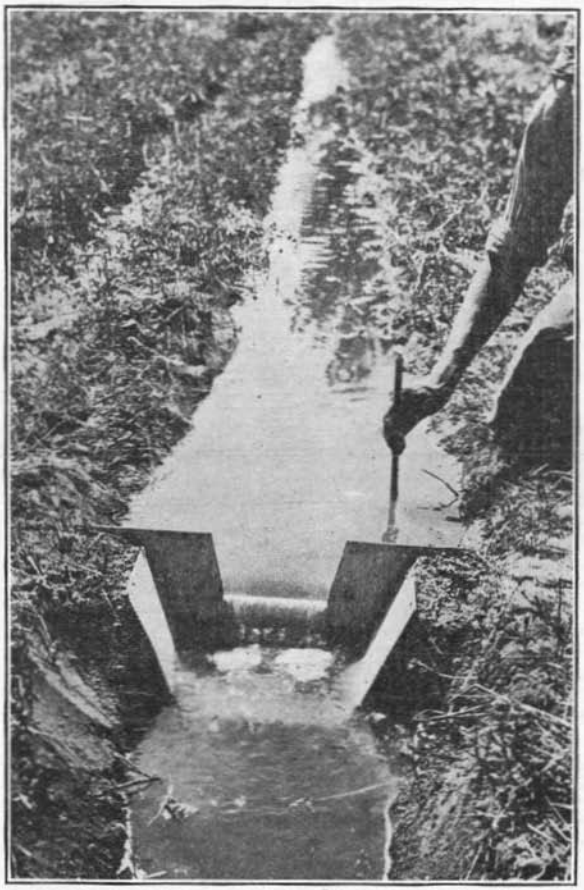
UNIVERSITY OF IDAHO
AGRICULTURAL EXPERIMENT STATION

DEPARTMENT OF HORTICULTURE

Experiments in the Irrigation of Apple Orchards



Measuring water with a Cipolletti weir for application in the Nesbit Experimental Orchard.

E. P. TAYLOR G. J. DOWNING

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INTRODUCTION

The supply of moisture is a leading factor in limiting the production of apples in Idaho. Practically all of the apples in the state are produced under irrigation. Natural annual precipitation in the apple districts ranges from around nine inches in the driest sections of South Idaho to slightly over nineteen inches in a few districts of North Idaho. The greater percentage is grown where the annual precipitation is about twelve inches. Varying systems of irrigation are, therefore, necessary and the questions involved in the use of water in apple orchards is one of constant and increasing interest. On account of South Idaho being so largely an irrigated district, great progress has been made in the use of irrigation water. Some of the largest irrigation canals in the West are located here and over a million acres are farmed by irrigation. The land is far in excess of the water available for cultivation and the need for water conservation is ever increasing. During the period extending from 1900 to 1910, the valuation of irrigation water increased in the irrigated areas of the West about 300 per cent. It is the duty of the fruit grower to employ every method and device for an economical administration of water so that the highest possible efficiency of this resource may be secured.

The artificial control of moisture supplied to fruit under irrigation brings many new and complicated problems for solution. Irrigating to produce fruit is infinitely more complex than irrigating to produce the average farm crop, since the husbandman is dealing with plants of long life and high individual value rather than with field-crop annuals.

The high water content of apples demands a liberal supply of water at the proper time. The color, flavor and keeping-quality of the fruit produced has to be borne in mind as being influenced by moisture supply. Manifestly the quality of fruit grown, the yield and the profits secured depend in a large degree, not only upon the manner of application of the water to the crop, but upon the growth and general health of the tree itself. In addition to this, we have to consider such vital and intricate relationships as exist between moisture and the formation and vigor of fruit buds for the succeeding year and the well known fact that irrigating at times of spring frosts serves to protect foliage or bloom from injury in many cases by raising the air temperature in the zone of the plants. In the discussion of duty of water in apple production. it should be borne in mind, also, that fertility is an influencing factor because it has been shown by experiments that fertile soils require less water for crop production than soils low in fertility and that soils high in humus have greater water-holding capacity.

EXPERIMENTAL

For the purpose of supporting investigations in the irrigation of orchards, a special appropriation was made by the State Legislature in 1913. A portion of the sum first appropriated remained unexpended at the end of the biennium and reverted to the State. The 1915 Legislature made no special appropriation to follow up the orchard-irrigation experiments which had been undertaken. A small sum, however, was set aside from other funds which permitted the continuance of the work in one of the experimental orchards.

Two orchards were leased by the Experiment Station in 1913 in order to carry out certain definite lines of investigation. One was the orchard of Mr. H. Harland of Payette in the Wood Spur district. The other belonged to Mr. S. K. Nesbit of Twin Falls and was located on the Kimberly road. Work began in the Harland orchard in 1913 and continued thru the years 1914 and 1915.‡ The Nesbit orchard at Twin Falls was secured for the years 1914, 1915 and 1916.

The apple being the most extensively planted fruit of the state, it was deemed advisable to concentrate the experiments upon the irrigation of apples. The plan of investigation called for special attention being given to the determination of (1) the most economical amount of water to mature an apple crop, (2) the relation of irrigation to the formation of fruit buds, (3) proper irrigation systems to produce apples of best keeping quality, (4) the best irrigation scheme for the production of relatively large amounts of extra fancy and fancy fruits, (5) the influence of soil moisture upon the health of the tree as indicated by winter injury and blight.

Results from the conduct of experiments to secure information on these points form the basis of this bulletin.

THE TWIN FALLS EXPERIMENT

Eleven plats of eight-year old Jonathans were set aside in the Nesbit 40-acre orchard. These plats covered approximately 4 acres or 270 trees. Ten of the plats were practically of equal size, each containing a little more than one-fourth of an acre set with 18 trees. The eleventh was a plat of about 1 1-2 acres containing about 90 trees. The trees were planted 25 feet apart in rows 30 feet apart. A few of the trees were replants of younger age and a few were of odd varieties that were scattered thru the orchard. The number of replants and odd varieties, however, did not exceed ten per cent of the whole. There were no low or uneven spots and the plats appeared to be perfectly comparable in soil, slope of land, and in the size and vigor of trees. The orchard

‡The first season's work at the Harland orchard was supervised by E. W. Hamilton, Professor of Agricultural Engineering at the University of Idaho. In the fall of 1913 E. P. Taylor, Field Horticulturist assigned to the Division of Agricultural Extension, assumed charge of the investigations. At the beginning of work in 1914, G. J. Downing, Assistant in Horticulture at the University, was detailed to assist Mr. Taylor in the conduct of the work. Messrs. Taylor and Downing have had during the course of the work the assistance of Joseph Sudweeks and Albert Kinnison, graduates of the University in Horticulture, and of Messrs. Ferrin and Albert Harland of Payette.

was one admirably adapted to cutting up into small plats for the conduct of an experiment in irrigation. No plat was smaller than three tree-rows wide by six tree-rows long. The influence of water applied to one plat or conducted in service or waste ditches could not be noticed in adjacent plats. The plan of the orchard with plat numbers, treatments and other details is illustrated by Chart 1.

Two variable conditions as regards moisture were recognized in laying out the plats: (1) The time of application and (2) the amount of water to be used. Eleven irrigation combinations were selected as the ones most likely to give the information desired. The map of the orchard plats and the legend accompanying it show the range in treatment. A brief explanation of the terms used, however, may be necessary.

The "A" period extended from early spring to the time when most of the twig growth was finished. The latter date at Twin Falls ranged from July 1 to July 10.

The "B" period extended from the cessation of twig growth to the time of the setting of terminal buds in bearing orchards; that time at Twin Falls, except for the terminal buds in the tips of branches in the tree tops, averaged about August 15.

The "C" period extended from the setting of the majority of terminal buds to harvest time.

Sub 1 indicates a soil-moisture content below the normal; for soil in the Nesbit orchard, a moisture content of from 8 to 13 per cent. Generally speaking this treatment implied irrigations at longer intervals than normal and the running of water for a shorter length of time at each irrigation.

Sub 2 indicates a soil-moisture content about normal; for soil in the Nesbit orchard a moisture content ranging from 14 to 20 per cent.

Sub 3 indicates soil moisture above normal; for soil in the Nesbit orchard ranging from 21 to 28 per cent. Generally speaking this treatment implied irrigation at shorter intervals than normal and the running of water for a longer time at each irrigation.

Plats 30, 31 and 32 represent maximum, medium and minimum irrigation respectively thruout the season. Plats 33 to 39 inclusive represent various combinations of time-of-irrigation and amounts of water. Plat 40 was given normal treatment during the growing season and a fall dormant irrigation.

The foregoing represents the general plan attempted and in the main adhered to. The deviations from this plan made necessary for various reasons may be seen by reference to Charts 2 to 11 inclusive and to Table 1 which shows the actual treatments. The increased moisture applied during the "A" or early period in 1914 was occasioned by uniformly heavy irrigation being given to all plats during that spring at the time the cover crop of clover was being started. It will be noted that all additions of moisture from natural rainfall were measured and that the irrigations given were based upon actual soil moisture present determined by methods described in a succeeding paragraph.

Table 1. Three-Year Summary—Nesbit Experiment.

YEAR	PLAT NUMBER		30	31	32	33	34	35	36	37	38	39
	PLAT TREATMENT		$A_2B_3C_2$	$A_2B_2C_2$	$A_1B_1C_1$	$A_2B_3C_1$	$A_1B_2C_2$	$A_2B_2C_1$	$A_1B_3C_1$	$A_2B_1C_2$	$A_1B_1C_2$	$A_2B_2C_2$
1914	IRRIGATION WATER IN ACRE-INCHES	A	17.53 ***	15.87 ***	9.95 **	17.02 ***	15.75 ***	15.66 ***	17.10 ***	9.95 **	9.95 **	9.95 **
		B	14.16 **	4.83 *	4.59 *	15.99 **	5.30 *	6.20 *	15.40 **			3.94 *
		C	7.70 *	7.06 *			7.52 *			5.97 *	6.20 *	
		TOTAL	39.39	27.76	14.59	33.01	28.57	21.85	32.50	15.95	16.15	13.89
	SOIL MOISTURE-AVERAGE PER CENT	A	21.50 ****	20.70 **	19.70 **	19.50 ****	19.10 **	20.50 **	21.50 ****	20.60 *	19.00 **	18.40 **
		B	22.30 ***	20.80 ***	15.80 ***	21.50 ***	20.00 ***	21.10 ***	23.50 ***	13.50 ****	13.40 ****	16.90 ***
		C	19.30 ****	18.40 **	10.00 **	14.20 **	17.80 **	15.20 **	16.50 **	17.30 ***	18.60 **	9.40 ****
		AVERAGE	21.00	20.00	15.20	18.40	19.00	18.90	20.50	17.10	17.00	14.90
1915	IRRIGATION WATER IN ACRE-INCHES	A	12.80 **	4.55 *	1.98 *	4.78 *		5.74 *		6.46 *		10.59 **
		B	11.16 **	10.53 **	5.65 *	17.28 **	6.06 *	6.23 *	13.99 **	3.12 *	2.54 *	4.63 *
		C	15.40 **	5.55 *			19.00 **	5.20 *		6.20 *	6.54 *	
		TOTAL	39.36	20.63	7.63	22.06	25.06	17.17	13.99	15.78	9.08	15.22
	SOIL MOISTURE-AVERAGE PER CENT	A	21.70 ********	19.00 *****	11.80 *****	19.40 ******	14.70 *****	19.00 *****	14.20 *****	17.10 ****	14.50 *****	17.90 ******
		B	20.70 ****	16.50 ****	14.50 ***	18.90 ****	15.90 ****	16.20 ****	18.40 ****	13.00 ***	13.20 ***	14.80 ***
		C	22.30 *****	15.90 *****	11.60 ****	14.00 ***	22.30 ****	12.60 ****	14.10 ****	17.60 ***	16.70 ****	12.50 ***
		AVERAGE	21.50	17.10	12.60	17.40	17.60	15.90	15.60	15.90	14.80	15.10
1916	IRRIGATION WATER IN ACRE-INCHES	A	27.51 ***	12.88 **	5.03 **	13.04 **	7.21 *	10.41 **	16.80 **	9.38 **	12.02 **	11.44 **
		B										
		C										
		TOTAL										
	SOIL MOISTURE-AVERAGE PER CENT	A	23.20 *******	18.10 *****	11.40 *******	17.70 *******	14.80 ******	19.20 ******	13.90 ******	17.30 ******	11.90 ******	15.50 ******
		B										
		C										
		AVERAGE										

Irrigation-water figures are after waste is deducted. The soil moisture is figured on the dry basis. The stars (*) indicate the number of irrigations or the number of times the soil was sampled.

Table 2. Precipitation in Inches During the Nesbit Experiment.

YEAR	PERIOD	A	B	C	Total
1914		1.75	.45	2.34	4.54
1915		*6.25	.24	4.15	10.64
1916		*6.49			

*Moisture indicated in A periods in 1915 and 1916 also includes winter moisture.

General Care Given the Nesbit Orchard

As nearly as they could be made so, all operations of cultivating, corrugating, cover cropping, fertilizing, pruning, spraying, thinning, picking, and harvesting were uniform thruout all plats. Moisture differences were the only differences desired.

The orchard had been planted upon sagebrush land without dynamiting for the tree holes and had been grown with clean cultivation. It had borne a few light crops and was, at the beginning of the experiment, in what might be termed its early bearing stage. Barnyard manure at the rate of about five tons per acre had been applied during the winter of 1913-14.

The trees had been headed uniformly with leading branches dividing at from 18 to 24 inches from the ground. The pruning, tho uniform, had been after a system which left comewhat more branches in the tree tops than would usually be considered best and with many superfluous branches hanging low about the base of the trees. No pruning was done during the winter preceding or during the spring of the year in which the experiment was begun. During the spring of 1915 a thinning out of limbs was done, especially of the ones hanging lowest. In the spring of 1916 from four to six medium-sized limbs per tree were taken out. The 1916 prunings averaged in weight 14.4 pounds per tree. No summer pruning or heading back of limbs, except the cutting of the blighted limbs, some of which were removed in the spring and some in the summer, was done during the experiment.

All plats were seeded to red clover in the spring of 1914 and maintained in clover for the three years of the experiment. The first year the first clipping of clover was allowed to lie upon the ground. The second and third years, hay was made of the first cutting and clover seed harvested from the second.

Thinning was done in 1914 over all plats. In 1915 the crop required no thinning and in 1916 there was a total fruit failure on account of frost. No spraying was done for codling moth in 1913. In 1914 and 1915, the spraying was uniform on all plats. Not more than five per cent of the apples were wormy any year of the experiment; sprays for other insects or fungous diseases were unnecessary.

Methods of Irrigation and Moisture Sampling

A contour map of the experiment, showing slope, location of trees,

size and general plan is shown on page 9. The land sloped to the northwest, dropping about 4 feet in 500. A system of ditches was planned and made whereby any combination of plats could be irrigated at the same time without interference. The corrugations were made about two and one-half feet apart. Sufficient water for irrigation work in this experiment was obtainable at all times. In irrigating a plat, the water is first measured by means of a Cipolletti weir with a six-inch crest. Along the north edge of each plat, a waste ditch was made and the collected waste water was measured with a four-inch Cipolletti weir. After the amount of water was well regulated, weir readings were made every two hours. The amount of water applied was accurately calculated in terms of inches in depth over the plat (acre-inches). All calculations were so carefully checked that the likelihood of error is very small.

The exact moisture content to a depth of four feet was kept during the entire growing season for each plat. This was done by means of a five-foot King soil tube with a diameter of 13-16 inches at the point, soil cans, accurate balances reading to .5 gram and a Sargent electric oven equipped with a thermostat. In order to obtain the correct percentage of soil moisture in a plat, it was found necessary to drill two four-foot holes in different parts of the plat between the second and third corrugations from the tree row and at points about one-fourth of the distance from one corrugation to the next. The soil moisture in the top two feet was calculated separately from that in the third and fourth feet. The average percentage of moisture in the samples of these two holes was taken as the moisture content of that plat. All moisture percentages were figured upon the dry basis, that is, the number of grams of water in a soil sample was divided by the weight of the dry soil. The soil was subjected to a heat of approximately 115 degrees Centigrade in bringing it to constant weight, which required, as a rule, 10 hours.

The Soil

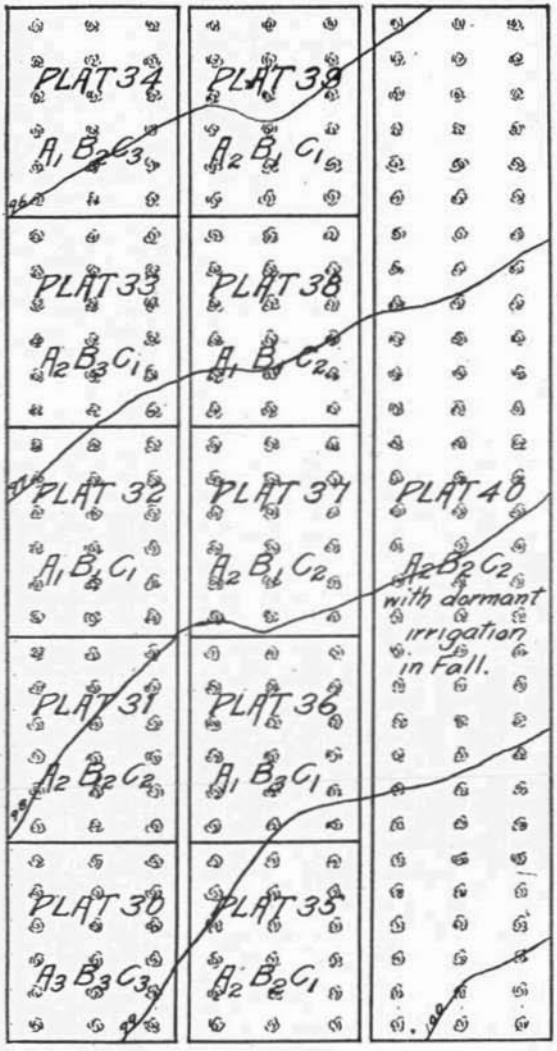
The chemical and mechanical analyses of the soil in the Nesbit orchard are given in Table 3.

Table 3. Chemical and Mechanical Analyses of Soil in Nesbit Orchard

SOIL	Nitrogen per cent	Organic carbon dioxide per cent	Calcium oxide per cent	Carbonate carbon dioxide per cent.	Total sand per cent	Silt per cent	Clay per cent
Surface 12 inches.....	.06	1.51	5.6	5.79	71.1	25.2	5.6
Between 12 and 24 inches.....	.03	.55	5.5	9.20	70.7	25.3	4.0
Between 24 and 36 inches.....	.04	.00	5.3	7.51	77.1	21.6	2.7

Most of the sand is very fine sand. The chemical analysis shows that this soil is low in nitrogen, is not acid and contains a medium amount of humus or decayed organic matter. The mechanical analysis shows it to be a fine sandy loam.

The percentage of hygroscopic moisture in this soil is about 5 and the average percentage of capillary water about 16. This soil is saturated with water when it contains about 28 per cent. When the soil moisture reaches about eight per cent, plants will begin to wilt.



MAP
SHOWING
ORCHARD IRRIGATION
EXPERIMENT
Nesbit Orchard—
3 Miles East of Twin Falls-Idaho
Scale 1"=100'

LEGEND

A=period from early Spring to July 1st.
B= .. .. July 1st to August 15th.
C= .. .. August 15th to time of picking apples.
1=less than normal amount of irrigation water applied.
2=approximately .. ..
3=more than .. ..

Chart 1. Contour map of Nesbit Experimental Orchard at Twin Falls, Idaho, showing trees and plan of irrigation for each plat.

The Weather During the Nesbit Experiment

At the Nesbit orchard, a record was kept of the total precipitation during the period of the experiment (May 1914 to July 1916). The precipitation by months is shown in the following table.

Table 4. Precipitation in inches in the Nesbit Experimental Orchard from May 16, 1914 to July 1, 1916

	1914	1915	1916
January		.61	1.47
February		1.17	2.05
March		.25	1.09
April		1.07	1.16
May	.73	3.14	.66
June	1.02	.01	.06
July	.40	.24	
August	.05	.02	
September	2.01	1.44	
October	.06	.00	
November	.00	1.31	
December	.27	1.38	

The normal precipitation at the government volunteer Station at Twin Falls for a ten-year average is 11.67 inches. The total for the year 1915 at the Nesbit orchard showed 10.64 inches, about 1 inch below normal. During the irrigation period, or the months from May to August inclusive, the total precipitation was 2.2 inches in 1914 and 3.4 inches in 1915. The rainfall was distributed principally thru the months of May and June and came in such small quantities that it scarcely had an appreciable effect on tree growth.

The prevailing winds had a drying effect upon the soil and increased the requirements for irrigation water. The strongest winds were during the spring months. During the summer and fall the wind movement was not unusual compared with the remainder of the state. Wind velocities at Twin Falls for the year are higher than at the points mentioned in table 5 which follows:

Table 5. Average Hourly Wind Velocity (miles per hour); from U. S. Weather Bureau Records

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Boise	4.8	5.0	6.0	6.2	6.2	5.3	4.8	4.5	4.6	4.2	4.6	4.2	5.1
Lewiston	4.6	4.5	5.0	5.2	4.9	5.1	5.2	4.8	4.1	3.3	4.2	4.5	4.6
Pocatello	9.6	9.4	9.3	9.0	8.7	8.3	7.9	7.9	8.4	8.2	9.0	8.9	8.7
Spokane	5.3	5.7	6.6	6.8	6.7	6.8	5.9	5.2	5.4	5.0	5.9	5.5	5.9

The mean monthly temperatures recorded at the Twin Falls volunteer Station during the growing months were as follows:

Table 6. Twin Falls Mean Monthly Temperature (in degrees Fahrenheit)

Year	April	May	June	July	August	September
1913	49.2	58.0	62.8	68.2	70.8	60.8
1914	47.6	58.6	60.6	74.6	71.6	57.6
1915	53.8	53.2	61.5	69.0	73.7	56.0
1916	51.2	51.6	60.9	70.7		

The evaporation of soil and surface water under the above temperatures and wind movements was considerable. Mr. J. S. Welch, Superintendent of the Gooding Sub-Station, reports a total evaporation of 37.13 inches in the 183-day period between April 4 and October 1 in 1914, and 42.2 inches in 1915 for the same period from a free water surface in an evaporation pan. Actual soil moisture evaporation was not measured.

In the season of 1914, Jonathans bloomed on May 10 and the apples were picked between September 21 and 24. In 1915 Jonathans bloomed on April 26 and picking was done between September 20 and October 4. In 1916 the trees were in full bloom May 4 and a frost on the nights of May 10 to 12 inclusive destroyed the crop.

Treatment and Results of Twin Falls Experiment as Shown by Profile

The profile charts, numbers 2 to 11 inclusive, show, for each of the 10 plats, the times of irrigations, the amount of water in acre-inches applied at each irrigation, the percentage of soil moisture at all times during the growing season, and the results obtained in terminal growth, trunk growth, and apple growth from the different systems of irrigation. The terminal growth is platted in linear inches, the apple growth in cubic inches, and the trunk growth in percentage increase of the area of a cross-section about four inches above the ground. The curves for the trunk, terminal and apple growth show the time during the growing season of most rapid and least rapid growth. In order to obtain the trunk-increase curve, the circumference of each tree was measured several times during the growing season, with the exception of 1914 when only two measurements, one in early spring and another in late fall, were made. From the circumferences, the area of the cross-section and the percentage of increase from the time of the preceding measurement were calculated. The terminal curves were platted from the averages of several hundred terminal measurements on each plat, care being taken that the pruning was uniform, and the differences noted due to the differences in irrigation only. The apple curves were platted by measuring the circumferences of several hundred apples at different times during the season and calculating the average volume from the average circumference at each measurement. Care was taken to make the thinning uniform in order that the difference in size of apples would be influenced by no other factors than differences in irrigation. In 1914, the apples were not measured a sufficient number of times to show the period of greatest growth.

Correlation of Irrigation and Growth of the Trunks of Trees

Chart 14 is a profile chart summarizing the trunk growth in percentage increase of cross-section area for each of the ten plats for three years. During the season of 1914 but two measurements were made (in early spring and late fall) and, in consequence, the curves for this season do not show the time of greatest increase. The experiment was carried only to July, 1916, and hence the curve for this sea-

son ends at that date. The main facts shown by this profile may be summarized as follows:

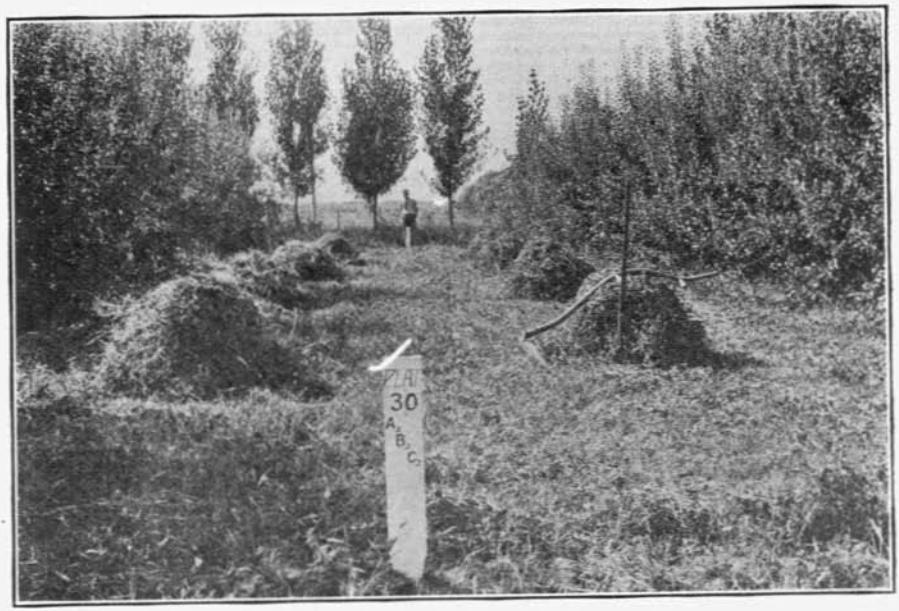


Fig. 1. Plat No. 30 in Nesbit experiment, showing results of maximum application of water on clover cover crop.

1. The average percentage increase of trunk growth for all plats during the 1914 season was 33; during 1915 it was but 25 altho the same scheme of irrigation for each plat was followed during both seasons. This was undoubtedly due to two factors: first, the trees were approaching the age of maturity when the growth would naturally become slower; and second, the orchard had been clean cultivated during 1912 and 1913 and was seeded to red clover in the spring of 1914. This red clover did not become as fully established during the 1914 season as it did the following year. After becoming fully established, a cover crop will, of course, greatly lessen the amount of soil moisture that the trees will obtain.

2. The trunk growth was most rapid during the first part of the growing season, over 75 per cent of the total season's growth being completed by August 1. The growth was very slow during the last half of the growing season.

3. On account of the fact that the greater part of the trunk growth is before August 1, it would seem that heavy irrigation from early spring to about July 15 would result in greater trunk growth. This was found to be true during the season of 1914. With but two exceptions the trunk increases varied directly as the number of acre-inches of water applied before July 15. It must be remembered that all plats were given the same irrigation during the season of 1913 and, therefore, all

went into the winter of 1913-14 with practically the same percentage of soil moisture. However, in 1915, the trunk increase did not by any

Fig. 2. Plat No. 31 in Nesbit experiment, showing results of medium application of water on clover cover crop.

means vary directly with the number of acre-inches of water applied before July 15, several plats making greater growth than several others which were given almost double the amount of water. Upon making a study of this, it is seen that in practically every case where trees did not make large trunk growth, even tho irrigated heavily the first half of the growing season, those trees went thru the previous winter with a low percentage of soil moisture. As later discussion will show, the amount of moisture in the soil at the time of freezing in the fall affects very materially the amount in the soil in the spring.

From these results, the following conclusion would seem to be justified: trunk growth of Jonathan apple trees is directly affected by the amount of irrigation water applied during the first half of the growing season and by the percentage of moisture in the soil the preceding dormant season. The latter factor may easily overbalance, in its effect, the former one.

Correlation of Irrigation with Growth of Twig Terminals

A profile summarizing the average terminal growth in inches for the trees of each of the ten plats for three years is shown by Chart 13. A study of this chart reveals the following facts:

1. Much greater growth was made in 1914 than in 1915, and more in 1915 than in 1916. This checking not only of the twig terminal

growth, but also of the trunk growth and size of fruit, was due very largely to the clover cover crop. The clover was seeded in 1914 and

Fig. 3. Plat No. 32 in Nesbit experiment, showing results of minimum application of water on clover cover crop.

became more thoroly established in 1915 when it took much of the soil moisture from the trees. Such a decrease in growth is considered desirable in young Jonathan orchards first coming into bearing and a clover or alfalfa cover crop is strongly recommended. The amount of irrigation water needed is increased thereby and where the irrigation water is short, bearing orchards must sometimes be maintained by clean cultivation.

2. Practically all the terminal growth was made in April, May and June and in the early part of July. The following table was compiled from the profile chart:

Table 7. Average Terminal Growth in Inches During each Month

During Month of	Heavy irrigation	Medium irrigation	Light irrigation
May	5.3	5.2	4.3
June	5.3	5.2	3.8
July	2.0	1.8	1.4
August	0.1	0.1	0.0
September	0.0	0.0	0.0

3. As a rule, the more water applied before July 1 the greater the terminal growth, as shown by the preceding table. The profile charts,

however, show a number of exceptions to this rule. These exceptions are undoubtedly due to the following factors:

(a) All plats did not have the same percentage of soil moisture during the preceding winter. As before stated, the amount of winter soil moisture affected the trunk growth and it seems reasonable to suppose that it would affect also the terminal growth.

(b) A large number but not all terminals were measured on every tree. Failure to measure all might be a source of error.

(c) Altho an effort was made to prune all trees alike, it is doubtful if absolute uniformity in pruning was secured. A heavily pruned tree will make a much longer terminal growth than a lightly pruned one.

(d) In the individuality of each tree there lies a source of error.

These factors would undoubtedly account for the exceptions to the rule that the more irrigation in the spring, the greater the terminal growth.

Correlation of Irrigation With Water Content and Weight of Leaves

In June, 1916, a large number of leaves were gathered from each plat, and their average weight and percentage of water determined. The results obtained are given in the following tables:

Table 8. Relation between Soil Moisture and Water Content of Leaves

Plat No.	Water content of leaves	Soil moisture when leaves were taken	Average soil moisture during entire spring
	Per cent	Per cent	Per cent
34	64.8	19	16
33	64.2	18	18
39	63.8	15	15
38	63.8	11	12
32	63.6	12	11
30	63.3	22	24
35	63.0	18	18
36	62.9	15	17
37	62.8	11	16
31	62.8	19	18

Water Content of Leaves: The above figures show a notable uniformity in the percentage of water in the leaves from trees of different plats. From these figures no conclusions can be drawn upon the effect of high and low soil moisture upon the water content of leaves, as there is no effect within the limits of 11 to 22 per cent of soil moisture.

Table 9. Relation between Soil Moisture and Dry Weight of Leaves

Plat No.	Dry weight of leaves	Soil moisture during entire spring	
	In grams	Per cent	
33	.1414	18	
37	.1335	16	
30	.1296	24	
35	.1265	18	
31	.1263	18	Average 19 %
36	.1262	17	
32	.1236	11	
38	.1152	12	
34	.1115	16	
39	.1022	15	Average 14 %

Dry Weight of Leaves. The above figures show that the greatest difference in average dry weight of leaves is approximately 28 per cent. The average percentage of soil moisture in the five plats with the heaviest leaves was 19 while the average in the five plats with the lightest leaves was 14. In the latter five plats, the leaves were about 14 per cent lighter than were those of the first five plats. These data are not conclusive enough to warrant a statement without reservations altho they tend to support the following conclusion: The more irrigation water applied in the spring, the heavier the leaves.

The leaves on the trees showed a tendency to wilt when the soil water reached about 8 per cent. On the dry plats the foliage was of a lighter color than that on the wet plats altho more white leaves were present on the wet ones.

Correlation of Irrigation With Size and Growth of Fruit

A study of charts number 12, 18 and 19 leads to the following conclusions:

1. Apples grow very slowly during the first half of the period they are on the trees. If an apple is formed about May 10 and picked about September 25, it will have completed less than 30 per cent of its growth by July 15 which is one-half of the total period that it is on the tree.

2. The most rapid growth of apples is during the period beginning about July 10 or 15 and ending about two weeks before picking time. In this period growth is the slowest during the last two weeks before picking time.

3. Irrigation previous to the beginning of this period of rapid growth (before July 10) has very little influence upon the size of the apples.

4. Irrigation during this period of rapid growth of apples (starting about ten weeks before picking and continuing until about two weeks before picking) has a very decided effect in increasing the size of the apples.

Correlation of Irrigation With the Health of the Trees

Fire Blight. It has often been noticed that orchards which were making the most vigorous growth of wood were troubled the most with

fire blight. A considerable number of soil-moisture tests were made in orchards where the blight was very serious and in other orchards where there was very little blight. In every case, the soil moisture in blighted orchards was from three to eight per cent higher than in adjacent orchards which had few blighted limbs. Many times an orchard would be found where one portion was badly blighted and another portion had no blight, even tho the trees were of the same age and variety and were growing on the same type of soil. Invariably the soil of the blighted portion contained considerably the higher percentage of soil moisture.

Measurements were also made of a large number of terminals on blighted trees and on adjacent trees not blighted. The results showed a greater terminal growth on the blighted trees.

Chart number 13 shows that practically all the season's terminal growth is made in April, May, June and the first part of July and that a clover cover crop has a great effect in decreasing the terminal growth as seen by comparing the 1915 growth with that of 1914. Blight is usually at its height in June, Hence the following conclusions seem justified:

1. Heavy irrigation previous to July 1 increases the wood growth and this tends to increase the amount of fire blight.

2. A cover crop such as clover or alfalfa greatly decreases the wood growth and so lessens the amount of blight. Alfalfa is more efficient than red clover in decreasing the wood growth of trees on account of its deeper root system.

Winter Injury. As previously stated, the wood growth on a bearing apple tree ceases about July 10. From this date until the leaves drop in the fall, the new wood is going thru a hardening process altho it is not increasing in length. This, however, may not be true with regard to a vigorously growing young tree under clean cultivation which has not yet come into bearing. Here, growth tends to continue later in the season and can be forced quite late by continued heavy irrigation. In this case, the period of ripening may be too short and the wood may be green and soft when frost comes. Under these conditions winter injury may result. It is advisable to hold the water off during the latter part of the summer and let the wood ripen; then, if the fall is excessively dry, to apply a late dormant irrigation.

Chlorosis. White leaves or bunches of white leaves on apparently healthy trees are often noticed. This condition is called chlorosis. It is most frequent in over-irrigated orchards and may be considered as a sign of over irrigation. Determinations of the soil moisture surrounding these trees support this conclusion.

Correlation of Irrigation with the Fruit Crop

Size. Chart 17 gives the relative size of fruit produced in the Nesbit orchard for all plats in 1914. The following table gives the relative sizes of fruits together with the amounts of water applied for the various periods. The figures for the 1914 crop include all fruit harvested for all plats. For 1915 no record of relative size of fruit was kept at the first picking. It was noted however, that the apples of the first picking were much larger than those of the second. From the first pick-

ing 93.9 per cent of four and four and one-half tier apples was obtained; from the second picking 71 per cent of the same sizes was obtained. Only plats 30, 31 and 32 are shown in table 11 for the second picking. Spring frosts brought about a very light crop of fruit on the plats toward the lower end of the orchard tract.

Table 10. Percentage of Sizes of Jonathan Apples—Nesbit Orchard, 1914

Plat	Treatment	Number of irrigations	Total water applied acre-inches	4-Tier 96-104-112 113-125 per cent of total	4½-Tier 138-150-163 per cent of total	5-Tier 175-188-200 per cent of total
30	$A_3B_3C_3$	6	39.39	64.3	35.1	0.0
31	$A_3B_2C_2$	5	27.76	49.0	49.0	2.0
32	$A_1B_1C_1$	3	14.54	24.5	59.2	16.3
33	$A_2B_3C_1$	5	33.01	49.2	47.1	3.9
34	$A_1B_2C_3$	5	28.57	29.1	62.0	8.9
35	$A_2B_2C_1$	4	21.86	40.5	54.0	5.5
36	$A_1B_3C_1$	5	32.50	50.0	42.8	7.2
37	$A_2B_1C_2$	3	15.92	36.1	55.5	8.8
38	$A_1B_1C_2$	3	16.15	26.9	49.0	24.1
39	$A_2B_1C_1$	3	13.89	25.8	48.4	25.8

Table 11. Percentage of Sizes of Jonathan Apples—Nesbit Orchard, Second Picking, 1915

Plat	Treatment	Number of irrigations	Total water applied—acre-inches	4-Tier 96-104-112 113-125 per cent of total	4½-Tier 138-150-163 per cent of total	5-Tier 175-188-200 per cent of total
30	$A_3B_3C_3$	6	39.36	45.0	33.9	21.2
31	$A_3B_2C_2$	4	20.63	34.1	32.9	32.9
32	$A_1B_1C_1$	2	7.63	0.0	60.0	40.0

With size ratings of 10, 9, 8 and 7, in which 10 is rather large and 7 is small, the 1915 crop gave relative fruit sizes as follows for the different plats: 30-10; 31-9; 32-7; 33-9; 34-8; 35-8; 36-9; 37-8; 38-7, and 39-7.

Reference to the foregoing tables and profiles will show that without exception large size was associated with maximum amounts of water. In 1914 the only plat yielding as large as a 96 (apples to the 50-pound box) size apple was plat 30 which received the most water, a total of 39.39 acre-inches during the season the clover was being started. That year the three plats which received the least water, namely plats 32, 38 and 39 with an average of 14.86 acre-inches for the season showed the greatest percentage of 5-tier or small apples. Over 22 per cent of the apples from these plats were 5-tier apples which is considerably too high a ratio of this size to be desirable for an entire crop. For young bearing orchards 4 and 4 1-2-tier Jonathans are desirable commercial sizes, all things considered, and all plats yielded fruit of satisfactory size except plats 32, 38 and 39 which received an average of less than 15 acre-inches for the season. The results in 1915 also showed largest apples from plats receiving the largest amount of water and objectionally small apples from plats 32, 38 and 39 which received the smallest amounts of water for the season.

The time of year at which the irrigation was given had much to do with its effect upon the growth of the fruit. In 1914 plats 32, 38 and 39, which gave the smallest fruit, received an average of 4.9 acre-inches and were maintained at an average soil moisture content for the first four feet of 14 per cent during the apple-growth period (periods "B" and "C"), while plats 30, 34 and 36 which produced fruit of satisfactory size received an average of 16.7 acre-inches and were maintained with an average soil-moisture content of 19.9 per cent for the same periods. Plats might be given an equal total amount of water for the season, one receiving its quota during the vegetative or "A" period of the trees, and the other during the fruit-developing or "B" and "C" periods but the last mentioned system will invariably produce the larger fruit. This fact was well illustrated in 1915 from results secured on plats 36 and 39. Plat 36, given a total of only 13.9 acre-inches, all of which was applied rather late ("B" period), produced fruit of good size, while plat 39 with 15.2 acre-inches applied earlier in the season, mostly while the fruit was still small, but given no water late during the principal fruit-forming period gave fruit of very unsatisfactory size and of almost no market value.

The plats given the greater amount of water during the apple-forming periods ("B" and "C") produced apples of greater size and of more angular and irregular shape.

Color Variety, soil, exposure to sunlight, moisture and fall frosts contribute to color formation in fruit.

There is a natural time in the maturing of fruit for color to develop but the time and amount of watering can be made to influence coloration.

The plats receiving the highest amount of water in the Twin Falls experiment produced neither the poorest nor the best colored apples. Plats which were given very heavy irrigations during the early or vegetative peiod (A period) such as plat 30 showed a tendency to produce a heavy leaf growth which later in the season shaded the fruit and prevented the development of the normal red color of the Jonathan, therefore, too heavy foliage is detrimental to the best color.

On the other hand plats which had not been forced to excessive leaf and wood growth during the vegetative period (A period) gave better color and at an earlier date when given liberal applications of water well along toward the ripening period. Apparently the water hastened development and in a corresponding manner induced coloration. Some plats in the experiment and other orchards in the vicinity under observation showed very poor color when allowed to get too dry during the fruit-developing period (B and C periods.) Many growers are confused upon the point of relationship of moisture to color. If time of irrigation rather than total amount given is recognized as the important factor, as stated above and brought out by these experiments, fruit growers may, by irrigation, very materially augment color in fruit produced.

Yields and Grades. The following table and sharts 15 and 16 show the yields and grades secured on the various plats in 1914 and 1915.

Table 12. Yields and Grades of Jonathan Apples—Nesbit Orchard 1914 and 1915

Plat	Treatment	Times irrigated		Total water given A.-inches		Yield per acre boxes				Percent each grade of total yield									
						All grades		Ex. fancy and fancy		Extra fancy		Fancy		"C" Grade		Culls		Extra fancy and fancy	
		1914	1915	1914	1915	1914	1915	1914	1915	1914	1915	1914	1915	1914	1915	1914	1915	1914	1915
30	$A_2 B_2 C_2$	6	6	39.39	39.36	283.7	248.9	171.6	169.7	33.1	17.2	27.4	51.	23.9	21.4	15.6	10.5	60.5	68.2
31	$A_2 B_2 C_2$	5	4	27.76	20.63	278.7	222.6	179.5	127.1	25.2	12.1	39.2	45.	14.6	26.3	20.9	16.3	64.4	57.1
32	$A_2 B_2 C_2$	3	2	14.54	7.63	307.6	100.8	196.9	69.8	22.6	19.2	41.4	50.	11.8	15.4	24.1	15.7	64.	69.2
33	$A_2 B_2 C_2$	5	3	33.01	22.06	250.2	70.4	196.2	50.	41.5	32.8	36.9	38.2	4.6	16.4	16.9	12.6	78.4	71.(
34	$A_2 B_2 C_2$	5	3	28.57	25.06	380.2	102.4	318.2	64.5	34.9	15.8	48.8	47.2	6.	15.8	10.2	21.2	83.7	63.
35	$A_2 B_2 C_2$	4	3	21.86	17.17	317.2	206.9	175.7	119.8	22.5	10.9	32.9	47.	28.9	27.8	15.6	14.5	55.4	57.9
36	$A_2 B_2 C_2$	5	2	32.50	13.99	242.2	125.	169.3	73.	29.4	4.9	40.5	53.5	22.1	26.7	8.	15.1	69.9	58.4
37	$A_2 B_2 C_2$	3	3	15.92	15.78	267.3	114.1	219.7	73.4	41.1	16.1	41.1	48.2	12.1	10.7	5.7	25.2	82.2	64.3
38	$A_2 B_2 C_2$	3	2	16.15	9.08	262.3	42.8	210.8	26.5	45.4	20.5	34.9	27.3	5.2	9.2	14.5	42.8	80.3	47.8
39	$A_2 B_2 C_2$	3	3	13.89	15.22	253.0	53.5	202.1	30.5	46.4	18.3	33.5	38.7	4.5	20.4	15.6	22.7	79.9	57.0

As before mentioned a frost cut down the yield slightly in 1914. The damage seemed to be fairly uniform thru the various plats. The frost came in June after the apples were formed and russet rings were left about the middles and blossom ends. Moreover, many were left with brown areas within which caused them to grow one sided or flatter on their axes. At thinning time an attempt was made to pull these blemished fruits but many escaped notice and at picking time the culls and lower grades of fruit contained many so marked.

The grading of the apples was in accordance with the grade and pack rules published by the North Pacific Fruit Distributors. The culls picked up under the trees included small and misshaped apples discarded at picking time. These were combined with the culls secured at the packing shed and were measured in loose boxes. For comparison one loose box was considered equal to two-thirds of a packed box. There was but one picking made in 1914, therefore, the percentage of apples reduced from Extra Fancy to Fancy or from Fancy down to Choice on account of lack of color, was higher than would have been the case had two or more pickings been made.

Taking the total yields per plat in 1914, including all grades of apples, it will be seen that the highest yield was easily that of plat 34 which received a total of 28.57 acre-inches for the season. This plat yielded at the rate of 380.2 boxes per acre including all grades and 318.2 packed boxes per acre of the Extra Fancy and Fancy grades which is a good yield considering the age of the trees. It will be remembered that a cover crop of clover had been seeded in the spring and that the 28.57 acre-inches of water had kept the clover growing nicely and had given a perfect stand. A light clipping in the summer was left on the ground and a clipping for hay in the fall produced about three-fourths of a ton per acre. Seven samples of the soil in plat 34 taken at various times during the irrigation season, before and after irrigation, gave an average moisture content for a four-foot depth of 19 per cent. The dates of irrigation for plat 34, as well as the dates of irrigation for other plats, may be seen by referring to charts 2 to 11 inclusive, giving treatment and results. The schedule of treat-

ment for plat 34 was one calling for increasing amounts of water as the fruit began to swell and increasing frequency of irrigation almost up to the time of fruit maturity.

The plat giving the highest percentage of Extra Fancy and Fancy fruit in 1914 was also plat 34 with 83.7 per cent of the total yield in these two grades.

The table on yields and grades of fruit secured shows many deviations in results which are without satisfactory explanation. Individuality of trees in small plats often counter-balances the effect of the plat treatment and it is thought that this factor unquestionably vitiated the results of the 1914 crop in both yield and grade of fruit secured. Size and color of fruit, and to a less extent, keeping-quality, showed a more marked variation due to the different irrigation systems of the experiment in 1914 than did yield or grade of fruit. Since the yield factor is largely dependent upon the formation of fruit buds the previous year, the different systems of irrigation during the first year of the experiment could not be expected to influence this factor to a very great extent other than in the size of the apples.

In 1915 the spring frost at blooming time damaged the crop seriously and brought the yield for the orchard to less than one-half that of 1914. This would not have affected the yield and grade results so seriously if it had been uniform over all plats, but the frost damage was uneven, damaging most those that lay on the lower or south side of the orchard tract. The plats along the road on the north escaped with less frost damage. This fact makes comparison of fruit yields and grades of the different plats for 1915 of no value.

Storage Quality. An attempt to determine the effect of different systems of irrigation of apples upon the keeping-quality of the fruit was made by selecting each fall, representative samples of the fruit grown and placing them in storage for examination from time to time. From the Nesbit experiment two boxes were selected from each plat of the 1914 crop, care being taken to select apples of the same size, 125 to the box, and all of Extra Fancy grade. One series of these boxes was expressed to Payette and there held in cold storage; examinations were made on January 26 and March 22 to 24, 1915. The other series of sample boxes was likewise shipped to Payette and held in cold storage until January, then was loaded into a refrigerator car without icing and sent with other fruits to the Panama-Pacific International Exposition at San Francisco. An automatic thermograph instrument, loaned by the local U. S. Weather Bureau, was placed in the car with the fruit for the purpose of determining the temperature changes to which the fruit was exposed while in transit. The fruit reached San Francisco in good condition and was placed in cold storage where it was held at about 32 F. until March 1 when it was removed from the cold room and allowed to stand for several days in a room where temperature ranged from 50 to 60 F. On March 6 an examination was made of its condition. It was thought that by this plan the fruit would be subjected to the average range of conditions to which it would ordinarily be subjected in the process of marketing.

The results of the storage tests are shown in the tables which follow:

Table 13. Storage Results of Jonathan Apples—Nesbit Orchard 1914 Crop. Stored in Payette Cold Storage. Examinations Made Jan. 26 and Mar. 22-24, 1915.

Plat No.	30	31	32	33	34	35	36	37	38	39
	%	%	%	%	%	%	%	%	%	%
Perfect (including scald)	78.4	61.6	76.8	72.9	88.0	91.2	72.8	68.8	75.2	85.6
Fruit Spot	16.8	12.8	22.4	20.0	11.2	5.6	7.2	27.2	24.8	9.6
"Punk"	3.2	18.4	3.2	5.6	1.6	2.4	20.0	3.2	2.4	2.4
Rot	0.0	1.6	1.6	1.6	.8	0.0	0.0	0.0	.8	0.0

Table 14. Storage Results of Jonathan Apples—Nesbit Orchard 1914 Crop. Examinations Made at San Francisco, March 6, 1915.

Plat No.	30	31	32	33	34	35	36	37	38	39
	%	%	%	%	%	%		%	%	%
Perfect and scald	86.4	67.2	65.5	84.0	77.5	75.2		82.4	83.2	59.3
Spot	15.2	4.8	32.8	10.4	34.4	28.0	lost	12.8	16.8	42.4
"Punk"	8.8	30.4	2.8	8.0	0.0	0.8		7.2	2.4	0.8
Rot	1.6	0.0	1.6	0.8	2.4	0.0		4.8	2.4	3.2

The storage troubles noted in the tables include those common to the Jonathan apple. The "fruit spot" noted is the common black "speck" which frequently appears upon the skin of the fruit. The scald noted was a brown scald of the skin apparently developed as a result of wrapping the fruit while too warm or developed from overheating while in transit from Twin Falls to Payette. The rots developed were the commonly occurring ones and the trouble mentioned as "punk" was the brownish discolored tissue which caused the fruit to become soft and spongy from within prior to complete decay.

Punk. Among the conlusions to be drawn from the observations made in the examinations at Payette is the fact that the highest average percentage of "punk" apples developed in the plats which were given the most water during the period the principal growth of the apple was made. In plats 30, 31, 33, 34, and 36, the five plats which received the heaviest applications of water during the apple-forming period, the average percentage developing this condition was 9.7 of the total; the remaining five drier plats showed only 2.7 per cent. The least amount developing in any plat was in plat 34 with but 1.6 per cent. Other observations with stored fruit of varying sizes lead to the conclusion that large-sized fruit usually developed more "punk" than small sizes, and deeply colored Jonathans developed more of the trouble than the lightly colored ones. It was not surprising, therefore, to find that fruit from the plats given the most water late in the season developed the most "punk" even tho the fruits compared were of equal size. These observations were verified in the case of the examinations made at San Francisco where 11.8 per cent of the fruit from the four plats given the most water during the apple-forming period showed "punk" and but 3.3 per cent of the fruit from the four plats given the least water during that period showed the same blemish. We may say, therefore, that both size and color are known to be factors influencing "punk" in Jonathans. These conditions are partially under the control of the irrigator and it is readily apparent that the water applied can be made to have an important bearing upon the keeping-quality of Jonathans. While orchards of this variety are young the system of irrigation

should be such as to induce sizes not greater than 125 apples to the box as otherwise the percentage of "punk" apples will be high. The system of irrigation practiced with plat 34 showed good results in avoiding this trouble.

Fruit Spot and Shrivelling. There were two storage troubles which, on the other hand, were apparently aggravated in the plats kept driest during the apple-forming period. These were Jonathan "fruit spot" and shrivelling. Invariably the plats which were dry during the apple-forming period, like plats 32, 37, 38, and 39 showed least juiciness in the fruit and greatest withering and shrivelling in storage. "Fruit spot" developed similarly. For instance, in those shipped to San Francisco, from the four dry plats (32, 37, 38 and 39), 26.2 per cent developed "fruit spot," while in those shipped from the four wet plats, 30, 31, 33 and 34, but 16.2 per cent were affected and in some of these the trouble was very slight. A comparison of the samples stored at Payette also showed a greater percentage of "fruit spot" in the fruit from the plats given the smaller amounts of water. The scald did not seem to have any connection with methods of irrigation, nor did the ordinary rot which more often developed about blemishes and bruises. Duplicate boxes of fruit from all parts from the 1915 crop at Nesbit's were also held in Payette in cold storage and at the University of Idaho at Moscow for examination and verified the conclusions noted.

We may say, therefore, that the quality of apples may be influenced by the plan of irrigation. Neither the maximum nor the minimum amount of water is most desirable. An even amount increasing as the season advances to a week or ten days before picking time seems to develop the best keeping-quality without sacrificing any of the crispness and "snap" so essential to a good apple.

Correlation of Irrigation With the Setting of Fruit Buds

In this experiment, no observations were made on the time of formation of fruit buds, altho general notes were taken upon their development on the different plats. But very little difference in the development on the various plats could be seen with the unaided eye. The very great importance of the influence of irrigation upon the fruit buds for the following year's crop was realized and plans were made to determine the number of fruit buds which were developed upon each plat by counting the number of apples thinned off and harvested from each tree the following year. This procedure would have shown the effect of each system of irrigation upon the formation of fruit buds, had not the light frost in the spring of 1915, which affected the plats unevenly, and the heavy frost in the spring of 1916, which completely destroyed the crop, occurred.

It is a well-observed fact that a tree making an excessive wood growth forms very few fruit spurs. A slow-growing tree forms more fruit buds for the next year's crops of apples. Hence excessively heavy irrigations in the spring and early summer, especially in late June and early July, are determinal because they cause heavy wood growth and prevent the setting of fruit buds. A normal, moderate wood growth is

the best. Such a growth may be obtained, even tho heavy spring irrigations are applied, if a dense cover crop of a deep-rotted plant such as alfalfa is in the orchard. The greatest danger is heavy, early irrigations under clean cultivation.

It is also well known that thinning bears a very important relation to the formation of fruit buds. A tree which bears a very large crop which is not thinned will tend to bear a light crop the following year.

Dormant Irrigation

In this experiment, plat 40 was given normal irrigation during the growing season and a heavy application in the late fall after the wood of the trees was thoroly ripened, altho the leaves were still on the trees and quite green at that time. This application was made as late as possible before the earth froze. The results obtained lead to the conclusion that this late dormant irrigation is very beneficial.

The question often arises whether all orchards in a locality with the same type of soil come out in the spring with approximately the same percentage of soil moisture, even tho some went into winter moist and others dry. In other words, will a late dormant irrigation in the fall show its effect on the soil moisture the following spring? The figures for the following table were obtained from charts 2 to 11 inclusive, for the winters of 1914-15 and 1915-16.

Table 15. Relation between Soil Moisture in Late Fall and the Following Early Spring

Plat No.	Soil moisture in late fall per cent.	Soil moisture in early part of following spring per cent
30	17	16
31	22	17
32	9	8
33	9	9
34	21	15
35	15	13
36	13	10
37	19	15
38	15	10
39	9	9
39	10	10
Average	14	12

These figures tend to confirm the belief that the percentage of soil moisture in the fall affects the percentage during the entire winter. They also show that the soil loses an average of two per cent of its moisture during the winter period, despite winter precipitation. The average winter precipitation in this locality is five inches. This moisture must be passed off thru evaporation from the soil and the limbs of the trees, and by the cover crop.

The importance of having a normal supply of water in the soil during the winter is apparent when we consider that the dormant period covers practically six months. If the soil is excessively dry during this long period, the limbs will tend to shrivel, winter killing may re-

sult, and the orchard leaf out in the spring in an unhealthy condition. Many observers claim that this is one of the most potent causes of an excessive "June drop" of the apples. It is known that in a forest under natural conditions, the percentage of soil moisture during the winter is quite high, because the fallen leaves act as a mulch in retaining the fall rains.

The great danger in applying irrigation water in the fall lies in its tendency to keep the sap up during the winter in which case winter killing may result. After the apples are picked, the orchard should be allowed to dry out so that the trees will ripen their wood thoroly before dormant irrigations are given.

Some advantages of this fall irrigation when properly applied other than its beneficial effects upon the trees are: Greater amounts of available water, since other crops do not need it then; lessening of losses from evaporation because of the cooler weather; permitting the freer use of water in the spring for other crops.

EXPERIMENTS IN THE HARLAND ORCHARD

The Harland orchard is located in the Woods Spur district about three miles north and one-half mile east of Payette. It is representative of the orchards of that section, was in a vigorous condition, and had received good care. The experimental blocks consisted of separate blocks of Winesaps and Jonathan trees about 12 years old at the beginning of the experiment in 1913. The selection of the orchard for experimental work and the laying out of the plats was done before either of the authors of this report became connected with the work.

The soil in the plats is sandy and one of the best types of orchard soil to be found. The surface soil may be described as a sandy loam with slight clay admixture. Physically this surface soil is ideal under most conditions, cultivating loosely without baking or forming clods. This sandy loam extended in the experimental blocks to a depth of 1 1-2 to 3 feet to a layer of sand which in turn extended downward below the deepest tree roots and insured excellent drainage. There are many fruit districts along the Snake River and in the upper Payette Valley with a similar soil formation. The performance of irrigation water in these sandy soils is materially different from its performance in the typical clay loam or so-called volcanic ash soils so common in South Idaho, and a comparison between the water requirements of this and the Twin Falls soil will be of interest.

Red clover was grown as a cover crop in the Harland orchard in the years 1913 and 1914 with plants rather scattering the latter year. Two crops of hay each year were clipped and taken from the orchard and the pasturage was utilized in the fall. In the fall of 1914 the orchard was plowed both ways, thoroly worked, and kept under cultivation in 1915. Dormant sprays of lime-sulphur against scale insects and summer sprays against the codling moth were applied uniformly over all plats each year.

Pruning was uniform on all plats. The pruning consisted of

thinning out of branches where too thick and in a clipping back and thinning out of fruit spurs on the Winesaps in the spring of 1914. Some heading back of leading limbs, especially upon Winesaps, was done at about the time the experiment was started but after that no heading back was done except in the case of blighted or broken branches.

The crop was a normal one on both Jonathans and Winesaps in 1913. In 1914 frost reduced the Winesaps to a light crop but left a fair crop of Jonathans and in 1915 both Jonathans and Winesaps gave good crops. Thinning was done each year.

Difficulties Encountered

There were 75 Jonathan and 69 Winesap trees in the experimental blocks, and the number of trees per plat varied from 4 to 10. The small number of trees per plat was one serious objection in comparing yields and made comparisons of less value than they should have been.

The trees were planted about 25 feet apart, but to secure division into the required number of plats and to give water the most even distribution, corrugations were made and water was run diagonally with the rows. This made the plats small and it was found that trees on the border of plats receiving light irrigations were greatly affected by the water from adjacant heavily-irrigated plats and in places the proximity of service or waste ditches could be seen to have an effect upon bordering trees.

The source of irrigation water was the canal of the Payette Heights Irrigation District which canal is fed by an electric pumping plant from a canal which runs at a lower level and which gets its supply from the Payette River. The plan of irrigation for the experiment could not be adhered to on account of insufficient pumping equipment. There were times when a shortage of water was experienced and the schedule of treatment was obliged to vary in both time of irrigation and amount of water given.

All water applied and waste collected were measured thru standard Cippoletti weirs properly set. The samples for soil moisture determinations were carefully taken with a King soil tube, the drying was done in a Sargent electric oven equipped with a thermostat, and the weights were made with care.

In spite of the objectionable details from an experimental standpoint which became apparent, some important data were secured in this orchard and the results are briefly given tho in less detail and entirely independent of the results in the Nesbit orchard where the experimental conditions were under much better control.

The schedule of treatment for 1914 is shown in the following table:

Table 16. Schedule of Treatment of Plats at Harland Orchard

Plat	Variety	Approximate schedule	Water used in acre-inches; also times irrigated (1914) A	B	C	Total
10	Winesap	A6% B6% C6%	(1) 9.12	(1) 8.64	(1) 11.08	(3) 28.84
11	Winesap	A8% B8% C8%	(2) 18.60	(1) 7.34	(1) 8.32	(4) 34.26
12	Winesap	A10%B10%C10%	(2) 16.54	(2) 11.84	(2) 22.26	(6) 50.64
13	Winesap	A12%B12%C12%	(3) 22.22	(1) 7.63	(1) 4.48	(5) 34.33
14	Winesap	A14%B14%C14%	(3) 24.08	(2) 15.30	(2) 25.56	(7) 64.94
15	Winesap	A10% B7%C10%	(2) 7.83	(1) 7.79	(3) 26.08	(6) 41.70
16	Winesap	A10% B7% C7%	(2) 12.57	(1) 11.95	(1) 13.50	(4) 38.02
17	Winesap	A7%B13% C7%	(1) 5.06	(2) 17.38		(3) 22.44
18	Winesap	A7%B13%C13%	(2) 13.98	(1) 6.08	(2) 20.99	(5) 41.05
19	Winesap	A10%B10%C10%	(2) 13.32	(2) 13.85	(2) 14.44	(6) 41.61
20	Jonathan	A6% B6% C6%	(1) 7.54	(1) 8.82	(1) 8.98	(3) 25.34
21	Jonathan	A8% B8% C8%	(2) 10.85	(1) 5.97	(1) 3.28	(4) 20.10
22	Jonathan	A10%B10%C10%	(2) 10.14	(2) 11.38	(2) 12.90	(6) 34.42
23	Jonathan	A12%B12%C12%	(3) 17.64	(1) 5.77	(1) 10.32	(5) 33.73
24	Jonathan	A14%B14%C14%	(3) 13.36	(2) 10.88	(2) 16.40	(7) 40.64
25	Jonathan	A10% B7%C10%	(2) 10.60	(1) 8.37	(2) 18.25	(5) 37.22
26	Jonathan	A10% B7% C7%	(2) 13.85	(1) 8.78	(1) 11.35	(4) 33.98
27	Jonathan	A7%B13% C7%	(1) 6.81	(2) 18.11	(1) 15.37	(4) 40.29
28	Jonathan	A7%B13%C13%	(2) 14.41	(1) 4.22	(2) 21.28	(5) 39.91
29	Jonathan	A10%B10%C10%	(2) 8.45	(2) 10.95	(1) 4.62	(5) 24.02

Some Results at the Harland Orchard

Because of the sandy soil at the Payette orchard it was impossible to hold the moisture content as high as in the volcanic ash soil at Twin Falls. The hygroscopic moisture content was determined for the Payette sandy soil to be 2.4 per cent and free water in the soil prevented soil samples being drawn in the soil tube containing more than 13 per cent moisture. It is probable therefore that the range of available capillary moisture in the Payette sandy soil was about 10.6 per cent, a soil property which required shorter intervals between irrigations and close attention to prevent cover crops from burning and apple foliage from suffering. The range of available capillary water in the volcanic ash soil at Twin Falls was from 8 to 28 per cent.

In the Winesap block at Payette in 1914 the clover crop suffered

and the fruit was greatly under sized with a total application of 28.84 acre-inches in plat 10 which seemed to be the correct amount in plat 34 in the Twin Falls experiment. Jonathans in plat 20 at Payette receiving 25.34 acre-inches in 1914 also were undersized and unmarketable. The loss from deep percolation may have been considerable in this sandy soil.

Seven irrigations were applied to the maximum plat at Payette, plat 14, aggregating a total of 64.94 acre-inches in 1914. This was greatly in excess of what was necessary, for plats 13 and 18, with 34.3 and 41.0 acre-inches respectively, gave almost as good yields of Winesaps and fruit of better grade and keeping-quality. Plat 19 with 41.6 acre-inches also grave splendid results not only in 1914 but in the other years of the experiment.

Referring again to the 1914 crop of Jonathans at the Harland orchard, plats 23 and 24, with total amounts of 33.7 and 40.6 acre-inches respectively, gave the best results of the duty-of-water plats when yield, Fancy and Extra Fancy grades, and ratio of desirable storage sizes were considered.

Plats 28 and 29 gave good Jonathan yields of desirable commercial size, color, and quality with an average of 32 acre-inches.

Summing up the results obtained in the Harland orchard, it may be said that for the full bearing orchard of Winesaps and Jonathans, with clover cover crop, from 34 to 40 acre-inches per season gave the maximum results from the standpoint of yield, grade, color, size, keeping quality, health of trees and fruit development. The most successful applications were timed with an increase in amount of water as the maturing crop advanced to meet the demands of the fruit when making the greatest increase in size, and when the loss from evaporation and transpiration resulting from high temperature is great. Duplication of these results will ordinarily require about five irrigations with the first one given about the middle of May when the soil moisture has reached six or seven per cent. The early irrigations should follow at intervals of about three weeks or a month; the purpose being to hold if possible the soil moisture above eight per cent in the early or vegetative period. During the middle of the growing season (early "B" period), the irrigations should be given at intervals of about two weeks so that the soil moisture can be held at not less than 10 per cent. Later in the "B" period and all thru the "C" period, when the apples are growing most rapidly, the times between irrigation should be shortened to 10 days and the soil moisture maintained at approximately 12 per cent. Just before picking, the water may be withheld but a dormant application of water late in the fall is desirable if fall rains do not saturate the ground. The average amount of water per irrigation will approximate seven or eight acre-inches. The corrugations should be not over three feet apart and the runs short.

SUMMARY

1. The trunk of an apple tree makes its growth during the first part of the growing season. By August 1, 75 percent of the total season's growth is completed. A cover crop greatly checks the rate of growth of the trunk. The trunk growth of Jonathan apple trees is directly affected by the amount of irrigation

water applied during the first part of the growing season and by the percentage of water in the soil the preceding dormant season (winter). The latter factor may easily overbalance, in its effect, the former one.

2. The terminal (limb) growth of Jonathan apple trees is practically completed by the first part of July. No growth is made after July 15. Irrigation after this date has no effect on the wood growth of the tree. As a general rule, the more irrigation water applied before July 1, the greater the terminal growth altho the percentage of moisture in the soil the preceding fall and winter probably affects the terminal limb growth. A cover crop in an orchard greatly checks the limb growth of the trees.

3. Jonathan apples grow very slowly from the time they are formed until about July 15, completing less than 30 percent of their total growth during the first half of the total period they hang on the trees. Irrigation during this period (before July 15) will not increase the size of the apples. Jonathan apples grow most rapidly during the period starting about July 15 and ending about two weeks before picking time, when the rate of growth becomes considerably slower. Irrigation during this period of rapid growth has a very decided effect in increasing the size of the apples altho it has practically no effect on the wood growth of the tree.

4. Heavy irrigations in the spring tend to increase the wood growth of an apple tree and this tends to increase fire blight. A cover crop, preferably alfalfa, greatly decreases the wood growth and so lessens the amount of blight.

5. Winter injury to apple trees, especially young trees, is usually the result of the wood of the tree not being thoroly ripened or due to the ground being too dry during the winter. It is advisable to hold the water off during the latter part of the summer and let the wood ripen; then, if the fall is excessively dry, to apply a late dormant irrigation just before the ground freezes. Cholorosis, or bunches of white leaves on apple trees, is often a sign of over-irrigation.

6. Where two plats were given an equal total amount of water for the season, one early during the vegetative period of the tree and the other later during the fruit developing season, the last mentioned system invariably produced much the larger apples.

7. Plats irrigated heavily early in the season produced heavy foliage which was detrimental to the development of color on the apples. Plats which were not forced to excessive leaf and wood growth during the vegetative period by early irrigation gave better color to the apples when given liberal applications of water during the period of most rapid apple growth. This experiment shows that fruit growers may, by irrigation, very materially augment color in fruit production if the water is applied at the right time.

8. The plat which was given little irrigation early in the season (before July) and liberal appplications during the period of most rapid apple growth (from July until two weeks before picking time) gave the highest percentage of extra fancy and fancy grades and also fruit of the best storage qualities. This plat (at Twin Falls, Idaho) with a dense clover cover crop was given a little over two acre-feet of water during the entire season. An even amount of water increasing as the season advanced to about two weeks before picking time gave apples of the best keeping qualities without sacrificing any of the crispness so essential to good apples.

9. A dormant irrigation applied in the late fall just before the ground freezes is very essential and beneficial in most of the irrigated fruit districts of Idaho. From the time that the apples are picked until this time, the orchard should be allowed to dry out in order that the wood of the trees may become thoroly ripened. The percentage of soil moisture in the late fall affects the percentage during the entire winter and early spring following. If an orchard is given this late dormant irrigation in the fall, the first irrigation the following spring may be put off considerably later than if the orchard went into the winter in a dry condition. This fall irrigation is very desirable.

10. On the sandy soil in the Payette Valley, in a full bearing orchard of Winesaps and Jonathans with a clover cover crop, about three acre-feet of water per season gave the maximum results considering yield, grade, color, size, keeping-qualities of the fruit and the health of the tree. Here, also, the best results from the application of water was obtained when most of it was applied during the period of greatest apple growth.

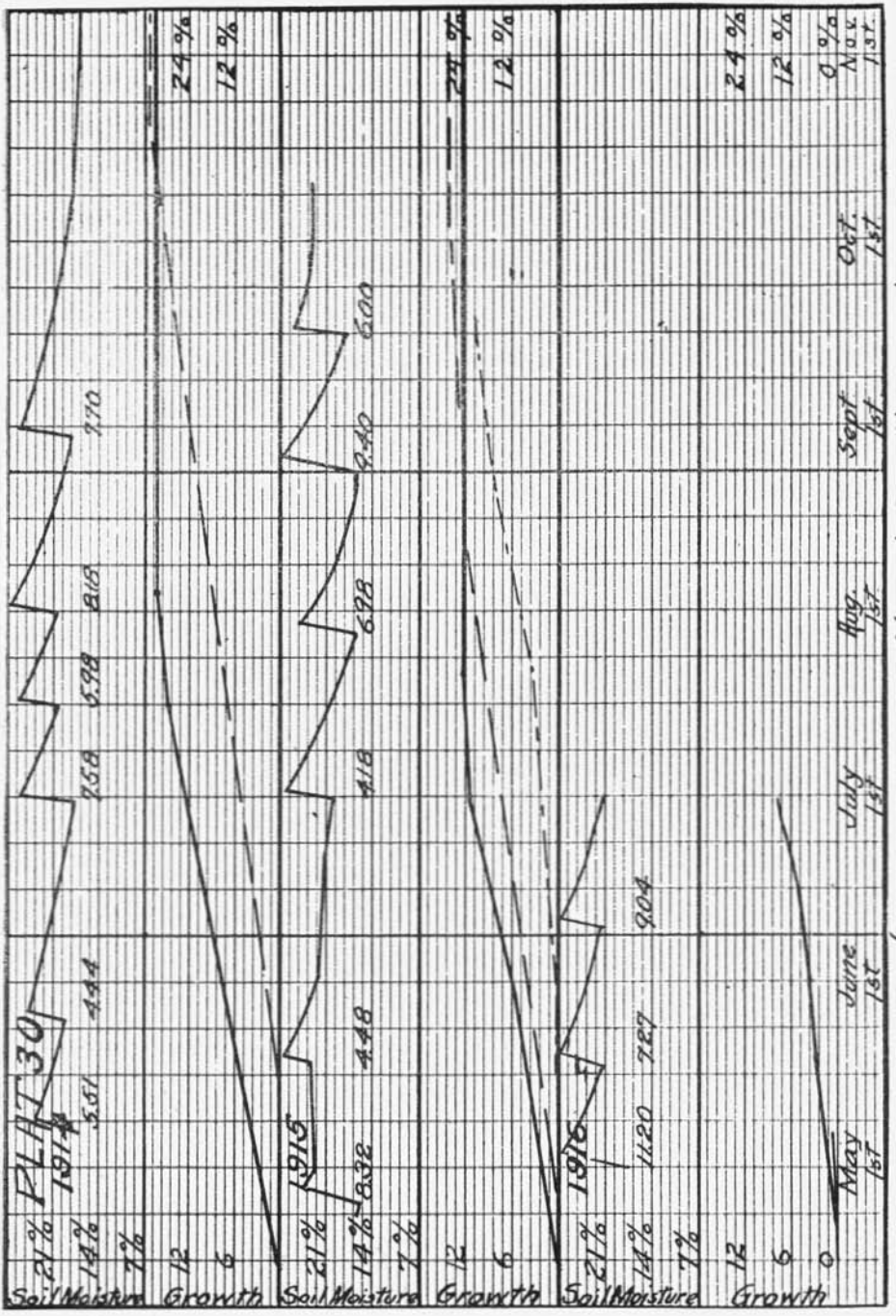


Chart 2. Plat 30 for the years 1914, 1915 and the first part of 1916, showing date of each irrigation, number of acre-inches applied by each irrigation, soil-moisture curve, and the resulting growth of terminal limbs, trunk and apples.

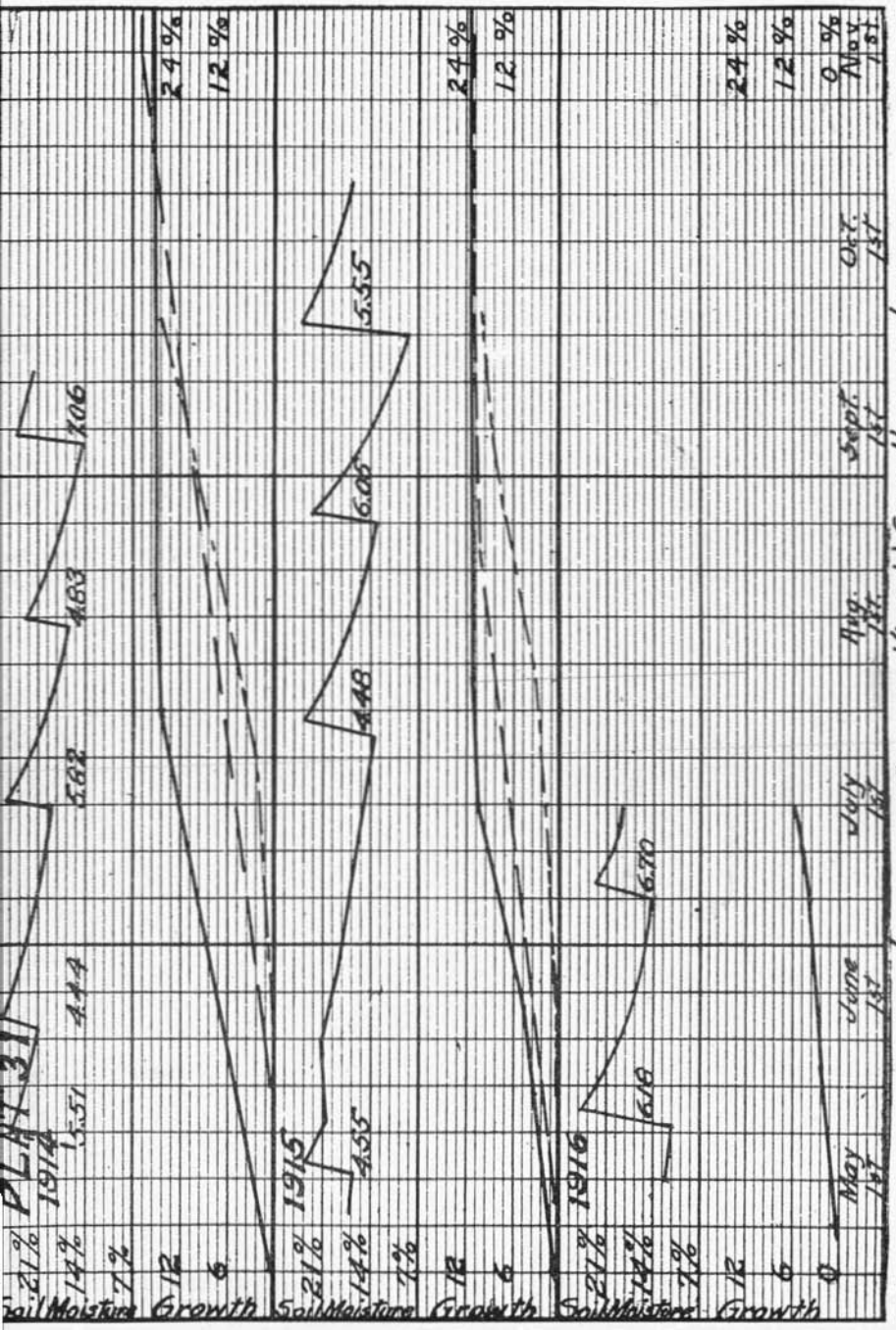


Chart 3. Plat 31 for the years 1914, 1915 and the first part of 1916, showing date of each irrigation, number of acre-inches applied by each irrigation, soil-moisture curve, and the resulting growth of termnal limbs, trunk and apples.

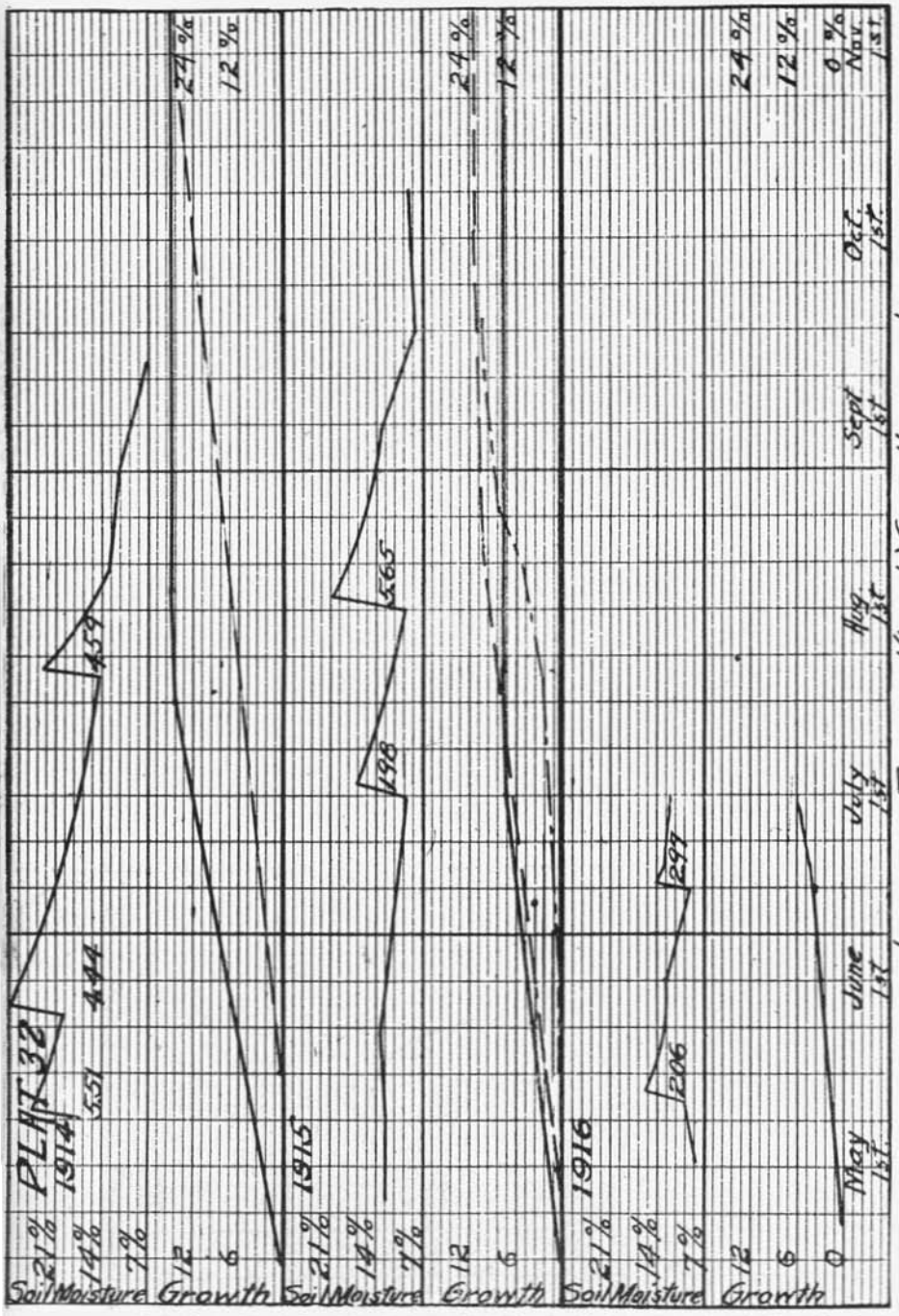


Chart 4. Plat 32 for the years 1914, 1915 and the first part of 1916, showing date of each irrigation, number of acre-inches applied by each irrigation, soil-moisture curve, and the resulting growth of termnal limbs, trunk and apples.

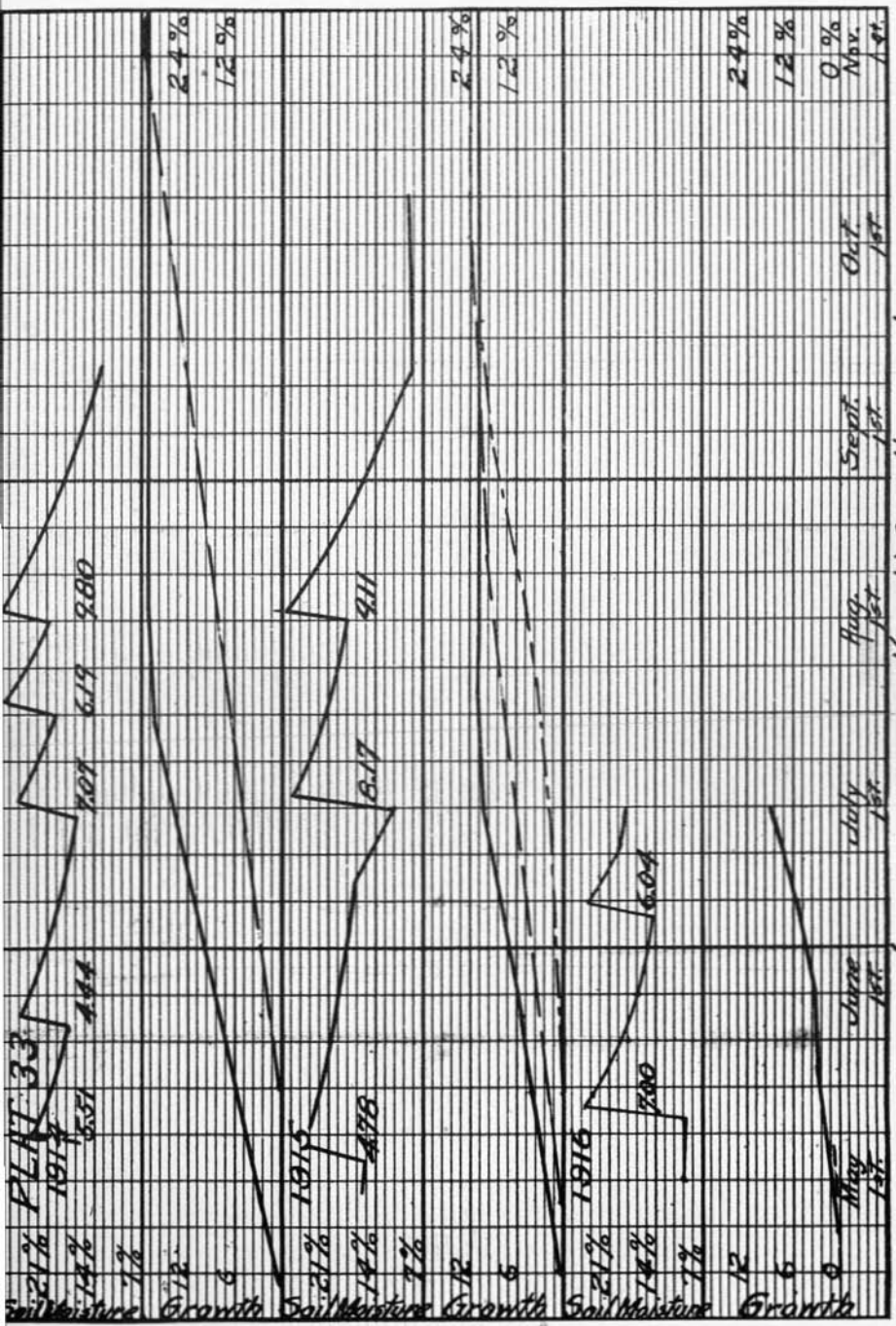


Chart 5. Plat 33 for the years 1914, 1915 and the first part of 1916, showing date of each irrigation, number of acre-inches applied by each irrigation, soil-moisture curve, and the resulting growth of terminal limbs, trunk and apples.

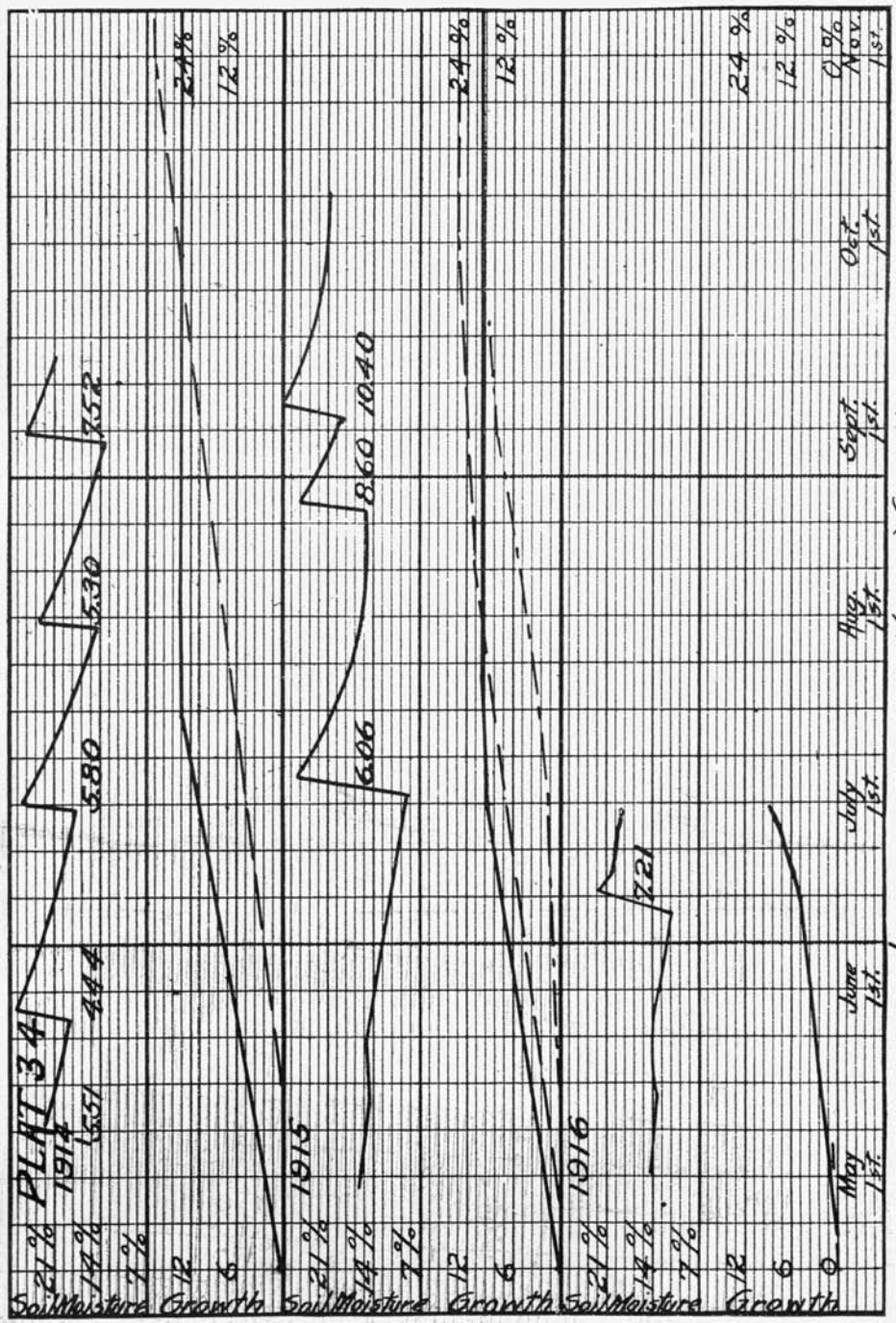


Chart 6. Plat 34 for the years 1914, 1915 and the first part of 1916, showing date of each irrigation, number of acre-inches applied by each irrigation, soil-moisture curve, and the resulting growth of terminal limbs, trunk and apples.

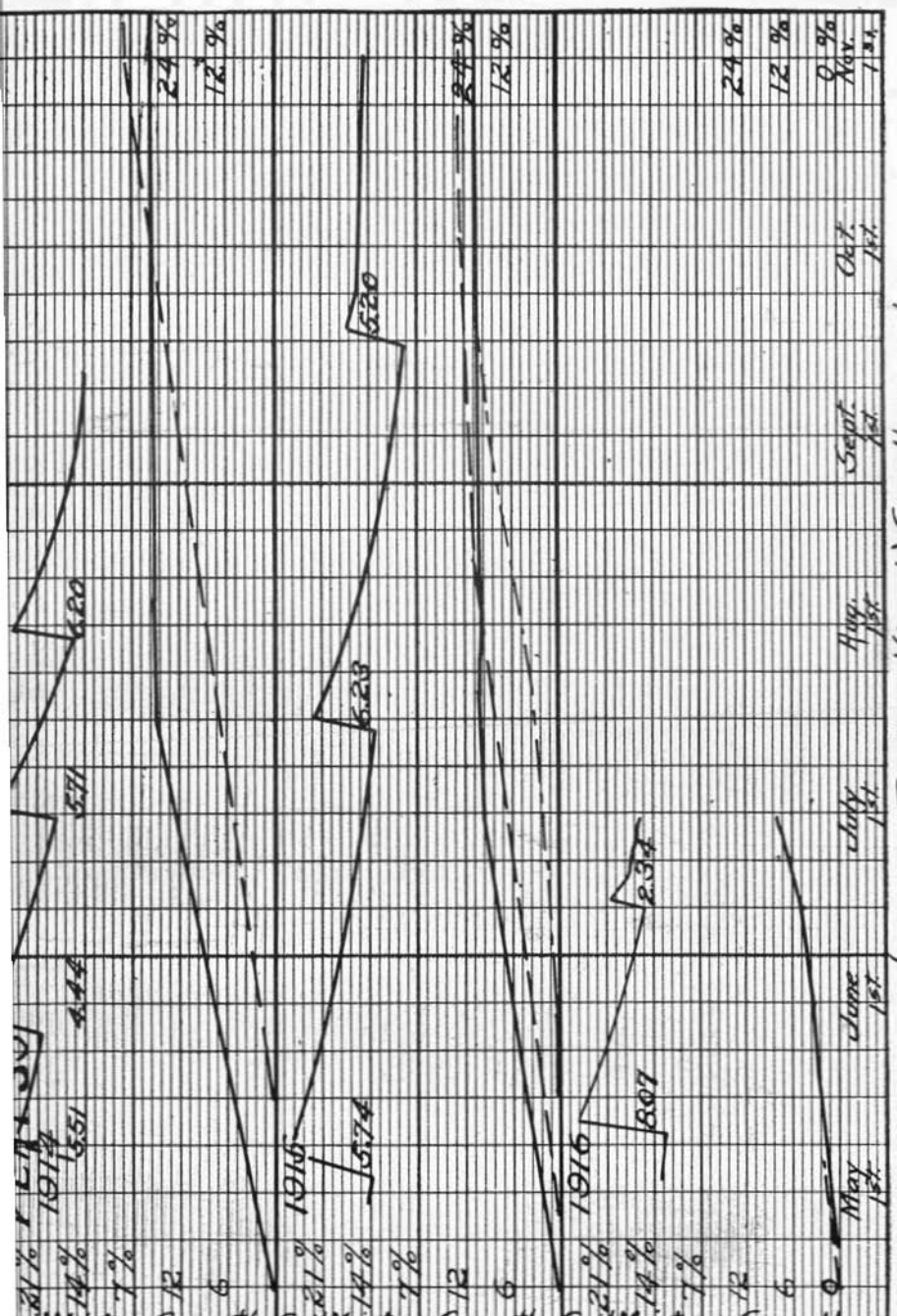


Chart 7. Plat 35 for the years 1914, 1915 and the first part of 1916, showing date of each irrigation, number of acre-inches applied by each irrigation, soil-moisture curve, and the resulting growth of terminal limbs, trunk and apples.

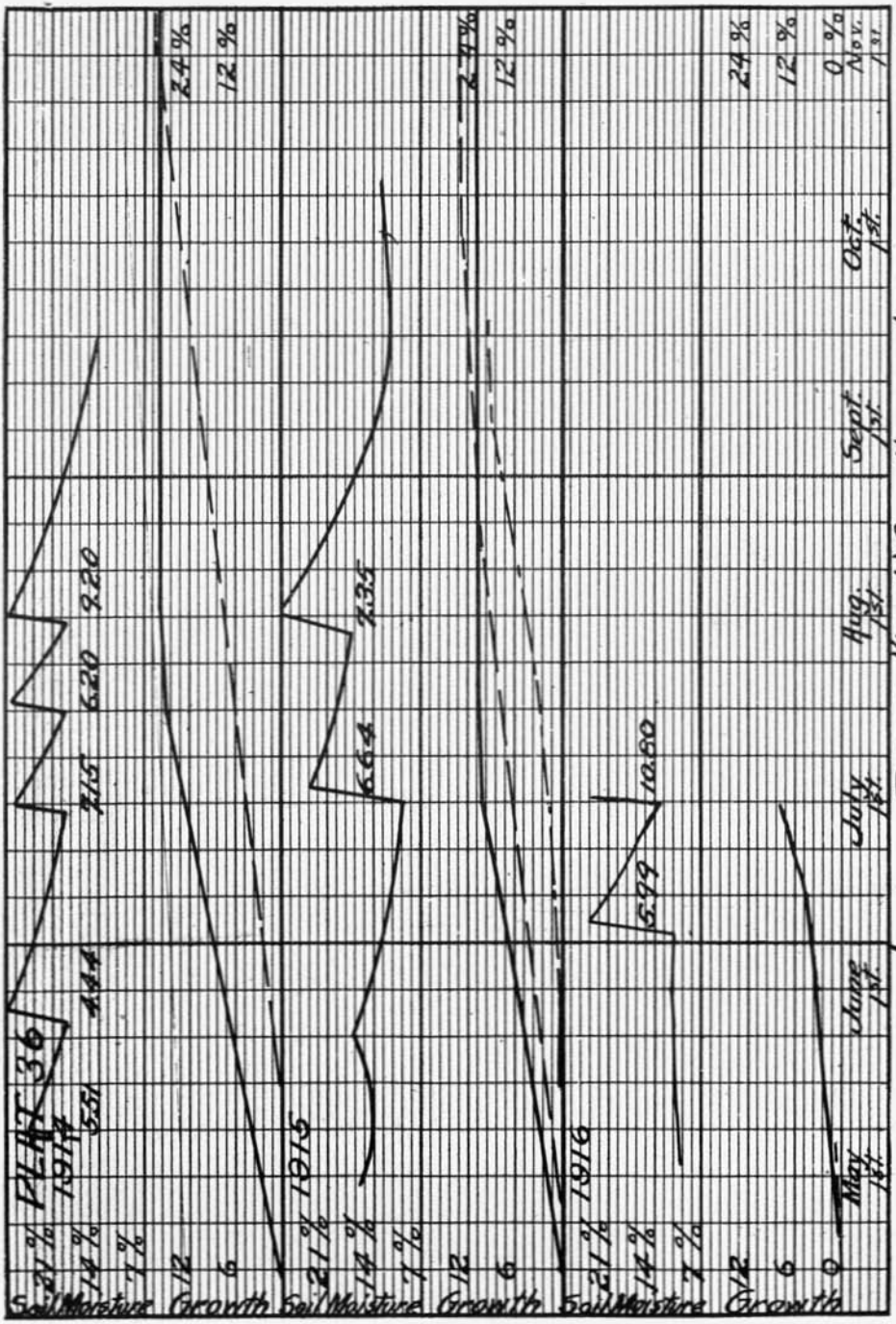


Chart 8. Plat 36 for the years 1914, 1915 and the first part of 1916, showing date of ea irrigation, number of acre-inches applied by each irrigation, soil-moisture curve, and the resulting grow of terminal limbs trunk and apples.

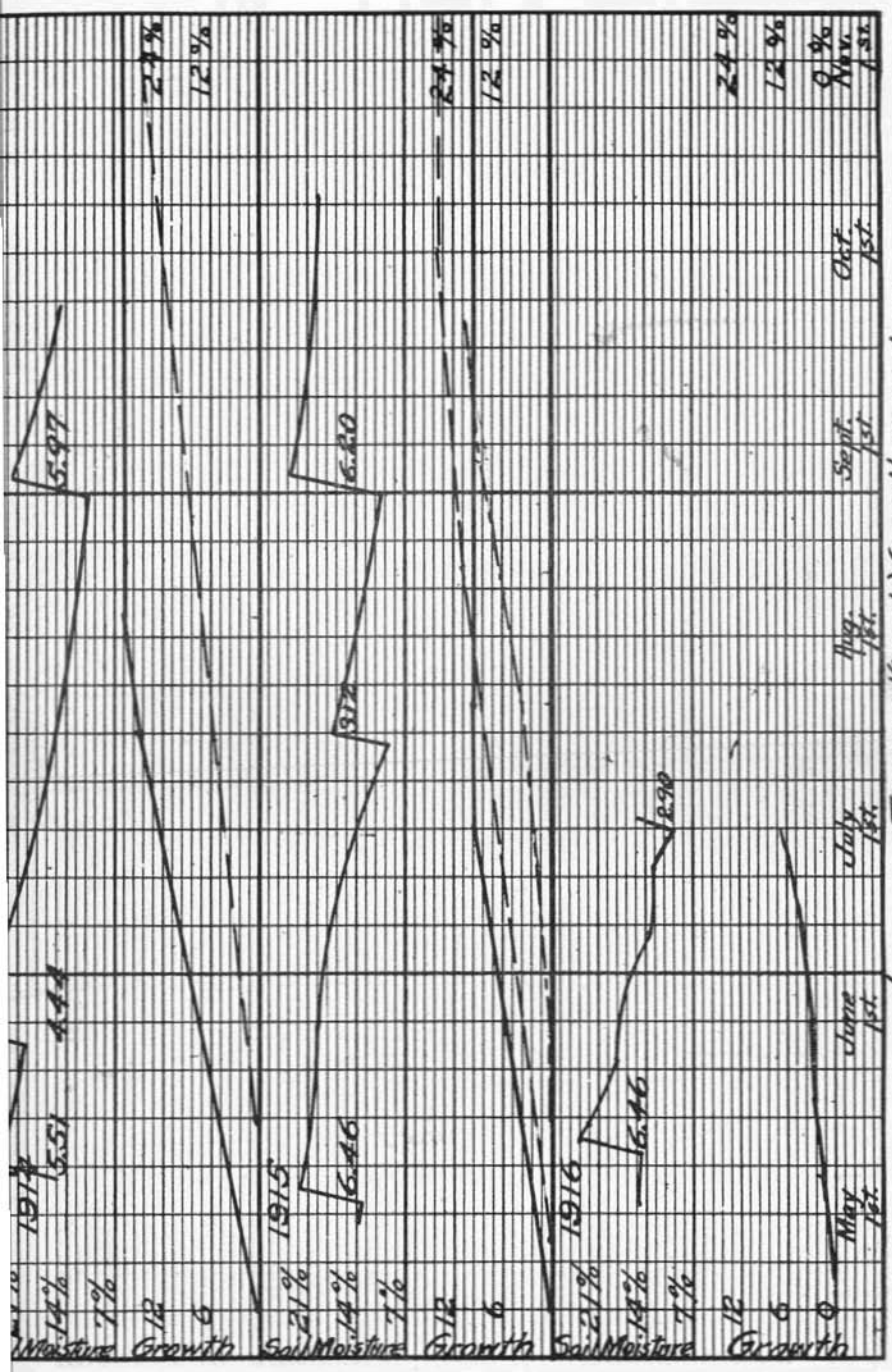


Chart 9. Plat 37 for the years 1914, 1915 and the first part of 1916, showing date of each irrigation, number of acre-inches applied by each irrigation, soil-moisture curve, and the resulting growth terminal limbs, trunk and apples.

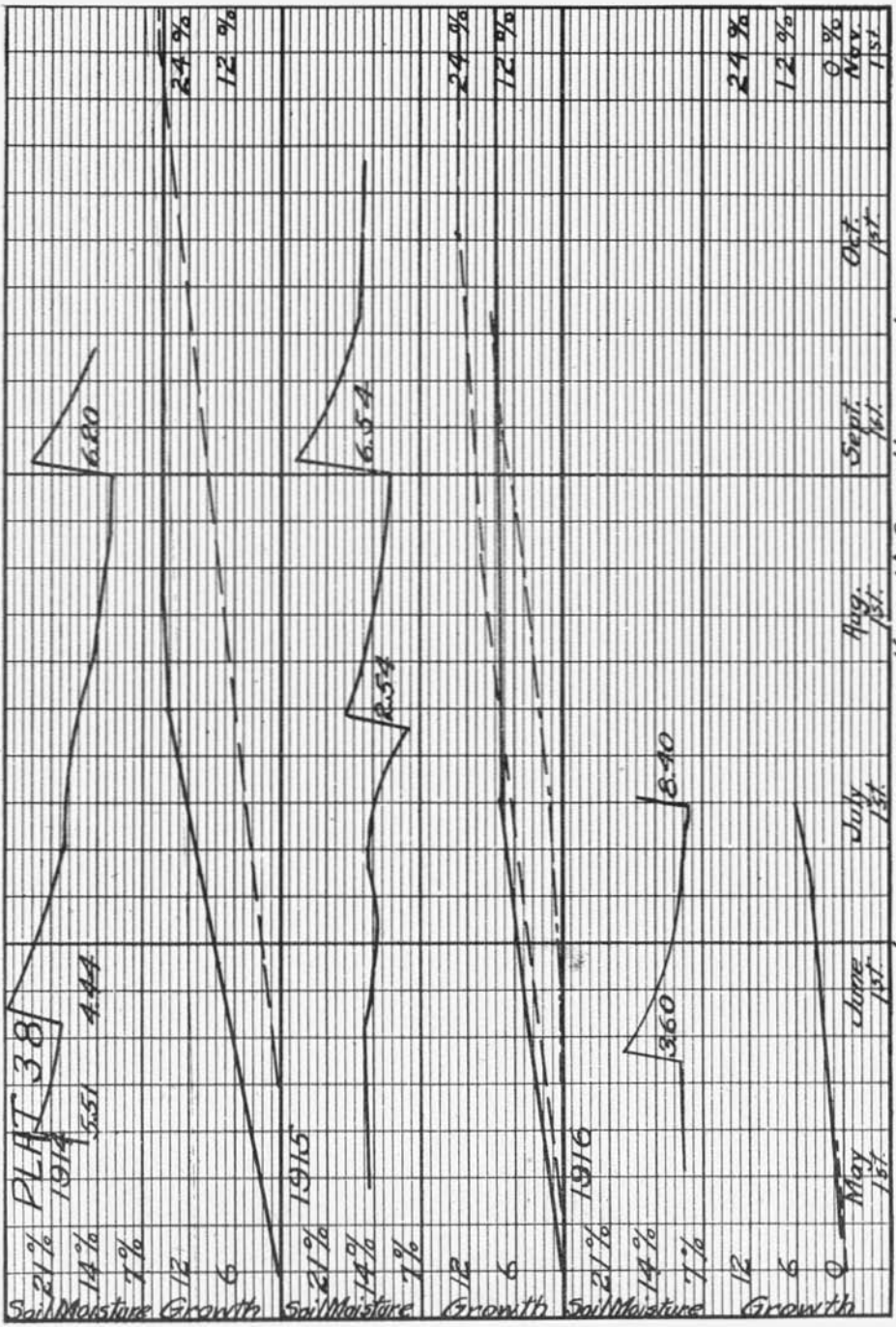


Chart 10. Plat 38 for the years 1914, 1915 and the first part of 1916, showing date of each irrigation, number of acre-inches applied by each irrigation, soil-moisture curve, and the resulting growth of terminal limbs, trunk and apples.

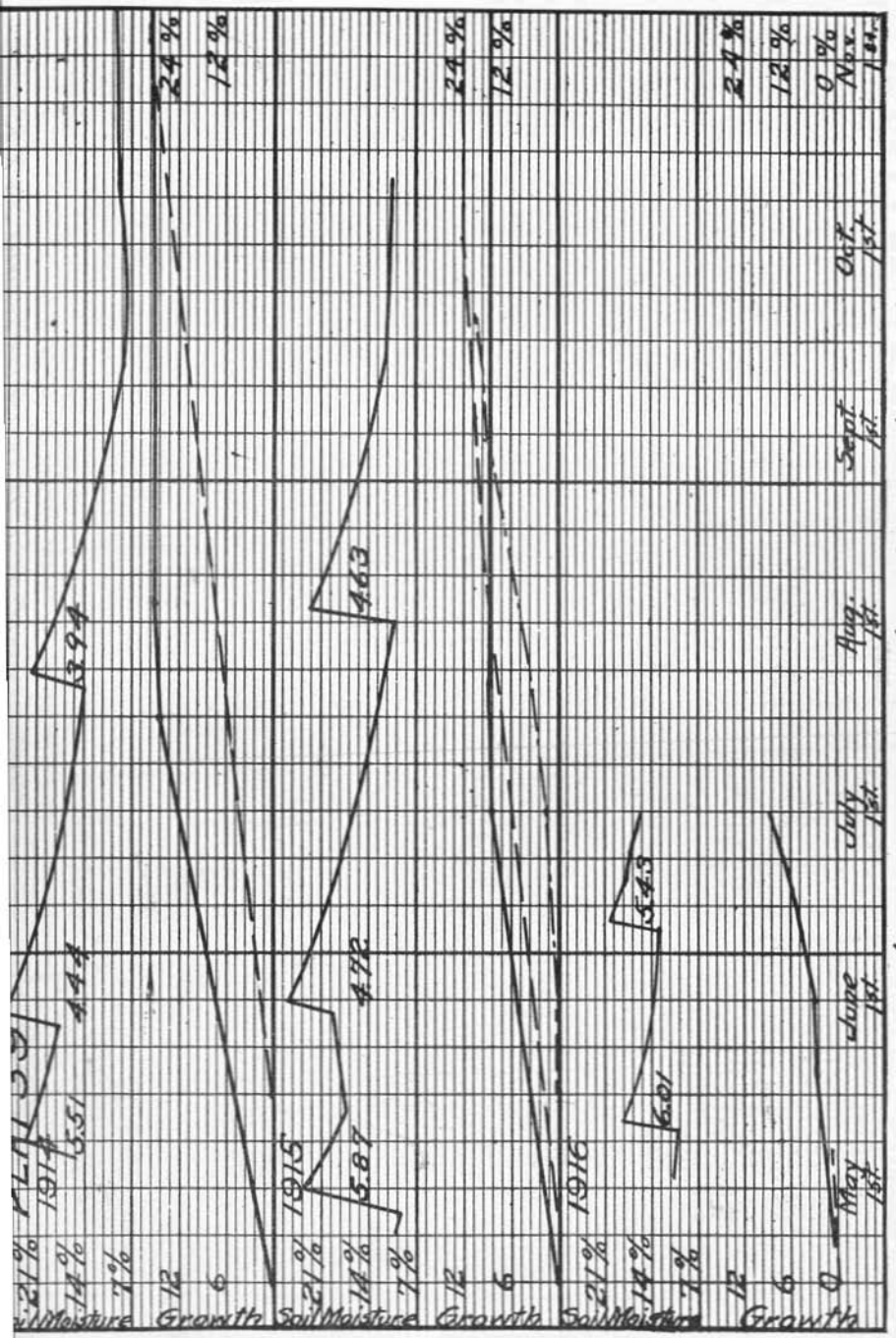


Chart 11. Plat 39 for the years 1914, 1915 and the first part of 1916, showing date of each irrigation, number of acre-inches applied by each irrigation, soil-moisture curve, and the resulting growth of terminal limbs, trunk and apples.

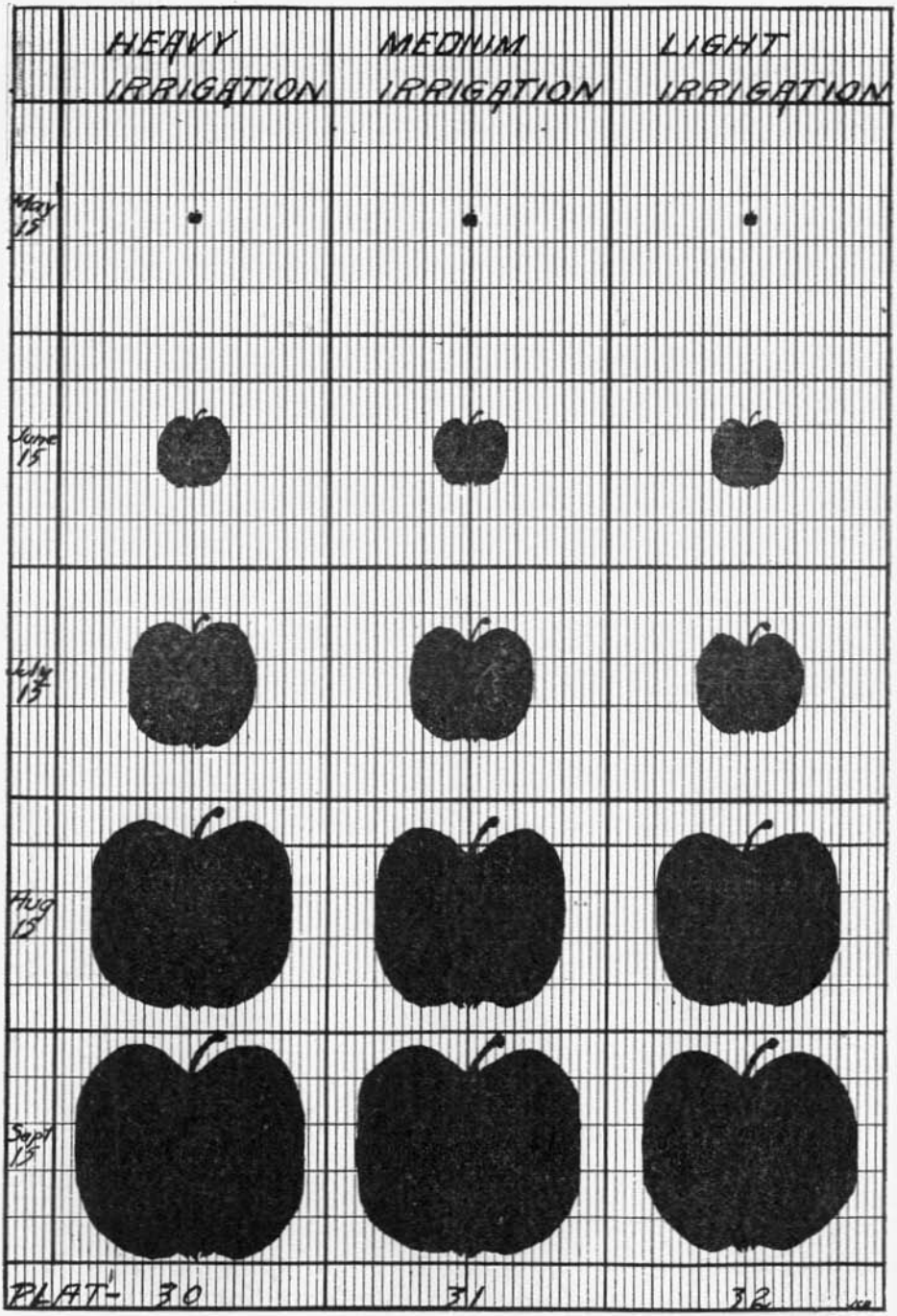


Chart 12. Showing, graphically, the time and amount of growth of apples under heavy irrigation, medium irrigation and light irrigation during the entire growing season. Note, first, that apples make their most rapid growth during the last two months before ripening, and second, that apples cannot be swelled in size by heavy irrigation previous to July 1. The area of each of the above apples is drawn to scale equal to the volume of the apples instead of the area of a cross section.

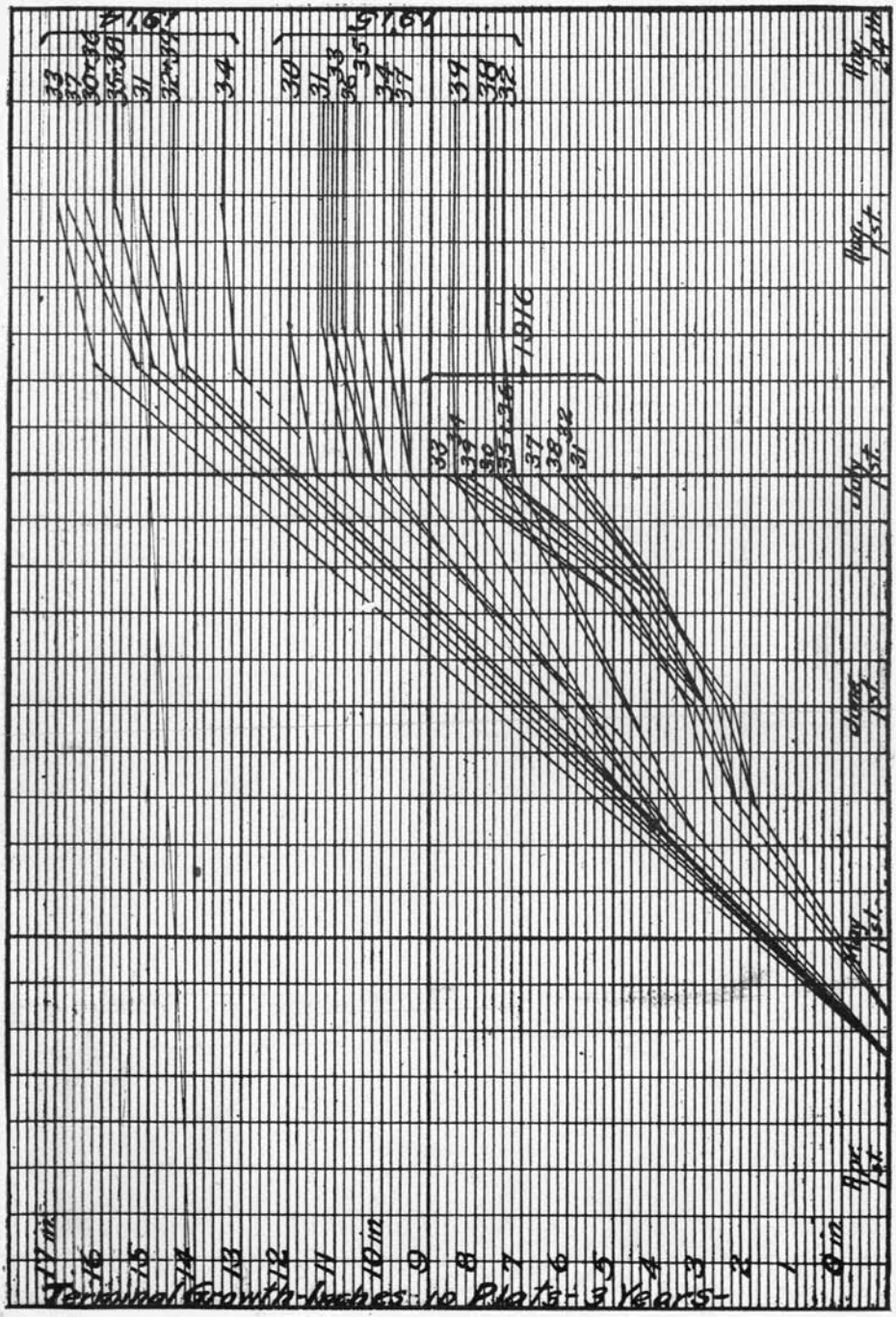


Chart 13. Showing time and amount of terminal limb growth for the ten plats for the years 1914, 1915 and 1916. Note, first, the decrease in growth each year due to the clover cover crop, and second, the fact that the growth very largely ceases by July 1. The curves for 1914 do not accurately show the time of limb growth because no measurements were made between April 15 and July 14 of that year.

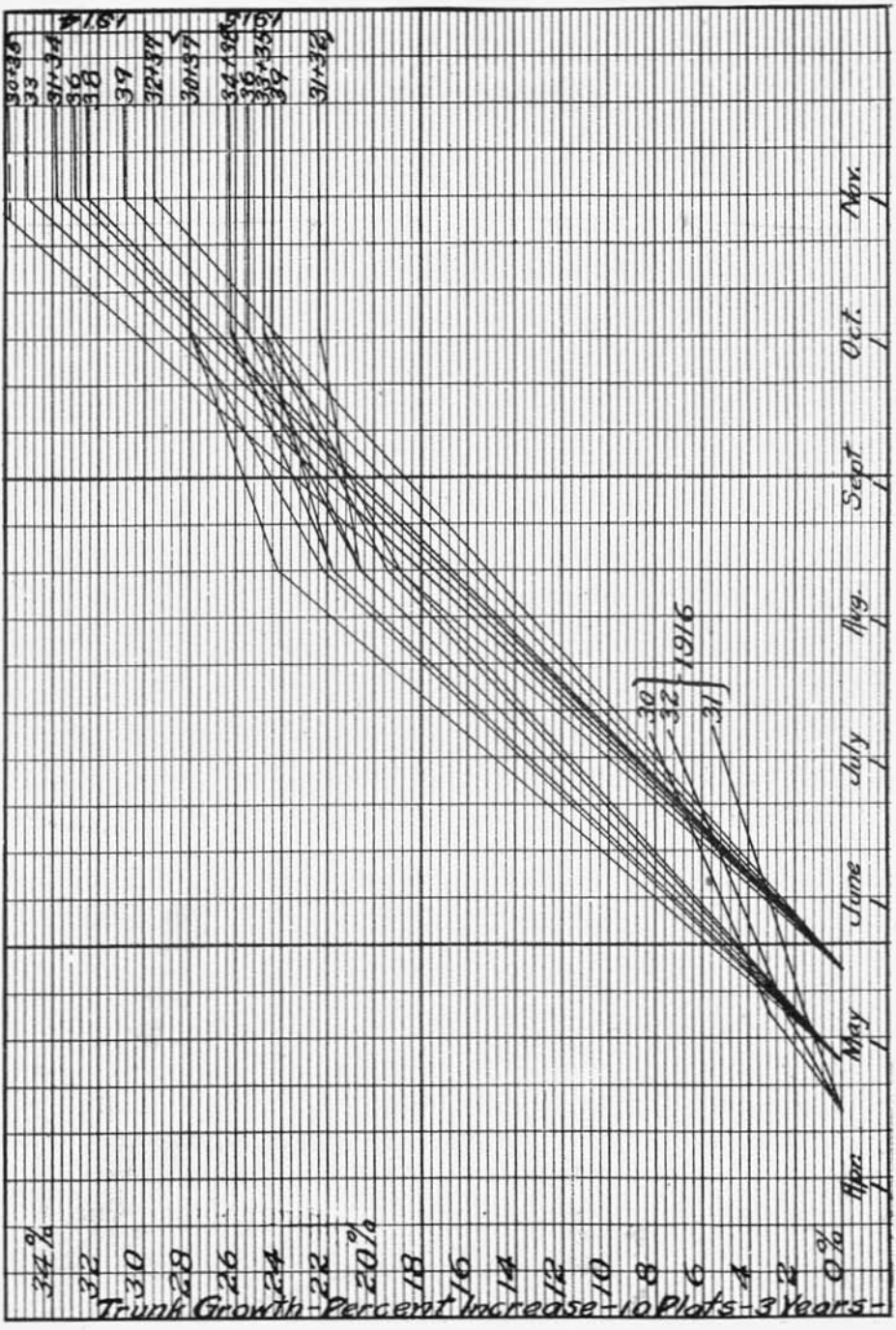


Chart 14. Showing the time and percentage increase of trunk growth for the ten plats for the years 1914 and 1915 and for plats 30, 31 and 32 for 1916. Note. first, the decrease in growth each year due to the attainment of maturity and the clover cover crop, and second, the fact that the trunk growth is made in the first part of the growing season as is the terminal limb growth. The curves for 1914 do not accurately show the time of trunk growth because no measurements were made between May 15 and November 1 of that year.

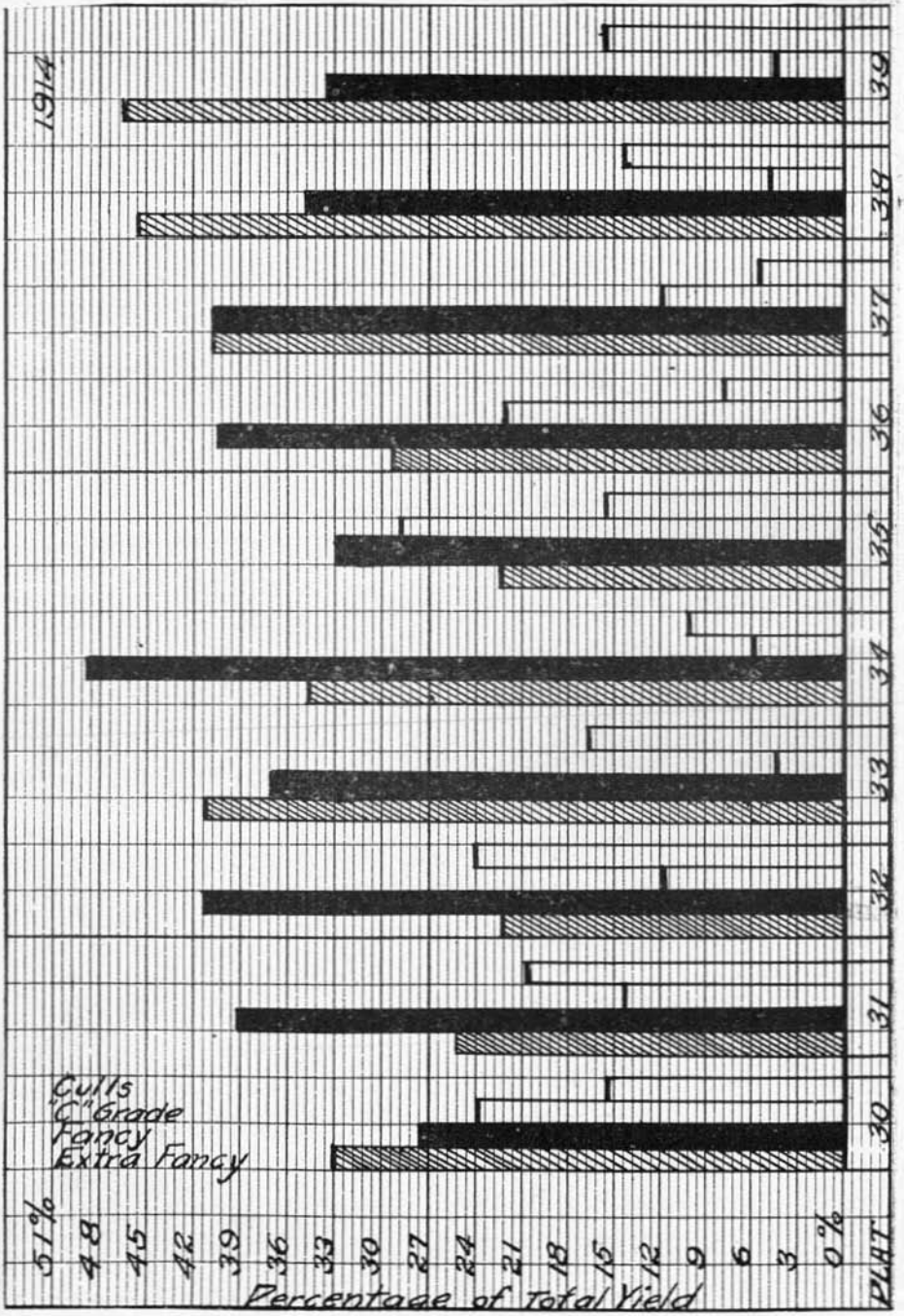


Chart 15. Showing the percentage of culls, C grade, Fancy and Extra Fancy apples on the ten plats for 1914.

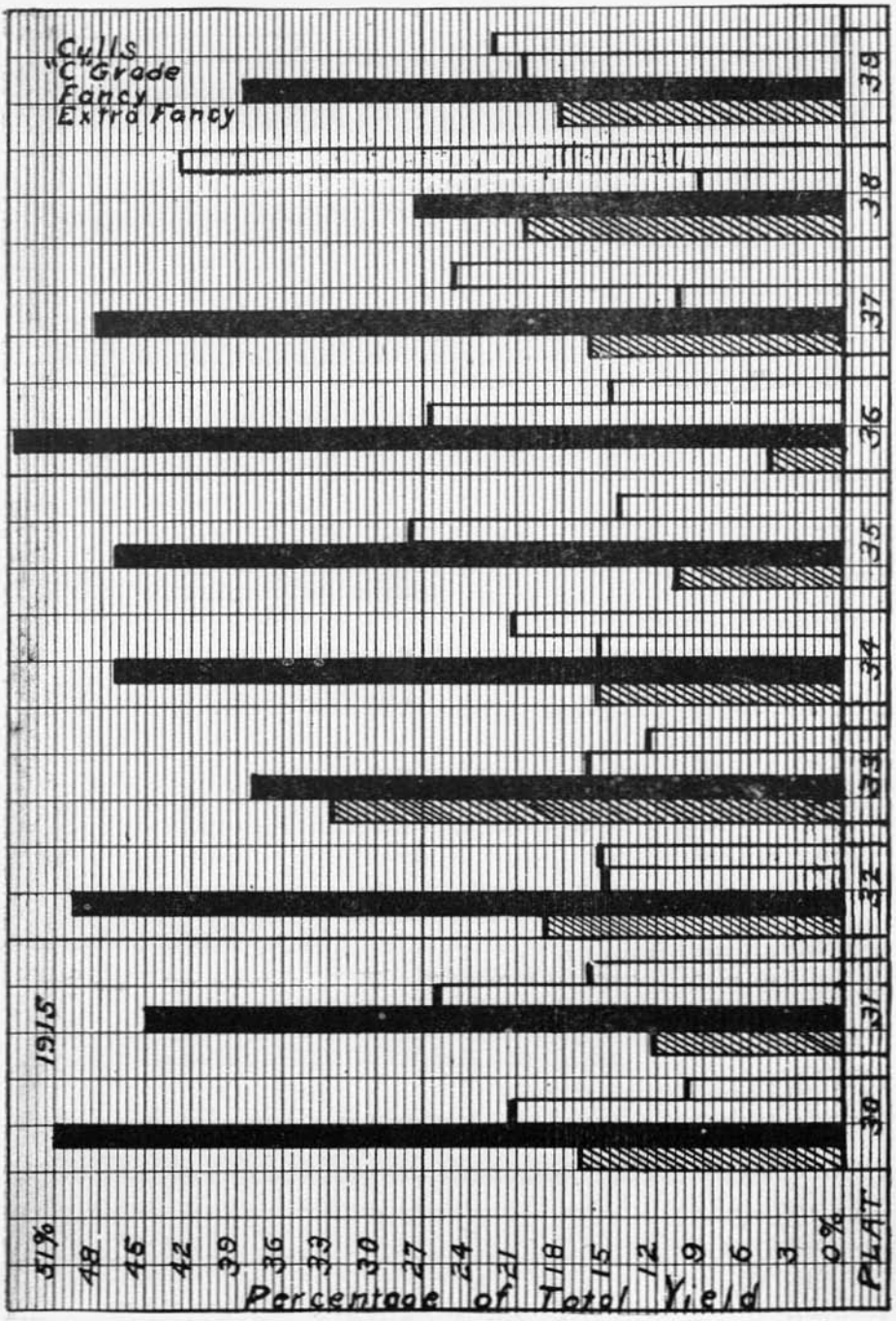


Chart 16. Showing the percentage of culls, C grade, Fancy and Extra Fancy apples on the ten plats for 1915.

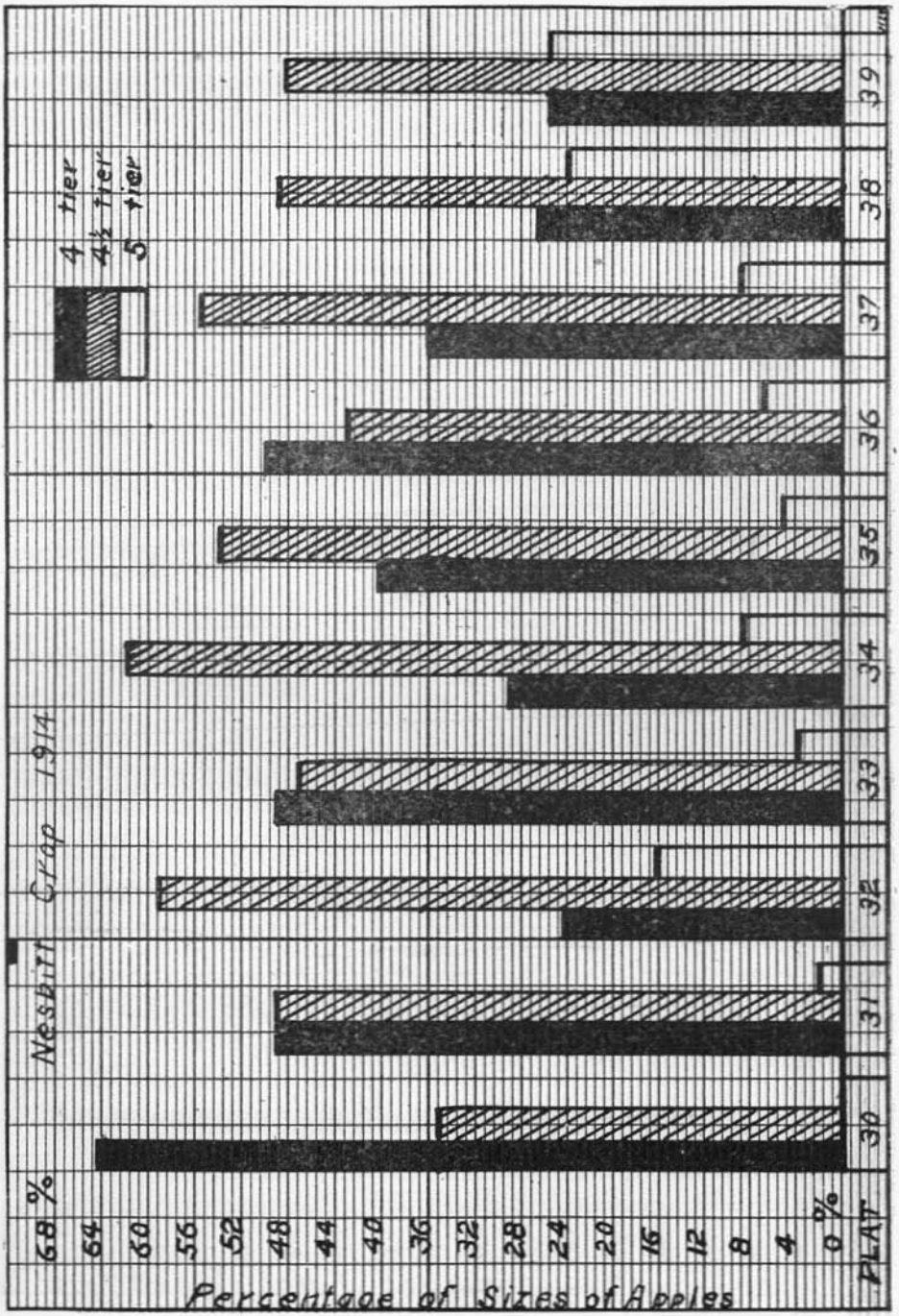


Chart 17. Showing the percentage of 4-tier, 4½-tier and 5-tier apples for the ten plats for 1914.

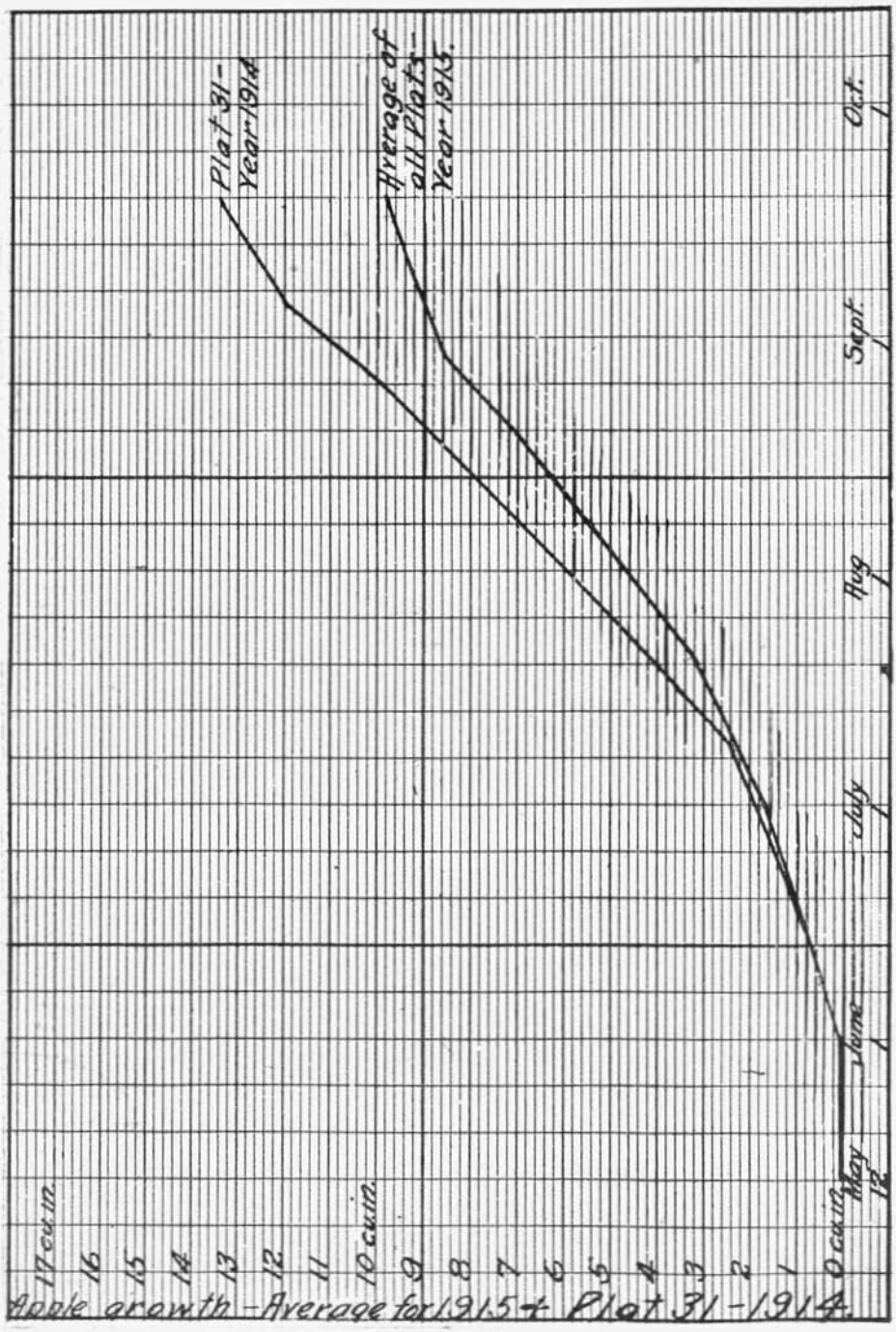


Chart 18. Showing the average time and rate of growth of apples on all ten plats in 1915 and on plat 31 in 1914. Note the time of most rapid increase in size from July 10 to September 1 and the slower growth during the last two weeks just before picking.

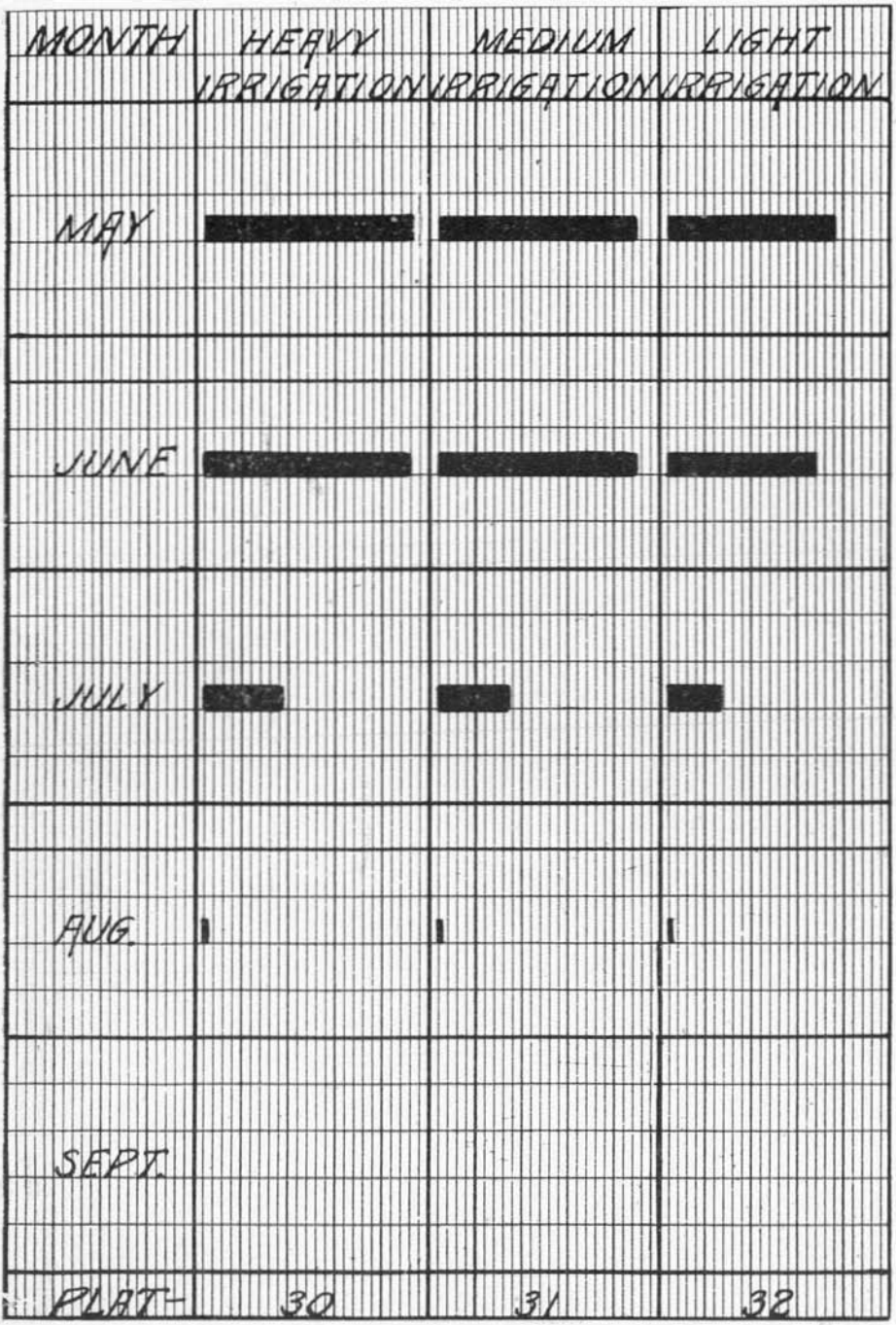


Chart 19. Showing time of greatest limb growth and the effect of irrigation upon the growth of limbs. Note that the limb growth of apple trees is made early in the season while apples are growing very slowly.

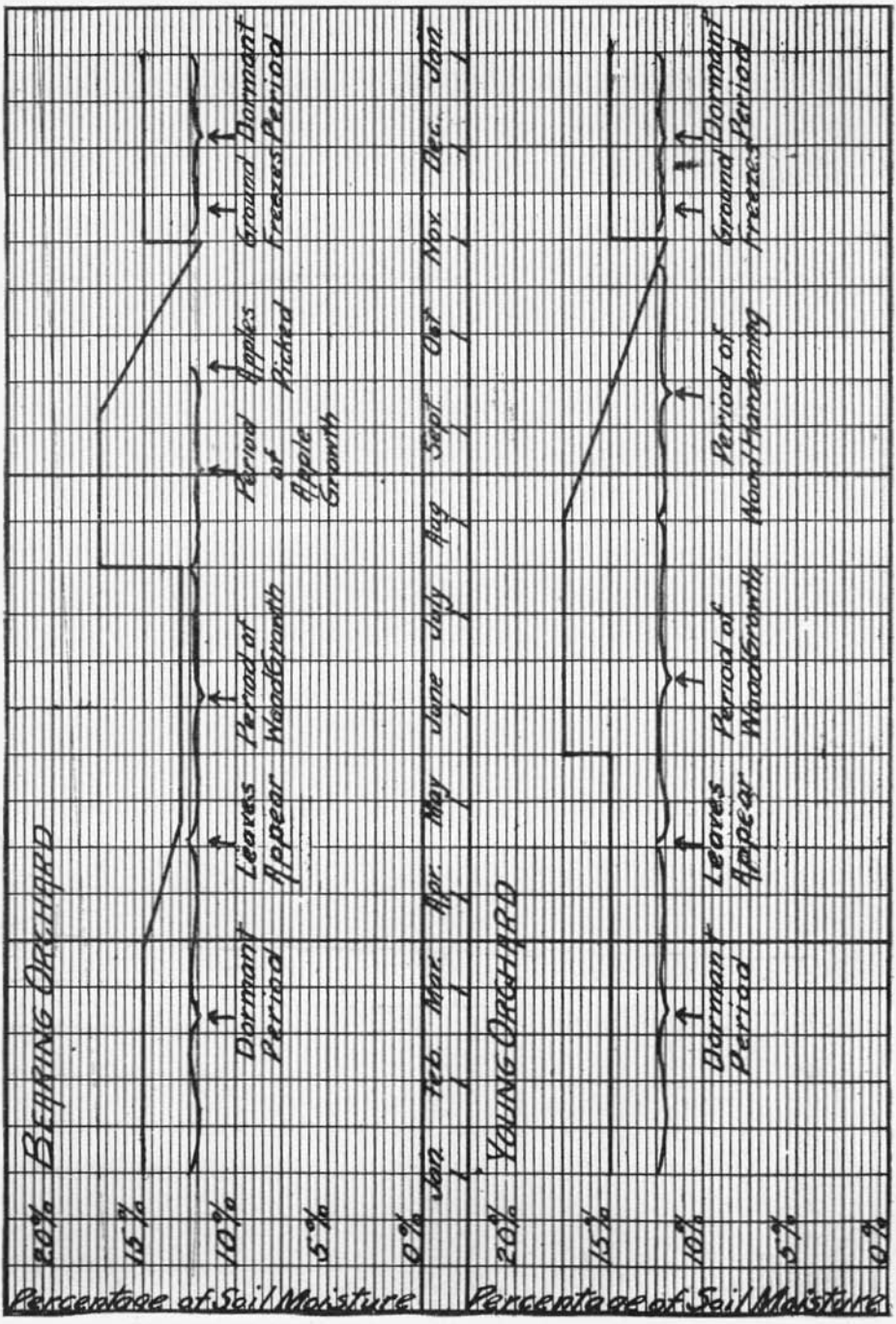


Chart 20. Showing the best moisture curves for bearing apple orchards with a crop, and for young apple orchards, as determined by this experiment.