutes. The size of basin and amount of water running in the furrow of course governed the length of time, as well as the amount desired in depth in the basin. At the next irrigation water was allowed to run down the entire length of furrow and the operation reversed by irrigating the lower basin first and proceeding up the slope, a series of basins at a time.

A great disadvantage of this basin system with mulch is the fact of inducing a great many mice to congregate there with a consequent girdling of the tree trunks. They tunnel in the soil, making screens and repellent paints useless. A liberal and systematic baiting with poison (strychnine) is of most value.

MOISTURE ANALYSES

The thirty-seven blocks under consideration have an average wilting coefficient of approximately 7%. Some run as low as 5½% and others up to nearly 8%. The variation is not as marked as would be the case in some localities. Poor soils have a lower wilting point than good ones but that does not indicate good growing characteristics. Light soil devoid of humus cannot hold much water against force of gravity or against evaporation. Hence, altho a plant can wrest moisture from such a soil closer to zero point, it does so without good results and with a much narrower margin of available moisture. For example: A good soil may retain 25% of moisture forty-eight hours after irrigating. Its wilting coefficient is perhaps 12%. The difference (13%) is available moisture for plant growth. Some poor soils retain about 14% following like irrigations and although their wilting coefficient is about 7% or less, this leaves as available moisture only about 7%. It is easy to see how much more risky plant growth is under the latter conditions. In Southern California it is common to find hot dry climate with accompaning wind in those sections having the soils of low moisture retaining power.



Block 14 1918

The power of holding moisture in the soils considered in this thesis was approximately 14% in the upper three feet.

What is termed as moisture equivalent in this discussion is the amount of moisture which a soil can retain when subjected to a force one thousand times gravity. This is accomplished by whirling the samples in porous containers in a centrifugal machine. Briggs and McLane worked this out as an empirical factor to be used in determining the wilting coefficient. (See Bulletin #230, Bureau of Plant Industry.) By long and patient experimentation it was found that such a factor divided by 1.84 would give the correct wilting point for any soil. To ascertain this by plant growing trials in every type of soil involves too much time and expense for practical purposes. Also it is obvious that such information is quite necessary in going about an investigation of moisture conditions. To get data that reflects accurately the influence of various treatments of irrigation, we must know the natural possibilities of the soil in question.

FRUIT GROWTH

A bulletin is in process of publication written by C. A. Jensen, Associate Biophysicist, Bureau of Plant Industry, U. S. Department of Agriculture. The title is "Some Relations of Citrus Fruit Growth to Soil Moisture Content, Temperature and Relative Humidity in Southern California, 1917-1918."

The Author is acquainted with much of the data in question as Mr. Jensen and his assistants did part of their investigations on the same ranch involved in the discussions in this thesis. As this bulletin is not yet regularly issued, no data from it can be here used. However, as a regular ranch practice it was attempted to correlate fruit growth with our soil moisture and nitrate content. One lemon or orange on a tree in each row was measured regularly every ten days. The tree was selected by starting at one corner of a block and proceeding across in a diagonal direction to the opposite corner. A fruit on each tree selected was tagged and measured. It was planned to have all fruits of about 1¼ inch in diameter at time of the first measurement. A flexible steel tape was used and results entered as circumference at largest point in millimeters. Record was made by entering on the date of measurement in the graph book a column whose height represented the growth following the previous measurement.

LABOR COSTS

To indicate some results in costs the following figures are given. Considerable explanation would be in order to thoroughly clear up some points, but at any rate these are actual expenditures:

	Power & Water per acre	All other costs Irrigation & cultivation per acre	Labor Costs Irrigation only per ac.	Total inches water used
1913	31.49	29.10	7.82	
1914	32.60	30.84	9.53	36550
1915	28.62	31.12	10.62	35600
1916	27.08	26.09	18.08	29771
1917	18.52	28.02	20.50	39250

NOTES: Part of the ranch was basined in 1915.

Basining was completed during 1916.

Water costs vary from year to year partly due to difference in length of season and partly to inconstant expenses of cooperative water company.

There is no knowledge that the correct amount of water was given the soil during any year, especially before soil tests were made, which work was begun in 1916.

Labor cost for irrigation only, increased heavily with basins and the consequent more frequent applications. The amount of water used fell off in 1916, but increased beyond furrow years in 1917.

IRRIGATION LABOR COSTS

	1914	1915	1916
Jan.	$85.80	$151.40	$233.77
Feb.	128.15	181.05	300.20
Mar.	578.45	693.35	279.20
Apr.	893.63	800.28	832.57
May	709.23	622.70	1258.89
June	714.65	656.99	1923.43
July	849.21	809.59	1881.15
Aug.	766.81	859.67	2239.08
Sept.	659.37	1254.96	1852.47
Oct.	668.82	1090.57	1472.47
Nov.	704.23	417.62	978.57
Dec.	296.25	327.99	588.67
	$7054.60	$7866.17	$13840.47
Inches Water	36550	35600	29771
Cost per inch	19.3¢	22.1¢	46.5¢

IRRIGATION LABOR

	1914	1915	1916	1917
Jan.	85.80	151.40	233.77	598.51
Feb.	128.15	181.05	300.20	951.82
Mar.	578.45	693.35	279.20	2341.24
Apr.	893.63	800.28	832.57	2287.03
May	709.23	622.70	1258.89	1005.49

DIVISION OF IRRIGATION LABOR

	Furrow	Making Connections	Pump attendance	waste & storm	Repairs	Basin Irrigators	Basin Repair
Jan.			24.60		99.80		474.11
Feb.		728.55	48.11	4.20	170.96		
Mar.		1874.04			306.60	149.45	11.15
Apr.		1574.09	3.65		145.75	543.29	20.25
May.	Misc. 75.65				198.05	662.19	69.60

Notes: It can be noted that cost of cultivation decreased, but that cost of labor for irrigation increased heavily with the basin system.

The costs by months indicate the seasons when the most irrigating is performed.

Irrigation Labor includes the following:

A 1 - Irrigation in furrows
A 2 - Making connections
A 3 - Tending pump--work and repairs on motor and pumps.
A44 - Care of waste and storm water
A 5 - Work and repairs on flumes, ditches and canals.
A 6 - Basin irrigators
A 7 - Repairs and care of basins.

1917 was a transition year in system of irrigating and method of doing the work. New Parts of the ranch were being put under the new plan and the scheme of using portable pipe was elaborated upon and finally abandoned.

Irrigators worked night and day, there being two shifts each working twelve hours. Later a reservoir was constructed into which the water was delivered nights and all labor of running water was performed during a ten-hour period of daylight.

CLIMATIC INFLUENCE

The records show when summed up that the loss of moisture from the soil is much more during the summer months. The percent per day loss increases roughly from .2 to .3 percent per day in spring to .5 per cent and more in summer. The increase largely begins in June and remains until cooler weather in October. The relative humidity is largely dependent on temperature of course, but when the humidity is low there is a large loss of water although the absolute moisture may remain about the same. Wind velocity is perhaps the biggest factor in moisture loss. Tests made by Experiment Station in Arizona proved that wind velocity had greatest effect in evaporating water.

SOIL INFLUENCE

Water does not return to surface by capillarity to any great extent when it has passed beyond the feeding zone of the roots. Especially is this true when it hits a stratum of loose gravel. Water in the soils under observation would travel laterally but little. Roughly it passed outward fanwise to the extent of about two feet for every three feet downward. The soil continued to take water readily in the basins even after long use. No crust formed where a good mulch was maintained.

MULCH INFLUENCE

As a moisture conserver, a mulch does not equal good cultivation. It must be six inches in depth to approximate a soil mulch in this particular. The rootlets tend to come to the soil surface under the mulch. A splendid black humus accumulates in basins where the mulch is plentiful. Mulch attracts rodents which tunnel the banks and bottoms of basins causing water loss and uneven penetration.

TREE INFLUENCE

Large trees with loads of fruit naturally use up more moisture. Less water is used by trees where the moisture per cent is kept close to the wilting point. In other words, the power of trees to take up water is greatest when the supply is liberal, (that is, fluctuating about the moisture equivalent).

Trees will show wilt on hot days with a given percent of soil moisture where they would not do so on a cool day with the same moisture content.

DISCUSSION OF FERTILIZER RESULTS

Cover Crops

This ranch was dry land farmed for about forty years. Barley was grown for hay and the crop sold and not fed at home. When purchased as a tract upon which to develop citrus groves no irrigation lines were in, hence, the first step was the installation of canals, flumes, etc.

Some experimenting was done with commercial fertilizers of various sorts, but their use was abandoned and resource taken to cover crops, principally rye and hairy vetch. Some very heavy crops of these were plowed in for several years. The humic content of the soil was not built up by this method. Perhaps it was not carried out in entirely the correct way. Following the serious injury to trees by freezing during the winter of 1912 and 1913, it was found that the trees did not rally in thrift with usual culture. A change was deemed essential and the permanent basin system of irrigation already discussed entered upon. A mulch is imperative in the basins to secure efficiency and it was well known that the soil needed organic nitrogen; therefore, the ways and means of securing this mulch became a vital question. The cost and availability of mulch material being so serious led to the formation of plans to determine the practical value of such stuff as could be obtained.

Before outlining this test, another word in regard to cover crops. The value of cover cropping is not to be denied. However, this appears to be the case in some instances. The long hot season in Southern California is favorable to decomposition of vegetable matter in the soil. Accentuating this also are the alternate periods of wet and dry due to artificial watering and still further influence is lent by the frequent plowing and tilling. Where the cover crop is allowed to become large and woody, then plowed down and tumbled about by harrows, it is decomposed and available about the time trees should be hardening up for winter. By the next spring there is little fiber left.

MULCH TEST PLOT

Damaged alfalfa hay, bean straw, manure, and barley straw being the most available materials, it was decided to pit them, one against the other. To get a line on the value of certain combinations, a few commercial fertilizers were used as illustrated in the plan following. Four years previous individual tree picking records were available to use as a check against results obtained. The mulch was put into round basins 10 ft. in diameter from the inside of the banks.

MULCH TEST PLOT

	Row No.
Alfalfa	1
Bean Straw	2
Manure	3
Barley Straw	4
Alfalfa (buried)	5
Bean Straw (")	6
Manure (")	7
Barley Straw "	8
Alfalfa+6# tankage	9
Bean straw-6# "	10
Manure+6# tankage	11
Barley straw+6# "	12
Alfalfa+Am. Sul.2#	13
Bean straw " "	14
Manure + Am. " "	15
Barley straw " "	16
Alf.+ Am. Sul.2#+Bonemeal 4#	17
Bean Straw+Am.Sul.2#+Bonemeal 4#	18
Manure+Am.Sul.2# + Bonemeal 4#	19
Barley straw+Am.Sul.2# + Bonemeal 4#	20

Amounts Mulch -	Alfalfa, approximately		125# per tree
	Bean Straw	"	125# " "
	Horse Manure	"	20 cu.ft. "
	Barley straw	"	125# per tree

The first year's crop following the application gave no clue as the crop had already formed. The excessive heat in June, 1917, caused the most of the oranges to drop the next year so the appearance of the trees had to be the best guide.

RESULTS

All the rows improved in color,thrift, and size of leaf except the rows mulched with barley straw which not only failed to gain but actually went backward. Of these, those receiving commercial fertilizer appeared in best condition, but at that were in poor thrift. Between the three combinations there was little choice except possibly a little in favor of the Ammonium Sulphate, plus bone meal. As far as the eye could see the barley rows could be picked out by the yellowish color of the leaves. This condition also prevailed on another block mulched exclusively with barley straw as a regular ranch operation. Also similar bad results followed heavy mulching with kaffir corn fodder. So far as eye inspection could go no preference could be given to any of the other mulches over each other, nor to either the buried or unburied mulch. It is to be noted that after the barley straw had mostly decomposed the trees would gain back a better color. Some scientists have advanced the proposition that bacteria which break down materials mostly made up of cellulose are antagonistic to nitrogen forming bacteria, hence the trees cannot get hold of nitrates until these first named bacteria cease to be active. Whether this is the correct solution or not, it at least, answers, according to the behavior of the trees under experiment.

An analysis of the soil in the various basins showed a marked difference in quantity of total soluble nitrates Alfalfa mulch ranked first and barley was considerably the lowest. It is to be regretted that picking records were abandoned on this ranch, and more conclusive checking of the results cannot be had.

MANURE VALUES

Much work has been done in analyzing manure from different animals and also the various straws and feeds. To ascertain in a practical way, however, some fundamental facts on which to base purchase prices of manures many analyses and tests were made. Manure is usually purchased by the ton or car or load. It is often purchased by cubic measure. Some dealers are offering it on a guaranteed percent of plant food constituents. Formerly it was a common practice when selling by the ton to take the hose and add all the water the car would soak up. When selling by cubic content much fluffy, dry material as loose straw, would be mixed in. When scraped from dirt corrals it would contain great quantities of inorganic material as sand and gravel and even good-sized stones. Many cars were sampled by boring down through the manure with a steel tube two inches in diameter and having a corrugated cutting edge. The core thus taken would be thoroughly mixed and a portion taken for analyzing. The percent of water was first ascertained by weighing, drying and reweighing. The inorganic matter was found by weighing the ash after carefully burning out the organic with a blue flame. Some of the dried manure was analyzed for nitrogen.

The following figures give the results found by thus testing a few of these cars. Also values are given on a ton price basis, a cubic foot basis and by the Dr. I. G. McBeth formula, which at current market prices was $4.00 per unit for nitrogen and 5¢ per unit for organic matter. Note the erratic variations.

- - TABLE OF ANALYSES AND FIGURES - -

Car No.	Car Weight	Cu. Ft.	Moisture	Wt. Dry Matter.	Organic	Nitrogen	Value McBeth Ton	Value Formula Car	Cost 5½¢ cu.ft	Cost $3.50 Ton wet
81338	70800	1739	25%	56640	25%	.42%	2.93	82.97	95.64	123.90
81513	90640	1739	58%	57400	40%	.85%	5.40	154.98	95.64	158.55
79840	50980	1740	28%	39828	62%	.967%	6.97	139.40	95.70	89.25
79551	42760	1717	99%	21457	70%	1.087%	7.84	83.88	94.44	74.55
	65520	1860	44%	45846	50%	.73%	5.42	124.66	102.63	114.45
	70220	1866	118%	32210	66%	.76%	6.34	101.44	102.63	122.85
	49140	1552	41%	34851	36%	.54%	3.96	68.90	85.36	85.75

FURROW METHOD OF MANURE APPLICATION

Although on the ranch under chief consideration the above method has not been in general practice sufficiently long to draw definite conclusions, yet some comment is in keeping with the subject matter presented.

Under direction of A. D. Shamel, manure was put into trenches half-way between rows of trees several years ago. This was in a small plot of Navel oranges. Following in a few years was the installation of the basin system which was not in spirit with the experiment so far as application of water was concerned. Nevertheless these trees assumed a size and color, also productiveness that was little short of phenomenal when contrasted with the surrounding trees not so treated.

Later several blocks of trees were put under this system and furrow irrigated. Other ranches tried the scheme with good success. Note pictures showing some details of the operation.

Practically the method can be used as follows: Use plow to open the trench which should not be more than 10 to 12 inches deep when in center of row and about 5 to 8 inches when under the ends of the branches. Put in manure in varying amounts according to size and thrift of trees as well as quality of manure and fertility of soil. Plow soil back to cover thoroughly. It is advisable to vary the position of the furrow from year to year as for example:

In center one way	- 1st year
In center opposite way	- 2nd "
Under ends of branches one way	- 3rd "
Under ends of branches opposite way	- 4th "
Half way between previous furrows one way	- 5th "
Half way between previous furrows opposite way	- 6th "
Repeat rotation beginning	- 7th "

Irrigation furrows are run close to one side of buried manure. Summer cultivation is performed shallow enough to leave material mostly undisturbed. Annual plowing when done should not be so deep as to turn much of the manure to the surface.

Notes:

The roots of trees invade this decomposing mulch with the avidity of tigers. The writer has personally found this loamy material completely bound together with millions of hair-like rootlets.

The theory is advanced that the ammonia gas liberated by the buried material is caught by the soil moisture and held to become a nitrate instead of passing into the air and thus lost.

It bids fair to become an established practice; valuable as a means of installing humus in the soil and promoting tree vigor by an economical use of manures.

TOTAL SOLUBLE NITRATE STUDIES

Equipment was secured to make colorimetric analyses of soils as outlined in Bureau of Soils Bulletin No. 31. Those were for nitrates only. Samples of soil were used after going through previous analysis for moisture. Results were entered as graphs in the same book with moisture data. Amounts were kept as parts per million in the first three feet of soil. To change to pounds it was only necessary to multiply by 12 on the basis of four million pounds to the acre-foot. The correct amount of soluble nitrate to secure optimum results in citrus groves is not absolutely known but Dr. McBeth states that from 50 to 100 pounds per acre appears to be sufficient. From 4 to 8 parts per million should then be available in the three-foot feeding zone of the roots.

Notes: Where water was added in quantities that did not pass much beyond the root system it did not appear to carry away nitrates. Observation based on reading made in same basin before and after an irrigation.

The amount of nitrate was very erratic. Two consecutive tests in same basin would rarely come alike. Slight applications of soluble plant foods as nitrate of soda would cause the readings to jump very materially.

Decomposing mulch without other plant food applications did not cause a large quantity of nitrate to be present in soluble form.

The quantity found present generally ran below the amount assumed to be necessary for best growth.

It appeared that where 4 p.p.m. could be fairly well maintained, good growth followed.

Other investigators have found that following the rainy season the amount of soluble nitrate will be reduced to a minimum regardless of the amount present in the fall. Of course, if it is taken up by cover crops, it is not lost, but has passed from the soluble state.

Some analyses would drop down to less than one p.p.m. or, in other words, just a trace of yellow could be detected. Other blocks sometimes showed over thirty p.p.m, or so strong a color that the sample would require division in order to reduce color to a comparable basis with standard solution.

Systematic study should be done in every farming locality. If growers were to become intimately acquainted with such tests for soluble nitrate and personally observe the growing crops for a practical correlation, it would become one of the most influential object lessons in scientific agriculture.

AMMONIUM SULPHATE DEMONSTRATION

During June 1916 two pounds of ammonium sulphate were sprinkled in the basin of each tree in eight different rows of trees on the ranch or approximately 620 trees. These rows were sometimes two in a place but on different blocks. During October, Mr. C. L. Dyer of the Pomological Investigations Office, of the Bureau of Plant Industry was conducted across these blocks at right angles to the rows and easily picked every row thus treated by casual inspection. The following year under trying climatic conditions these rows showed some advantage in quantity of fruit.

During the next year many rows were treated with two pounds of the same material per tree to compare with rows receiving one pound per tree. No especial difference could be noted, but it should be mentioned that the entire grove made unusual advance in thrift during this season due partly to being devoid of crop caused by the extreme heat, and thus slight differences between rows, even though they existed, would be difficult to point out.

CONCLUSIONS

WATER USES

Frequent discussion is made throughout this essay on lessons indicated by certain results. To generalize, however, the following is submitted:

Moisture Effects: Too much moisture is disastrous as proven by unthriftiness of trees near the water heads.

Good results were obtained when the moisture content was kept flucutating about the moisture equivalent line.

It always proved unwise to even allow the water content to approach within one or two per cent of wilting.

Water loss per day is low where the total content is low, thus indicating that as the moisture approaches the wilting point there is an increasing failure of trees to get it from the soil.

When trees get to wilting point the fruit may decrease in size. Twenty-four hours after irrigation it will increase over measurements of previous ten-day period.

Frequent irrigation of amounts sufficient to keep moisture content from a few percent above moisture equivalent to not lower than within 3 per cent of wilting point gave better results than heavy and infrequent irrigation.

There appeared to be no need of irrigating the soil beyong four feet in depth.

PLANT FOOD USES

Nitrogen gave good results. It was applied as Ammonium Sulphate, as nitrate of soda in tankage mixtures, as organic nitrogen in leguminous mulches and in manure.

It was evident that soluble nitrates should be applied in small doses but frequently enough to soon bring the total content up to at least 4 p.p.m.

Excellent growth and productiveness followed the use of mulches and commercial nitrogen-bearing fertilizers, indicating that nitrogen was the limiting factor.

PHYSICAL SOIL CONDITION AND EFFECTS

As humus is added to soil its water-holding capacity is much increased.

A splendid accumulation of black humus followed the heavy mulching in the basins.

The soil improved in texture where it was undisturbed by cultivation for one or more years.

Stones of varying sized tended to cause much of the erratic moisture data. They would often compose much of the sample by weight.

A loose stratum of gravel underlying the feeding zone of the roots causes a loss of water and plant food by reason of no return by capillarity.

The lack of moisture movement by lateral capillarity makes imperative applications of sufficient closeness to insure a meeting of the fanwise areas of penetration at a depth of about six inches below the surface.

CLIMATIC EFFECTS

Climate naturally is a limiting factor in agriculture. Not much can be done to change climate, although the use of smudge pots to ameliorate cold is a mild example. More must be done along the line of adaptation to climate rather than attempts to affect climate.

The moisture control work in soil is largely influenced by climate. In some districts like Whittier, three to four irrigations suffice for the season; while in others less than 50 miles distant, like Corona, it requires as many as twelve. The relative humidity, the soil, and the wind make the most of this difference.

It is necessary to mulch or cultivate or a combination of these in such a way to overcome in some degree these climatic conditions. Also the irrigation in quantity and frequency must answer the trees' needs despite climate.

Those who plant citrus in frosty locations recognize the liability and install equipment to combat the cold.

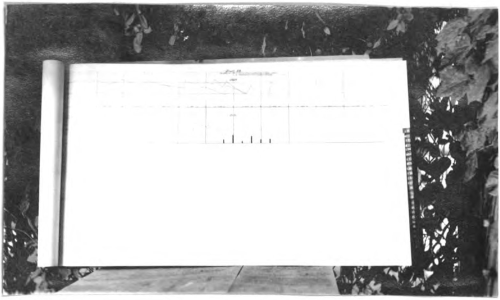
GENERAL RECOMMENDATIONS

Perhaps no more valuable recommendation may be offered than simply to affirm the necessity of every community making studies of the climate, the soil, and the ordinary practices of agriculture. It may be that such a study would change certain methods or even cause the abandonment of certain types of agriculture in that environment. At least it would be found interesting and remunerative.

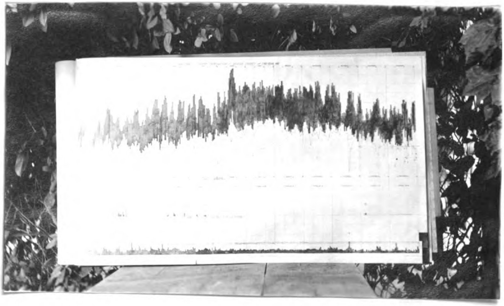
AFTERWORD

To those who are interested and anxious to learn more, it may be surprising that more actual data is not presented. The bulk of the data is in the hands of Mr. C. A. Jensen, of the Office of Bio-Physical Investigations, Bureau of Plant Industry, who is compiling the same for publication as a bulletin of that office. The record books of the ranch discussed are not in the hands of the writer who acknowledges that ready access to the same would have facilitated this writing and greatly accentuated its value.

The writer is pleased to hereby acknowledge his appreciation of the help and inspiration given by the following men in affording him the opportunity to make such important observations in the field of practical horticulture: Professor H. J. Eustace; Frank F. Chase; A. D. Shamel; C. A. Jensen; J. W. McLane; Dr. I. G. McBeth; and many others.



Showing one page of big book of graphs. The crooked line indicates moisture content. The solid columns indicate ten-day periods of fruit growth.



Page showing weather record. Upper edge of blocked in space indicates maximum daily temperature. Lower edge the minimum temperature. Note high point in June. It cost thousands of dollars in crop loss. Rainfall indicated across center of page. Wind velocity as 24-hour averages across bottom of page.

Cultivating spaces between basins.

Mammoth dam in mountains to maintain
Supply of water.

Portable galvanized pipe conveying water to basins.

Stand pipes with leads of pipe extending down the rows.