Bulletin No 133 November 15 1930

University of Arizona
College of Agriculture
Agricultural Experiment Station

LETTUCE IRRIGATION STUDIES

By
H C Schwalen and M F Wharton

PUBLISHED BY
University of Arizona
TUCSON ARIZONA

ORGANIZATION

BOARD OF REGENTS

EXPERIMENT STATION STAFF

ELMER D. BALL, M.S., Ph.D....................Dean and Director

AGRICULTURAL ENGINEERING DEPARTMENT (Irrigation)
- GEORGE E. P. SMITH, C.E., D.Eng....................Agricultural Engineer
- HAROLD C. SCHWALEN, B.S.in M.E., M.S.in C.E....................Associate Agricultural Engineer
- ARTHUR G. CARNS, B.S....................Field Assistant in Irrigation and Horticulture
- WILLIAM A. STEENBERGEN, B.S. in C.E....................Assistant Irrigation Engineer

BOTANY DEPARTMENT
- JOHN J. THORNBER, B.S., A.M....................Botanist

DAIRY DEPARTMENT
- WALTER S. CUNNINGHAM, M.S....................Dairy Husbandman
- RICHARD N. DAVIS, M.S....................Associate Dairy Husbandman

PLANT BREEDING DEPARTMENT
- WALKER E. BRYAN, M.S....................Plant Breeder
- ELIAS H. PRESSLEY, M.S....................Associate Plant Breeder

ENTOMOLOGY DEPARTMENT
- CHALES T. VORHIES, B.S., Ph.D....................Entomologist
- LAWRENCE P. WEHRLE, M.S., Ph.D....................Assistant Entomologist

HORTICULTURE DEPARTMENT
- ALLEN F. KINNISON, M.S....................Horticulturist
- DAVID W. ALBERT, M.S....................Associate Horticulturist (Phoenix)
- MALCOLM F. WHARTON, M.S....................Assistant Horticulturalist

AGRONOMY DEPARTMENT
- RALPH S. HAWKINS, M.S....................Agronomist
- STANLEY P. CLARK, B.S....................Assistant Agronomist
- IAN A. BRIGGS, M.S....................Assistant Agronomist
- CHARLES HOBART, M.S....................Research Assistant in Agronomy and Horticulture (Mesa)

ANIMAL HUSBANDRY DEPARTMENT
- ERNEST B. STANLEY, M.S....................Animal Husbandman
- EVERETT L. SCOTT, M.S., Ph.D....................Associate Animal Husbandman

PLANT PATHOLOGY
- JAMES G. BROWN, M.S., Ph.D....................Plant Pathologist
- RUBERT B. STREETS, M.S., Ph.D....................Associate Plant Pathologist
- MILTON M. EVANS, M.S....................Research Assistant in Plant Pathology

AGRICULTURAL CHEMISTRY AND SOILS DEPARTMENT
- PAUL S. BURGESS, M.S., Ph.D....................Agricultural Chemist
- †JAMES F. BREAZEALE, B.S....................Research Biochemist
- WILLIAM T. McGEORGE, M.S....................Research Chemist in Soils
- THEOPHIL F. BUEHRER, M.S., Ph.D....................Physical Chemist
- HOWARD V. SMITH, M.S....................Assistant Agricultural Chemist
- ROBERT O. GREENE, M.S....................Assistant Agricultural Chemist

POULTRY HUSBANDRY DEPARTMENT
- HARRY EMBLETON, B.S....................Poultry Husbandman
- HUBERT B. HINDS, M.S....................Assistant Poultry Husbandman

HUMAN NUTRITION DEPARTMENT
- MARGARET CAMMACK SMITH, A.M., Ph.D....................Nutrition Chemist
- EDITH LANTZ, M.S....................Research Assistant in Nutrition

RANGE ECOLOGY DEPARTMENT
- WILLIAM G. McGINNIES, B.S....................Range Ecologist

†In cooperation with United States Department of Agriculture, Bureau of Plant Industry.

ACKNOWLEDGMENT

The writers are deeply indebted to Mr. C. J. Wood, foreman, Salt River Valley Experiment Farm at Mesa, and to Mr. Louis Groehler of the Mesa Lettuce Growers Cooperative Association, for timely suggestions and criticisms. Credit is especially due to Mr. Charles Hobart, Research Assistant, for his constant and careful execution of this experiment.

CONTENTS

ILLUSTRATIONS

LETTUCE IRRIGATION STUDIES

By

H. C. Schwalen and M. F. Wharton

INTRODUCTION

Head lettuce has become the most important truck crop grown in southern Arizona. The acreage has increased from a few acres in 1915 to over 25,000 acres in 1929. Local climatic conditions are favorable to the production of this crop during the off seasons of competitive areas. However, the partial overlapping of the lettuce seasons in Arizona with those of the Imperial and Salinas districts in California necessitates maximum production of quality lettuce per acre. The New York Market is the exclusive commercial variety, at the present time, and was used throughout these experiments

Desirable soils for growing this crop have included a range in texture from loams to clays with comparative freedom from alkali. Experience has shown, however, that a fertile soil of high organic content is required for profitable production of lettuce. This has resulted in a demand for alfalfa sod lands and the development of a crop rotation which includes various green manures as well as alfalfa.

The wide variation in frequency of irrigation and quantity of water applied by different growers suggested the need for experimental work to determine the effect of different irrigation treatments upon the quality and yield of lettuce. These experiments were initiated and partially carried out with this end in view.

PRELIMINARY STUDIES

The preliminary experimental work was conducted on the Yuma Valley Farm during the winter* of 1925-26 according to the following plan:

Irrigation Treatment I.

Soil kept moist throughout the entire growing season.

- Plat 1. Shallow cultivation, only sufficient to keep down weed growth.
  - a. Single rows 30 inches apart.
  - b. Double rows 22 inches apart.
- Plat 2. Deep frequent cultivation.
  - a. Single rows 30 inches apart.
  - b. Double rows 22 inches apart.

*Conducted by M. F. Wharton

Irrigation Treatment II.

Soil kept at approximately the field water-holding capacity by frequent heavy applications, until heading, no later irrigations.

Plat 3. Deep, frequent cultivation.

a. Singles rows 30 inches apart.

b. Double rows 22 inches apart.

The field used had been in alfalfa sod and was comparatively high in organic matter. The soil is classified as a Gila loam. Seeding was done by the usual drag type drill (Fig. 1) on October 30, 1925, to a depth of one-quarter inch and immediately followed by an irrigation. The plants were thinned to 14 inches apart in the row on December 10, 1925, and an irrigation was given to settle the soil that had been disturbed around the remaining plants. The lettuce matured uniformly and the first cutting was made March 8, 1926, with the last cutting of harvest occurring March 23, 1926.

The results of this year's work are shown in Table I, in which a comparison of plats 1 and 2 shows the effects of cultivation and 2 and 3 the effects of the different irrigation treatments.

Fig. 1.—Seeding lettuce with a two-row drag-type drill seeder.

TABLE I.—RESULTS OF LETTUCE IRRIGATION STUDIES ON YUMA EXPERIMENTAL FARM, 1925-26.

	Treatment I				Treatment II	
	Plat 1 Non-cultivated		Plat 2 Cultivated		Plat 3 Cultivated	
	a	b	a	b	a	b
Total heads	2,797	4,566	2,775	4,580	2,801	4,660
Commercial heads	2,445	3,937	2,408	2,930	2,211	3,622
Percent commercial heads	87.4	86.0	86.8	85.8	78.9	77.7
Average weight	1.0	.93	1.04	.92	.95	.92

a—Single row
b—Double row

Due to an insufficient number of duplicates it is not possible to arrive at definite conclusions. However, both the single and double rows are consistent in that no effects of cultivation are evident, either beneficial or detrimental. Comparing the cultivated plats in treatments I and II it is noted that there is a decided favorable effect from the the use of irrigation treatment I on the head weight and the number of commercial heads produced.

In 1926-27* the lettuce irrigation studies were continued on the Libhart ranch approximately one-half mile southwest of the Salt River Valley Experiment Farm near Mesa, Arizona. The contemplated plan for this year included six different irrigation treatments and a continuance of the cultivation studies, as follows:

I. Irrigation every 2 weeks from thinning to maturity.

II. Soil to be irrigated only when approaching the wilting point from thinning to maturity.

III. Soil to be irrigated when the moisture content has been reduced to a point midway between the field water-holding capacity and the wilting point, from thinning to maturity.

IV. Soil to be irrigated only when approaching the wilting point from thinning to bunching stage and then kept as near the field water-holding capacity as possible to maturity.

V. Soil to be kept uniformly as near the field water-holding capacity as possible from thinning to bunching stage with no further irrigation unless the moisture content is reduced to the approximate wilting point.

*Conducted by M. F. Wharton and S. W. Armstrong.

VI. Soil to be kept uniformly as near the field water-holding capacity as possible, from thinning to maturity.
One-half of each plat was cultivated weekly and the other kept clear of weeds by hoeing, from thinning to maturity.

The plats were located on a Laveen clay-loam soil which had been cropped to alfalfa for the previous 5 years. Lettuce was seeded October 15, on the commercial type double-row raised bed, (Fig. 2), with furrows 44 inches apart and about 5 inches deep. The lettuce was thinned to 14 inches on November 14 and was estimated as a 90-percent stand. All plats were irrigated immediately following seeding; again a week later to soften the surface crust; and immediately following thinning. Harvest began with the first cutting on February 24 and was completed with the second and last cutting on March 7.

In the plan for this year's work the quantity of water applied to the plats was to be measured by means of calibrated 4-inch concrete pipe headgates, and waste water, or run-off, from the plats was measured with 90° V-notch weirs. Regulating and overflow gates were placed in the main ditch to provide equal and uniform head on the concrete pipe headgates. (Fig. 3.) Measurement of the irrigation water was dis-

Fig. 2.—Lettuce seeded in double row raised beds.

Fig. 3.—Wooden overflow gates regulating irrigation water. 1926-27.

continued before the end of the season and therefore only a schedule of irrigation treatments is given in figure 4.

TABLE II.—RESULTS OF LETTUCE IRRIGATION STUDIES ON LIBHART RANCH, 1926-27.

Treatment	Treatment I		Treatment II		Treatment III	
	Cultivated	Non-cultivated	Cultivated	Non-cultivated	Cultivated	Non-cultivated
Total heads	466	485	478	414	511	497
Percent heading	81.0	87.6	93.5	91.8	88.3	92.7
Percent commercial heads	59.7	54.5	54.0	46.2	60.2	57.4
Percent bursted heads	11.4	23.0	20.1	20.3	9.5	16.3
Average weight in pounds	1.11	1.13	.99	1.03	1.05	1.12
Compactness	.64		.63		.61	

Soil moisture sampling was relied upon as the guide in following out the irrigation program as outlined. Six-inch samples were taken to a depth of 2 feet, in the center of the bed, at the upper and lower ends of each plat, with a 2-inch Killifer soil auger. Succeeding samples were taken within 12 to 15 inches of each other in order to eliminate the effects of soil variation as much as possible.

Plats 4, 5, and 6 were discarded due to flooding and shade effects that rendered the data unreliable. The results from the remaining plats of this year's work are given in Table II.

From these results it again appears that a relatively high and uniform moisture supply is conducive to the production of large heads. Plats of treatment I, both cultivated and non-cultivated are consistently higher in weight than any of the other plats. The weekly deep cultivation shows a slight but consistent detrimental effect on size of head when compared with those plats merely hoed and scraped to eliminate the competition of weeds.

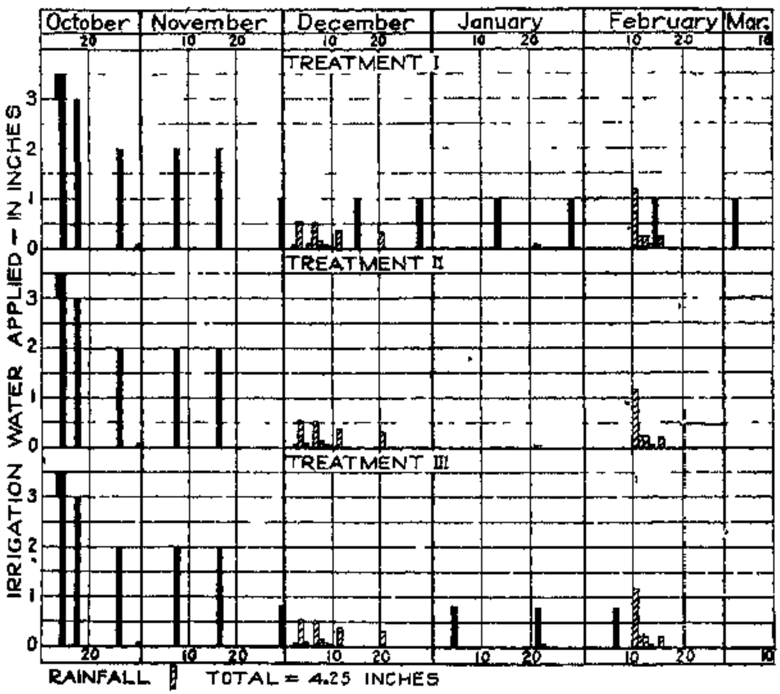

Fig 4—Irrigation schedule of treatments 1, 2 and 3 in 1926-27 on Libhart ranch

The effect of irrigation treatment on the development of heads is favorable in plat II, the lowest amount of water applied. Next in order of heading and also of water applied is plat III with the wettest plat showing the lowest number of plants forming heads. Segregating these heads as to commercial desirability it is noted that plats III and I are considerably better than plat II. Allowing the plat to dry down to an appreciable extent, while favoring the development of heading, has a detrimental effect in reducing the size of head below that of commercial desirability.

An examination of figure 4, in which is plotted the irrigation schedule and the precipitation, shows a 2.1-inch rain in December and another rain of 1.99 inches in February, the latter rain coming just 2 weeks before harvest. Due to these rains the moisture content of plat II did not approach the wilting point at any time, as had been planned Soil moisture samples indicate that the moisture content of the center of the beds in this plat was not reduced below 15 percent previous to the rain at harvest.

STUDIES OF 1927-28, AND 1928-29

GENERAL PLAN AND CULTURAL PROCEDURE

A more definite and comprehensive plan was laid out for the continuance of the experiment due to the results obtained in the preliminary studies of the previous 2 years. This plan provided that all plats were to receive the same irrigation and cultural treatment from seeding to the thinning stage as in the previous work. Five different irrigation treatments were carried out in quadruplicate consisting of two cultivated and two non-cultivated plats. The irrigation treatments were as follows:

I Plats 1, 2, 11, 12.

Soil kept uniformly moist at approximately the field water-holding capacity from thinning to harvest.

II. Plats 3, 4, 13, 14.

Water applied at such intervals that the soil moisture will not fall below a point midway between the field water-holding capacity and the wilting point.

III. Plats 5, 6, 15, 16.

Water applied only when soil moisture has been reduced to approximately the wilting point.

IV. Plats 7, 8, 17, 18.

Water applied only when soil moisture has been reduced to approximately the wilting point until heading starts, then by frequent irrigations to keep the soil moisture as near the field water-holding capacity as possible to harvest.

V. Plats 9, 10, 19, 20.

Soil kept uniformly moist at approximately the field water-holding capacity until heading starts and then irrigated only when the soil moisture has been reduced to approximately the wilting point.

The experimental plats were located on the Davis ranch in 1927-28 and on the Salt River Valley Experiment Farm, a mile west of Mesa, Arizona, in 1928-29, the former being located about one-half mile southeast of the latter. The soils on these places, as well as that of the Libhart ranch where the 1926-27 studies were conducted, are very similar and classified as of the same texture and type by the United States Bureau of soils.*

The above soil is designated as the Laveen clay loam in the recent reclassification of the soils of the Salt River Valley by the above agency and is described by them as follows:

"The Laveen clay loam surface soil varies from about 6 inches to 14 inches with an average of about 10 inches of light chocolate brown to faint or dull reddish brown, slightly gritty, moderately to highly calcareous material, carrying a few small lime hardpan fragments. This horizon owes its dark color to the silt that has been deposited upon the surface in years of early irrigation. This is underlain by a light brown friable, highly calcareous loam or light clay loam having a pale reddish brown or slightly yellowish tinge. The structure of this horizon is single grain or fine granular. The layer also carries a few small lime concretions. At an average depth of about 20 inches this horizon is underlain by a moderately compact light reddish to yellowish brown compact clay loam containing many lime nodules. This horizon averages about 20 inches in thickness and grades into a brownish gray, compact clay loam or clay, very high in lime nodules or lime hardpan fragments. This type is mapped in one large body about Mesa. It lies in a belt comparatively close to the lower edge of the old alluvial fan and on the lower lying lands of lesser slope than those of the loam type in this series lying adjacent to this type. The surface is smooth and the topography is characterized by very gently sloping or nearly flat lands. Surface and subsoil drainage is moderately well developed. The entire area is intensively farmed, being cropped with cotton, alfalfa, grains, truck crops, principally lettuce and cantaloupe, and citrus, deciduous fruits, and grapes."

*From the unpublished manuscript—Soil survey of the Salt River Valley Area, Arizona, by W. G. Harper in charge, A. T. Strahorn, F. O. Youngs of the U. S. D. A., Bureau of Soils, and S. W. Armstrong of the Irrigation Section. University of Arizona.

The Davis ranch had been continuously cropped to alfalfa for 5 years immediately previous to this experiment. The sod was irrigated, plowed and allowed to lie fallow for a period of 6 weeks prior to the preparation of the seedbed. This seedbed preparation was accomplished by a flood irrigation followed by double discing and floating. Borders were constructed dividing the field into 20 plots which were 25 feet in width and 200 feet long, excluding the borders, and having a net wetted area of 0.11 acre each. The average fall from the upper to lower end of each plat was between 0.1 foot and 0.2 foot. The general arrangement of the plats, ditches, headgates, and measuring devices is shown in figure 5.

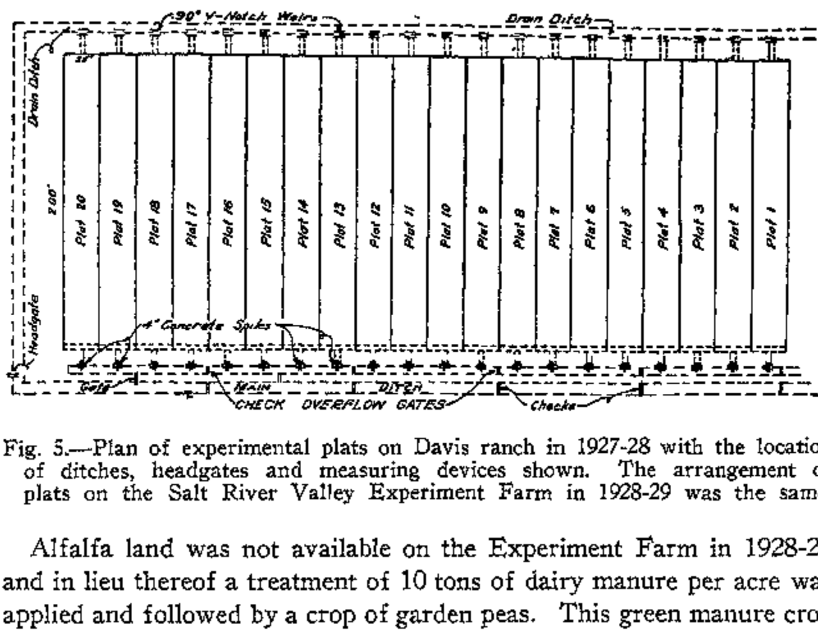

Fig. 5.—Plan of experimental plats on Davis ranch in 1927-28 with the location of ditches, headgates and measuring devices shown. The arrangement of plats on the Salt River Valley Experiment Farm in 1928-29 was the same.

Alfalfa land was not available on the Experiment Farm in 1928-29 and in lieu thereof a treatment of 10 tons of dairy manure per acre was applied and followed by a crop of garden peas. This green manure crop was plowed under in a manner similar to the alfalfa sod of the previous year and the field was allowed to lie fallow for 2 months prior to seedbed preparation. The seedbed preparation was carried out in the same manner as the previous year. The general plan and arrangement of the plats was essentially the same as on the Davis ranch with the exception that borders and rows were run east and west. (Fig. 5.) The plats were slightly larger, being 25 feet in width and 209 feet long with a net wetted area of 0.12 acre each. The ground within the plats was very carefully levelled across and lengthwise of each plat to insure uniform depth of irrigation.

The commercial type double row bed was used and was prepared 44 inches from center to center with furrows approximately 5½ inches in depth. Each plat therefore consisted of five of these beds, separated by a high border approximately 6 feet in width. Buffer rows were planted on both shoulders of the borders. The lettuce rows were of a uniform width of 22 inches. (Fig. 12.) A two-row drag type seeder was used to seed the beds to a depth of ¼ inch at the rate of 1 pound of seed per acre. The commercial strain of New York Market variety of lettuce was used, as in the preliminary studies, to seed the plats during these 2 years. Seeding was done on the Davis ranch September 28, 1927, and the following year on November 17. It was originally intended to seed the plats early in September during the season of 1927-28 to mature the crop in early winter, but heavy rains prevented the execution of this plan and the crop was seeded and grown as the late winter or early spring crop.

The lettuce plants were thinned, when at approximately the four-leaf stage, or about an inch in height, to as nearly 16 inches apart in the row as possible. Thinning was accomplished on October 8-21 in the 1927-28 season and on January 7-9, 1929.

The bunching stage, when the inner leaves begin to fold and start the heads, was determined to be from November 28 to December 8 in 1927. During the 1928-29 season this stage was reached on all plats between March 10 and 20.

Plats were uncultivated up to the thinning or "blocking out" stage, after which stage, the cultivated plats in 1927-28 were cultivated to a depth of between 1 and 2 inches following each irrigation. The uncultivated plats were kept clear of weeds by hoeing. The cultural practice was modified somewhat in 1928-29 to provide for knife cultivation, not to exceed 1 inch in the cultivated plats, and cultivations of approximately 3-inch depth following each irrigation on the cultivated plats.

MEASUREMENT OF IRRIGATION WATER

The 4-inch cement pipe headgates, which were used the preceding year on the Libhart ranch, were again used to measure the water into the plats on the Davis ranch in 1927-28. The installation of the pipe headgates in the ditch bank is shown in figure 7. The rating or discharge curve for this headgate which was determined by preliminary field tests is shown in figure 6. The head on the pipe was measured from the top of a stake set in the ditch 12 inches from the mouth of the pipe and level with the inside bottom of it. The pipe headgates were installed in sets of four, carefully levelled and at the same elevation in order to maintain the same head on each gate and, therefore, equal

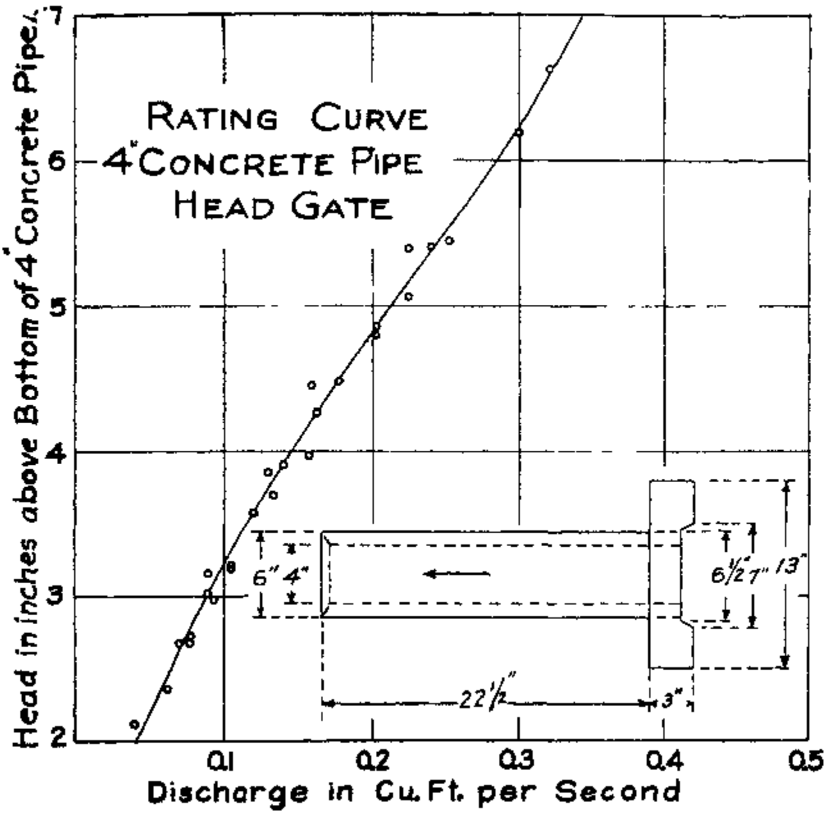

Fig 6—Rating curve and detail sketch of 4-inch concrete pipe headgate used in 1927-28 to measure water applied to plats.

discharge from all. An overflow headgate was provided in the distributing ditch for each set of four headgates to prevent fluctuation of head.

Water was run in the main ditch and turned into the distributing ditch at a single gate for each set of four measuring gates in sufficient amount to supply them with the required head. From the 4-inch pipe headgates it ran into a level basin across the upper end of each plat where it was distributed to the furrows by lath spiles. Overflow water from the plats was measured into a drain ditch at the lower end of the field by means of Cipolletti weirs. (Fig. 8.) Measurements of intake and run-off head were taken at intervals of only a few minutes apart when water was first turned into a plat. Later on, when the head had become adjusted, measurements of the head were made from 15 to 30 minutes apart.

It was found that when running as small a head as was practical to measure with the 4-inch concrete headgates that as much as 75 percent

Fig. 7.—Concrete pipe headgates together with regulating and overflow checks in main and distribution ditches.

of the water applied was measured as run-off by the overflow weirs. A small leak from one plat to another or into the run-off ditch, or even a small error of measuring the head at either the intake or overflow, would result in a comparatively high percentage of error in the computed amount of water applied. The computed amounts of water applied indicate clearly that those plats under the same irrigation treatment, both cultivated and non-cultivated, absorbed water at approximately the same rate. Water was applied to each plat in the series of four for the same length of time, and it is therefore felt that the average of the computed amounts for a series of four plats gives a relatively accurate figure for the amount applied to each plat.

The water was measured onto the plats in 1928-29 with 90° triangular weirs in weir boxes with regulating gates as shown in figure 9. Under this system only one head ditch was necessary, with check gates spaced about 150 feet apart and with the weir boxes installed in the banks of this ditch. (Fig. 10.) Water was turned into the plats at such a rate that all of it was absorbed and no run-off was permitted. The head on the weirs was measured from a nail driven into the side of the weir box, 12 inches in front of and level with the crest. This head was measured at intervals of a few minutes, while regulating the discharge, through the individual boxes, and at intervals of 30 to 45 minutes when

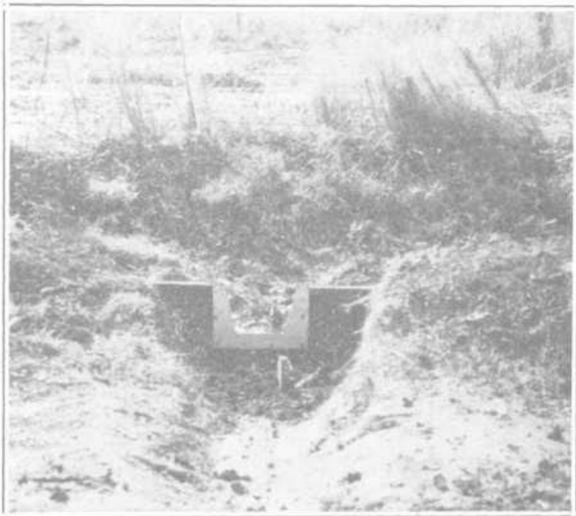

Fig. 8.—Six-inch Cipolletti weir used in measuring run-off water from the individual plats.

the flow had become somewhat stabilized. The same method of distributing water to the furrows with lath spiles was used as in previous years.

IRRIGATION AND SOIL MOISTURE CONTROL

All plats were given the same irrigation treatment up to thinning or "blocking out" as outlined in the general plan for irrigation. The irrigations immediately following seeding were for the purpose of securing a high percentage of germination by maintaining a favorable moisture, temperature, and soil texture condition in the seedbed. The irrigation following thinning was for the purpose of settling the earth firmly about the plants that were disturbed in this operation. The usual field practice of irrigating lettuce was followed in which the water is kept in the furrows continuously until the bed has become soaked. In later irrigations the water was held in the furrows for a period of 12 to 14 hours.

The differential irrigation treatments were based upon the percentage of moisture remaining in the soil within the root zone of the lettuce plants. As a basis for determining the arbitrary limits to which the soil moisture should be reduced under the different treatments, representative soil samples were taken in fields to a depth of 4 feet and their moisture equivalents determined. In preparing the samples for moisture equivalent determination the soil was pulverized on a bucking

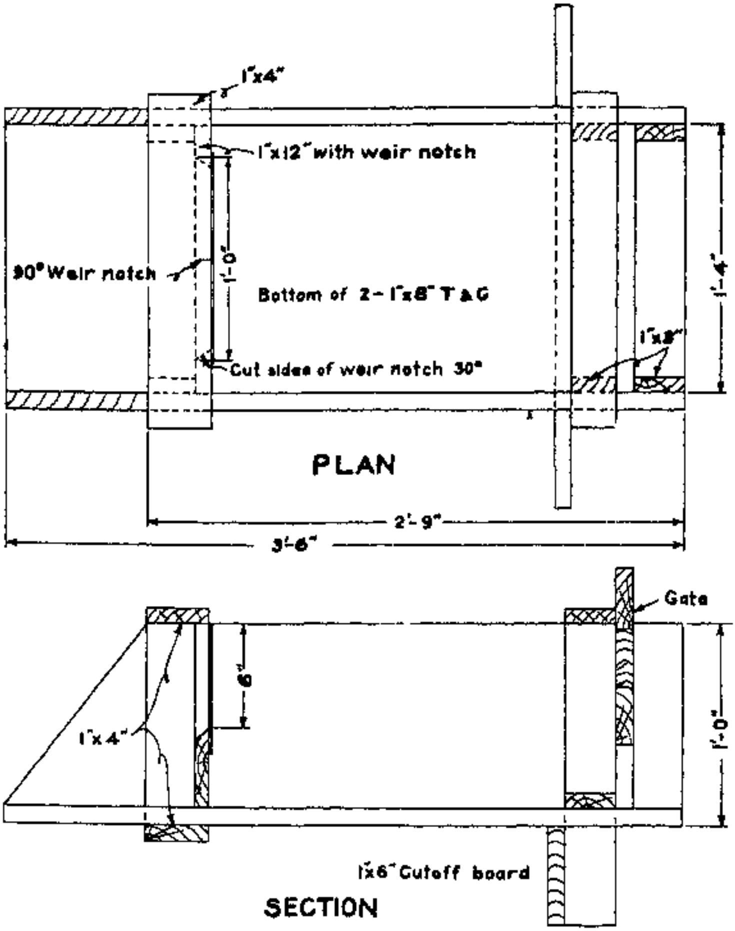

Fig. 9.—Detailed sketch of weir box with regulating gates in which 90° V-notch weirs were installed to measure water onto the plats in 1928-29.

board and screened through a standard 20-mesh screen. Results of these determinations are given in Table III for the Davis ranch and in Table IV for the Experiment Farm. The wilting points for the same soils, as given in the tables, were computed by dividing the moisture equivalents by the factor 1.84 as determined by Briggs and Shantz*.

*Briggs, C. J. and Shantz, H. L. 1912 The wilting coefficient for different plants and its indirect determination. U. S. D. A. B. P. I. p. 230 pg. 73.

TABLE III.—MOISTURE EQUIVALENTS AND WILTING POINTS OF SOIL SAMPLE TAKEN ON LETTUCE PLATS OF DAVIS RANCH.

Depth	Number of hole									
	1	2	3	4	5	6	7	8	Av.	W. P.
Ft.	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
0-1	22.6	22.4	20.0	21.6	21.0	21.0		19.3	21.1	11.5
1-2	17.6	20 5	19.6	17.1	19 2	17.1	19.5	18.7	18.7	10.2
2-3	19.6	20.2	19.8	16.2	19.6	19.0	21.0	16.2	19.0	10.3
3-4	19.8	19.8	19.0	19.0	20.6	19.4	20.9	17.8	19.5	10.6
Av	19.9	20.7	19.6	18.5	20.1	19.1	20.5	18.0	19.6	10.6

W. P.—wilting point—moisture equivalent divided by 1.84.

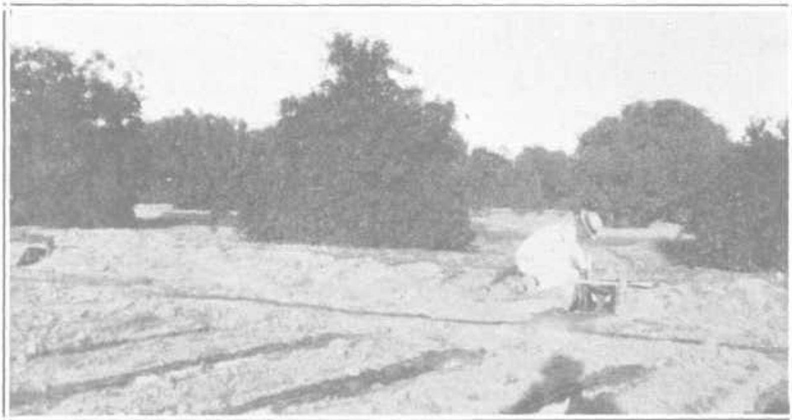

Fig. 10.—Measuring irrigation water through weir box set in ditchbank, 1928-29.

The figures in the preceding tables indicate to a certain extent the variation in soil on the lettuce plats for each of these 2 years. A comparison of the average moisture equivalents of the two fields, however, indicates that they are very nearly identical in moisture-holding capacity. Assuming that the moisture equivalent is an approximate measure of the field water-holding capacity of the soil then a value for the latter would be between 19 and 19.5 percent. On the same basis the wilting point would fall between 10 and 11 percent. However, it was found under actual field conditions, that the field water-holding capacity was more nearly between 17 and 18 percent.

Frequent soil sampling was required to determine the soil moisture content as a basis for the irrigation treatments. These soil samples were taken in triplicate, with a Killifer soil auger, about 30 feet from the ends and in the center of each plat. The holes were put down in the lettuce row and within the root zone of the individual plants to a depth of 3 feet, and samples taken at 0-6-inch, 6-12-inch, 12-24-inch and 24-36-inch depths. Results of the 0-6-inch and 6-12-inch samples were combined to give the moisture content in the first foot of soil. In order to eliminate the effect of soil variations in so far as possible, samples were taken not more than 12 inches to 15 inches apart. It was found impractical to take soil samples earlier than 48 hours after irrigation because of the wetness of the soil. Most of the sampling was done however not less than 72 hours after irrigation. An examination of the results of soil sampling for these 2 years indicates that from 4 to 7 days are required after irrigation for the soil moisture to reach equilibrium in this particular soil type. This is in contrast with the findings of Veihmeyer[1] on California soils in which equilibrium is established within 48 hours after irrigation.

BARE PLAT STUDIES

Additional information on the rate of movement of soil moisture, and the field water-holding capacity of this particular type of soil was secured in the fall of 1929. Four small plats 12 feet square, adjacent to the regular experiment on the University Farm, were carefully levelled and bordered up, without disturbing the surface soil These plats were kept clean of weeds and raked lightly, following the irrigations, to prevent surface cracking of the soil. Moisture equivalents were determined from three sets of samples taken to a depth of 7 feet, the results of which are given in Table VI. The method used in making these determinations was substantially that recommended by Veihmeyer, Oserkowsky, and Tester with the exception that a standard 20-mesh screen was used in place of the 2-mm. screen specified by them. It is noted that the moisture equivalents in this table are consistently higher than those given in Table V for the same soil. This can be explained only by the difference in the method used in preparing the samples for these determinations. Separate weighings were made of the portions passing through the screen, and those remaining on the screen, for each sample. The portion remaining on the screen was composed for the most part of caliche or calcium carbonate nodules, many of which were from ⅜ to ¾ of an inch in diameter. It is believed that the inclusion of these nodules in the soil moisture samples is responsible for the difference between the field water-holding capacity of this soil and the moisture equivalents as given in Table IV.

The amount of moisture which the coarse material or caliche will absorb and the extent to which it is available to plants are unknown. It is probable that the moisture content of the nodules is relatively small and that it does not fluctuate with changes in the moisture content of the adjacent soil. It is assumed that the caliche nodules are impervious to water and the moisture equivalents are decreased in proportion to the amount of coarse material screened out of each sample, then the results will be as found in Table VI under "corrected moisture equiva-

[1]Veihmeyer, F J, Oserkowsky, J, and Tester, K B 1927—Some factors affecting the moisture equivalent of soils Proceedings and papers, First International Congress of Soil Science, Vol I, (Reprint)

TABLE IV.—MOISTURE EQUIVALENTS AND WILTING POINTS OF SOIL SAMPLES TAKEN ON LETTUCE PLATS ON THE SALT RIVER VALLEY EXPERIMENT FARM. 1928-29.*

Depth	Number of Hole										
	1	2	3	4	5	6	7	8	9	Av.	W. P.
Ft.	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
0-1	20.5	21.4	19.3	23.0	18.9	17.7	17.6	19.1	17.9	19.5	10.6
1-2	17.6	24.2	16.3	20.3	19.0	15.3	17.5	17.8	17.7	18.3	9.9
2-3	20.1	23.6	17.8	15.4	20.4	15.3	21.0	20.7	16.2	19.0	10.3
3-4	21.2	23.6	18.7	18.2	20.7	15.2	21.2	22.3	15.2	19.5	10.6
Av.	19.9	23.2	18.0	19.2	19.8	15.9	19.3	19.9	16.8	19.1	10.3

*Moisture equivalents 1928-29 were determined by R. A. Greene, Assistant Agricultural Chemist, University of Arizona.

TABLE V.—RESULTS OF SCREENING SAMPLES FROM BARE PLATS THROUGH A STANDARD 20-MESH SCREEN FOR MOISTURE EQUIVALENT DETERMINATION.

Depth	Number of Hole								
	1			2			3		
	Total wt.	Wt. reclaimed	Pct. retained	Total wt.	Wt. reclaimed	Pct. retained	Total wt.	Wt. reclaimed	Pct. retained
Ft.	gms.	gms.		gms.	gms.		gms.	gms.	
0-1	67.3	499.0	13.5	49.9	448.1	11.1	34.2	495.2	6.9
1-2	101.1	621.6	16.2	92.8	443.2	20.9	45.1	374.7	12.3
2-3	97.3	434.6	22.3	111.4	489.0	22.8	90.2	409.3	22.0
3-4	147.5	555.0	26.5	145.6	530.1	27.4	130.3	476.2	27.3
4-5	133.4	489.0	27.2	119.3	508.7	23.4	94.0	493.6	26.4
5-6	159.1	526.1	30.2	35.6	318.1	11.1	69.3	415.6	16.6
6-7	71.9	461.7	15.5	49.1	342.3	14.3	54.1	412.0	13.1

Total weight—Total weight of sample.

Weight retained—Weight of material not passing through 20-mesh screen.

Percent retained—Percent of total weight of sample retained on 20-mesh screen.

lents." These corrections are made by multiplying the moisture equivalent of each sample by the ratio of the weight of portion passing through the screen to the total weight of the sample.

TABLE VI.—MOISTURE EQUIVALENTS FROM THE BARE PLATS AND CORRECTED VALUES BASED ON THE PERCENT OF COARSE MATERIAL.

Depth	Number of Hole							
	1		2		3		Average	
	M.E.	Cor. M.E.	M.E.	Cor. M.E.	M.E.	Cor. M.E.	M.E.	Cor. M.E.
0-1	22.7	19.6	23.1	20.5	22.8	21.3	22.9	20.5
1-2	21.6	18.1	21.2	16.8	22.5	19.8	21.8	18.2
2-3	22.7	17.7	20.4	15.6	21.3	16.6	21.5	16.6
3-4	22.0	16.2	19.6	14.7	23.0	16.7	21.5	15.9
4-5	23.1	16.8	18.1	13.9	20.4	16.5	20.5	15.7
5-6	25.8	18.0	20.6	18.3	23.6	19.7	23.3	19.0
6-7	27.3	23.1	13.9	20.5	26.4	22.9	25.9	22.2

An examination of Table VI reveals a wider variation in the corrected moisture equivalents than in the original values. This is due to the non-uniform distribution of the caliche nodules in the soil as stated in Table V. The average corrected value for the moisture equivalents more nearly approaches the actual field water-holding capacity of this soil as illustrated in figure 11, than does the moisture equivalent itself.

Irrigation water was applied to a definite depth on each plat and it was found, that with a 2.5-inch application, water remained on the soil surface from 6 to 8 hours. Samples taken within 24 hours after it disappeared from the surface showed that the soil in the first foot was still in saturated condition.

Soil sampling was carried on in duplicate with holes spaced not more than 1 foot apart to a depth of 7 feet at intervals of 1 foot in depth. A soil tube and soil auger were both used in taking samples but more consistent results were obtained with the soil auger. The caliche nodules in this soil are found in small pockets and not evenly distributed so that the very small sample secured with the soil tube is not a representative sample at all times. For the purpose of clearness the results of soil moisture sampling have been consolidated into 2-foot depths and the seventh foot has been omitted.

Typical results of these tests are given in figure 11, in which data from bare plats 1 and 2 are used. The irrigation schedule for these two plats, which was similar to irrigation treatments I and II in 1929, are

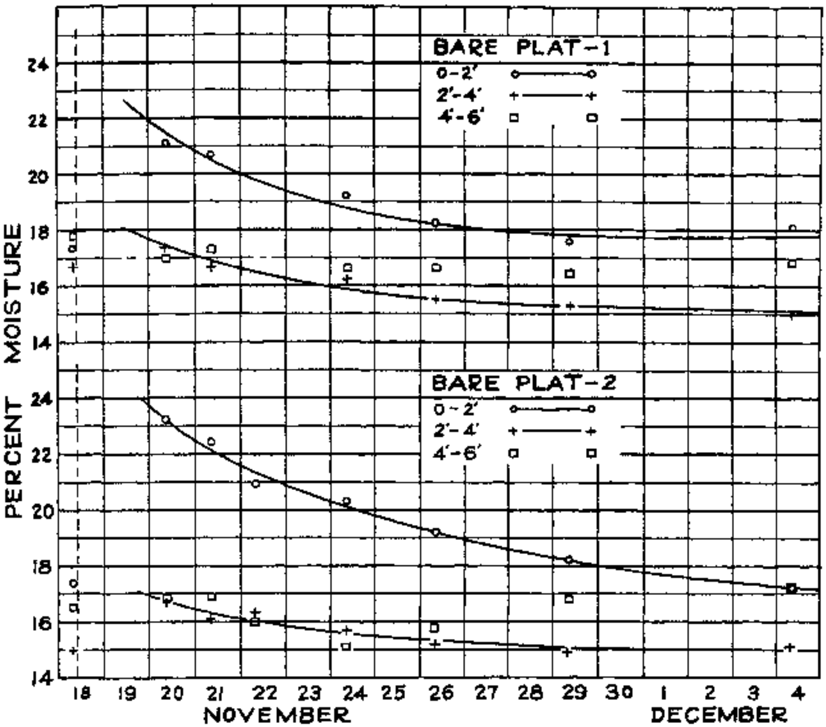

Fig. 11.—Soil moisture determinations on bare plats, 1928-29.

given in Table VII. Rain fell on the plats to the extent of 0.3 inch on September 18 and 0.04 inch on November 29.

TABLE VII.—SCHEDULE OF IRRIGATIONS GIVEN TO BARE PLATS 1 AND 2.

Date irrigated	Amount applied	
	Plat 1	Plat 2
	Inches	Inches
9-17-29	4.0	4.0
9-20-29	1.5	1.5
10- 9-29	2.5	0.0
10-15-29	0.0	2.5
10-30-29	2.5	2.5
11- 7-29	2.5	0.0
11-18-29	2.5	2.5

Curves have been constructed for only the 0-2-foot and 2-4-foot depths. No effect can be noted upon the moisture content of the 4-6-foot depth as the result of the application of water. The variance in the results obtained at this depth may be attributed to non-uniform distribution of caliche nodules making it extremely difficult to secure comparable samples.

It is only in the 0-2-foot depth that the moisture content is increased by irrigation to a marked extent above the field water-holding capacity. The soil moisture gradually decreased in this zone for a period of at least 10 days following irrigation until it was again at approximately its field water-holding capacity and in equilibrium. The 2-4-foot depth shows only a slight increase in moisture content as the result of irrigation with a gradual reduction for approximately 10 days afterwards.

There is no evidence of an appreciable increase of moisture content in the 4-6-foot depth which would indicate that water was passing downward through this zone. It would, therefore, appear that practically all of the water applied by irrigation is lost in 10 day's time by evaporation from the surface of the soil.

An estimate was made of the possible evaporation loss taking place during the 10-day period following the application of water based on the results obtained by Fortier* in his work on the comparative losses by evaporation from a free water surface and from moist and wet soil surfaces. Consideration was also given to the results obtained by Sleight† in his work on the comparison of the loss from a free water surface and that from the surface of river bed materials.

The surface of the plats during the period of 6 to 8 hours immediately following the application of water is covered with water, and the evaporation for this time may be assumed to be practically the same as that from a free water surface. Evaporation records from a free water surface were obtained from a standard U. S. Weather Bureau Class A evaporation pan located about 100 feet distant from the plats. The soil surface for approximately 12 hours following the disappearance of all the surface water is in a saturated condition, and it may be roughly estimated that the evaporation during this period is 1.5-2.0 times that from a free water surface. From this time on the surface of the soil contains a decreasing amount of moisture until at the end of the 10-day period it may be considered dry. On this basis the total evaporation from the bare plats could not have been more than 1.2 inches leaving unaccounted for very nearly 1.3 inches of the water originally applied

*Fortier, Samuel. Evaporation losses in irrigation and water requirements of crops—U. S D. A. Office of Experiment Stations Bulletin No. 177—1907.

†Sleight, R. B. Evaporation from surfaces of water and river bed materials.—Jour, of Agr. Res., Vol 10, No. 5, July 30, 1917.

or, roughly, about 8 percent of moisture distributed through the upper 4 or 5 feet. It will be noted, however, from the curves shown in figure 12 that this 8-percent increase in moisture content cannot be accounted for in the upper 6 feet of soil.

If there is no increase in the moisture content between the depths of 4 feet and 6 feet the gradual diminution in moisture content of the first 4 feet of soil must be attributed entirely to evaporation or the water must move downward through the fifth and sixth feet of soil without increasing the moisture content to an extent which could be detected by the methods used. It would seem that the soil moisture was in equilibrium previous to the application of irrigation water, and if this is true, then the forces acting upon the particles of water were in equilibrium, or practically so. A movement of water through this soil zone of 4 to 6 feet by displacement or without an increase in the actual moisture content of the soil must necessarily mean, therefore, that the forces acting upon the particles of water are no longer in equilibrium. A possible factor which may destroy this equilibrium of forces is that of the increased pressure of the entrapped air which is prevented from escaping to the soil surface by the water seal or at least the difficulty of this air making its way to the soil surface is increased. It is not likely that such a condition could occur where the subsoil is open and porous below the depths to which the irrigation water penetrates. But with a subsoil which becomes increasingly less pervious and tighter it is believed such a possibility exists and for this period an average value of .70 is used for the ratio of the evaporation from the surface of the soil to the evaporation from a free water surface.

Linford* reports the effect of water seeping down through soil columns in tubes, one of which was closed at the bottom with a porous plug and the other with a rubber stopper. Water was added to both at the top, the soil in the tube with the porous stopper was completely saturated, in the other the movement of water in the soil trapped the air and finally the pressure was great enough to force the wet soil as a body, upward far enough to separate the soil column and practically stop the flow of water. Under field conditions such an entrapping of air possibly might result in a delayed movement of water downward and in the increase in the time interval between irrigation and the establishment of equilibrium of soil moisture.

It is believed that a possible explanation for the length of time necessary for the soil moisture to reach equilibrium following irriga-

*Linford, Leon B.—Soil moisture in a saturated atmosphere. Soil Science, vol. 29, No 3. March 1930.

TABLE VIII.—LATERAL DISTRIBUTION OF MOISTURE IN LETTUCE BEDS ON SALT RIVER VALLEY EXPERIMENT FARM. 1928-29.

Date 1929	Plat No.	Location of Hole a	b	c	d	e	f	g	h	i	Av.
		Two days before irrigation									
		Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Mar.	3-E	14.9	14.2	13.8	15.0	14.8	14.5	14.7	14.5	14.6	14.6
16	3-W	15.4	15.1	14.5	13.6	14.7	14.5	14.2	14.6	14.9	14.6
Av.		15.2	14.6	14.2	14.3	14.8	14.5	14.4	14.6	14.8	14.6
		Four days after irrigation									
Mar.	3-E	17.3	16.5	16.8	16.4	13.7	15.4	15.4	15.7	16.2	
22	3-W	17.1	17.6	17.5	17.9	18.2	17.6	17.8	17.2	17.2	
Av.		17.2	17.0	17.2	17.2	16.0	16.5	16.6	16.4	16.7	
		Three days before irrigation									
Mar.	5-E	12.5	11.5	12.5	11.8	11.5	11.5	11.3	11.5	11.3	
26	5-W	13.2	12.0	11.3	11.5	11.5	10.7	11.4	11.0	12.5	
Av.		12.8	11.8	11.9	11.6	11.5	11.1	11.4	11.2	12.0	
		Five days after irrigation									
Apr.	5-E	15.1	15.1	15.9	15.8	15.9	16.3	16.0	15.0	14.8	
3	5-W	13.1	12.7	12.9	12.5	12.4	13.2	13.5	13.2	12.9	
Av.		14.1	13.9	14.4	14.2	14.2	14.8	14.8	14.1	13.8	
		Just before irrigation									
Apr.	2-E	16.6	16.5	16.2	16.4	16.1	16.3	17.1	17.1	17.4	
10	2-W	15.6	16.2	16.4	16.1	16.5	14.9	14.6	16.2	15.5	
Av.		16.1	15.4	16.3	16.2	16.3	15.6	15.8	16.6	16.4	
		Six days after irrigation									
Apr.	2-E	18.0	18.2	17.5	18.3	17.4	17.8	17.4	17.3	17.2	
16	2-W	16.9	16.1	17.8	17.2	17.0	16.9	17.3	16.9	15.6	
Av.		17.4	17.2	17.6	17.8	17.2	17.8	17.4	17.1	16.4	

E—East end of plat.

W—West end of plat.

The results as given in the foregoing table represent conditions under the two extremes in irrigation treatments in plats 2 and 5 and a treatment between them in plat 3. The samples were taken just prior to and during harvest when the use of water by the plants was at the maximum. It will be noted that the figures are more uniform than might have been expected in these cross sections. Considerable differences will be noted between the respective samples from opposite ends of the same plats, particularly in plat 5 on April 3, 5 days after an irrigation. This may be due to an actual difference in soil texture or to the selection of a non-representative cross section.

tion and also for the movement of soil water by displacement exists in the increased pressure of the soil-trapped air. It is realized that the experimental work done is only of a preliminary nature and the results inconclusive, but that they may point towards a factor which has heretofore not been given much consideration in the movement of soil moisture under field conditions.

LATERAL DISTRIBUTION OF MOISTURE BETWEEN FURROWS

A test of the lateral distribution of water from the furrows was made in the lettuce plats on the University Farm in 1929. A cross section of soil moisture conditions was made from samples taken at 5½-inch intervals to a depth of 4 feet about 50 feet from the east and west ends of each plat. A typical cross-section of lettuce beds and furrows, which were the same both years, is given in figure 12, together with the locations of the holes from which samples were taken. Some of the results obtained are set forth in Table VIII, in which the average moisture content of the upper 3 feet of soil is given.

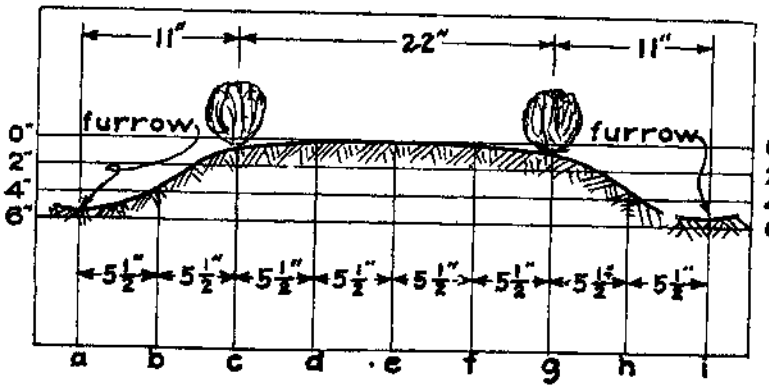

Fig. 12.—Cross section of a typical lettuce bed showing location of soil sampling holes for lateral distribution of moisture study.

SOIL MOISTURE AND IRRIGATION

The same irrigation plan as has been outlined previously was carried out as nearly as possible through both seasons. However, the irrigation schedules for the individual plats varied considerably under the same treatment, due to the difference in planting dates. The high temperatures in September, 1927 made it necessary to give the plats three irrigations following seeding to obtain a stand. The following year when the lettuce was seeded during the middle of November, only two irrigations were necessary.

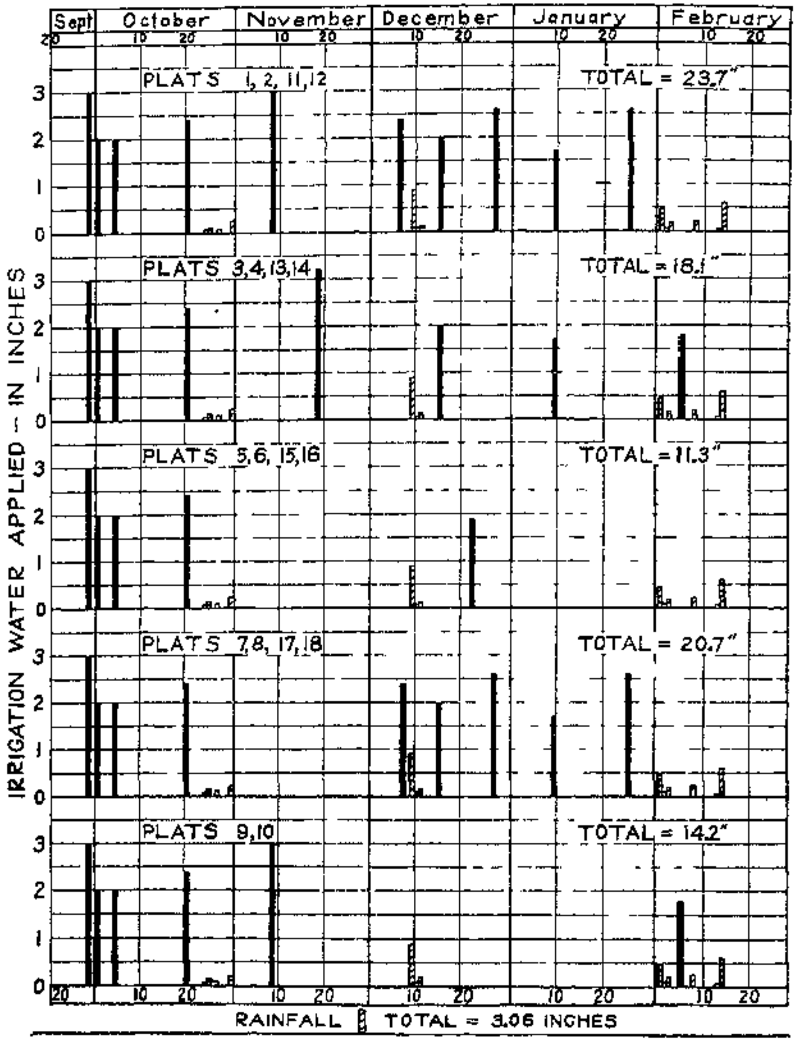

Fig. 13—Irrigation schedule by treatments, and rainfall, Davis ranch, 1927-28.

The irrigation schedule for the five different irrigation treatments 1927-28 and the rainfall for the lettuce season are given in figure 13. No measurements were made of the first three irrigations and the estimated amounts of water applied are shown in the schedule. The soil at this time was practically at the field water-holding capacity, due to the heavy rain just previous to seeding, combined with the irrigation applied previous to the preparation of the seedbed. The estimates for the

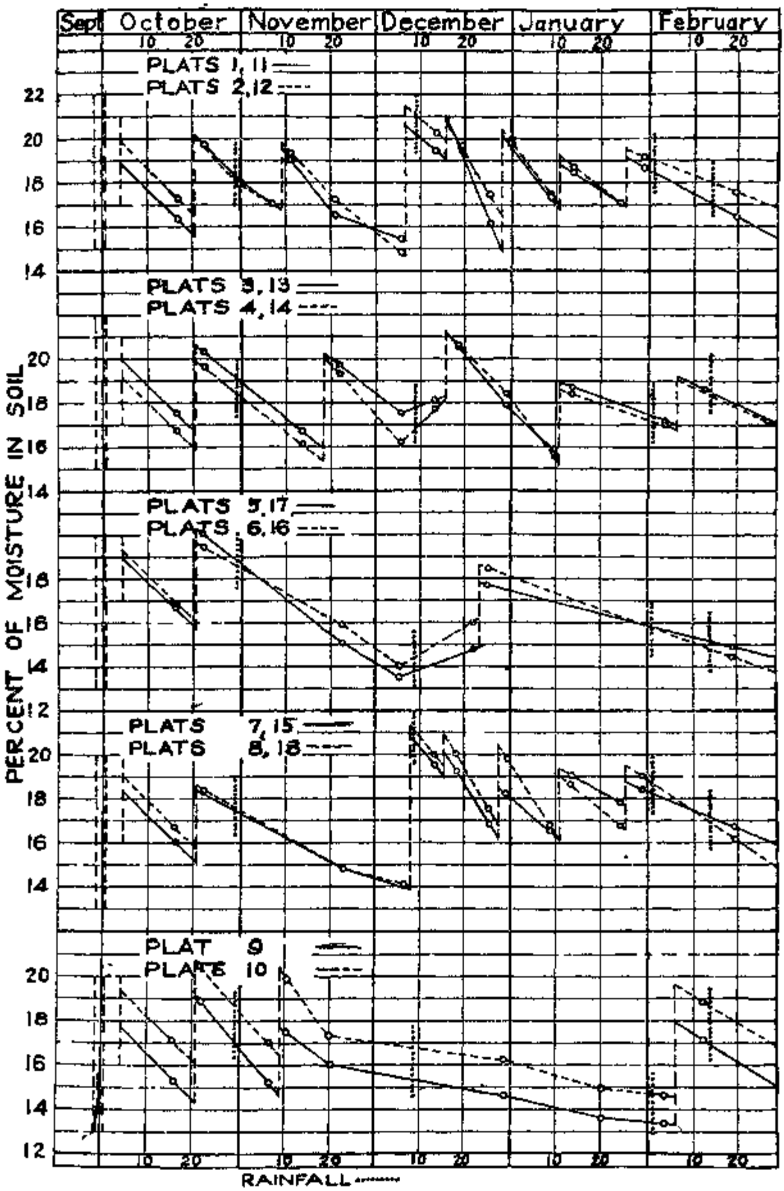

Fig. 14.—Soil moisture determinations 0-1 foot, Davis ranch, 1927-28

amounts applied at these three irrigations were therefore based upon the length of time which the water was run upon the plats, and it is felt that no very large error has been introduced. The irrigation on October 20, in ac-

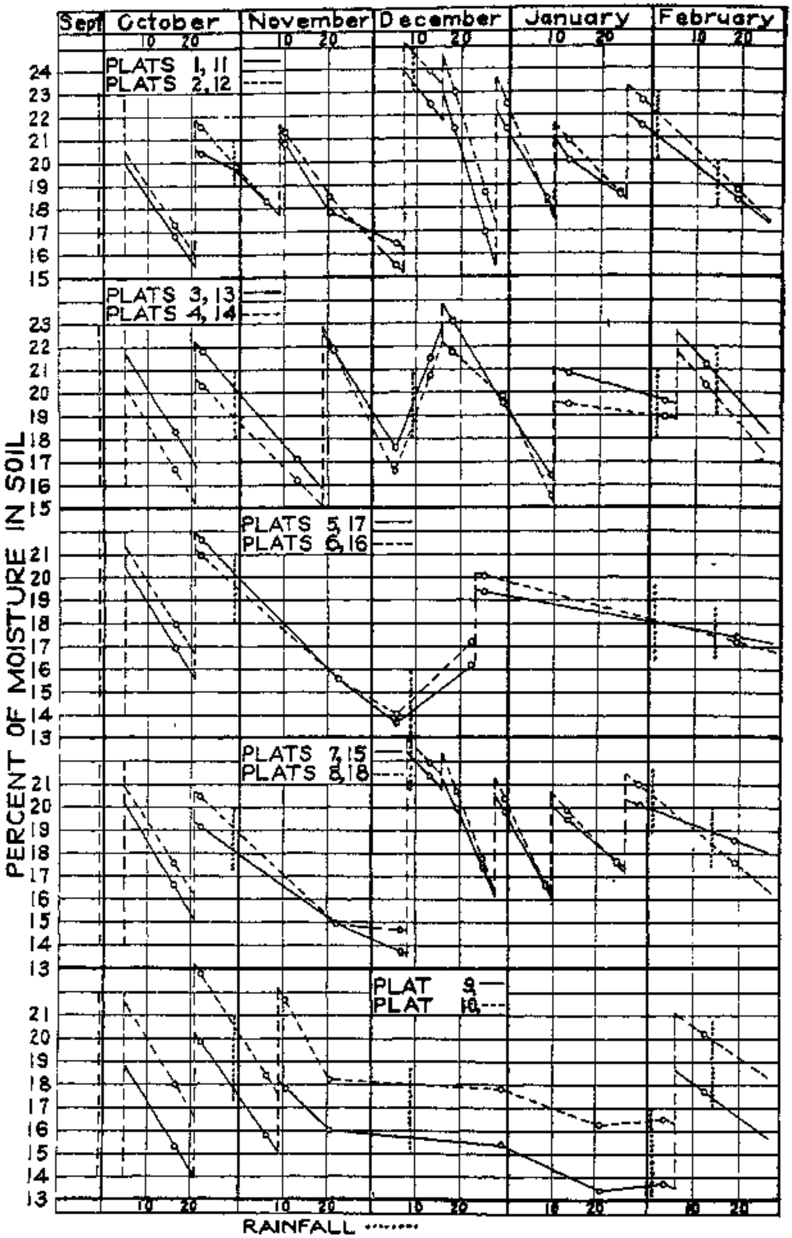

Fig. 15.—Soil moisture determinations 0-3 feet, Davis ranch, 1927-23.

cordance with the outline, was given to all plats and as nearly as possible the same amount was applied to each. After this date the plats were irrigated as nearly as possible in accordance with the soil moisture contents in the plats under the different treatments. A chart showing the variations in soil moisture throughout the season 1927-28 is given in figure 14 for the first foot and in figure 15 for the average soil moisture in the first 3 feet of soil.

An irrigation schedule for the year 1928-29, together with the rainfall chart, similar to that shown for 1927-28 is given in figure 16. All the irrigations to the individual plats for this year were measured and at the time of irrigation the same amount of water, as nearly as possible, was applied to all plats in the same treatment. In this chart the irrigation schedule as shown for the different treatments is the average of the amount of water applied to the four plats in the treatment. It will be noted that the first and second irrigations following seeding for this year are very much heavier than the estimated amounts applied the previous year at the same time. This difference is attributed to the fact that the soil in 1928-29 on the University Farm had been thoroughly worked and was in a dry condition. The original plan of irrigation for the five different treatments was modified in the case of treatments I and V in that both received an irrigation on December 19 before thinning, which was not given to the other treatments. The late planting of this year and the slow growth caused by existing low temperatures made it appear necessary, at the time, to give these plats an extra irrigation in an attempt to maintain the moisture content at more nearly the moisture equivalent which had previously been determined. It was expected at this time that the field water-holding capacity would more nearly approximate the moisture equivalents as shown in Table IV. The amount of water applied to each individual treatment together with the seasonal precipitation is given in the following table.

TABLE IX.—AMOUNT OF IRRIGATION WATER APPLIED ON EACH IRRIGATION TREATMENT DURING 1927-28 AND 1928-29 WITH THE SEASONAL PRECIPITATION.

Year	Irrigation treatment number					Precipitation
	I	II	III	IV	V	
	Inches	Inches	Inches	Inches	Inches	Inches
1927-28	23.7	18.1	11.3	20.7	14.2	3.06
1928-29	25.6	16.9	12.9	15.2	21.6	2.54

The results of the soil moisture sampling on the Experiment Farm are shown in figures 17 and 18, which are comparable to figures 14 and

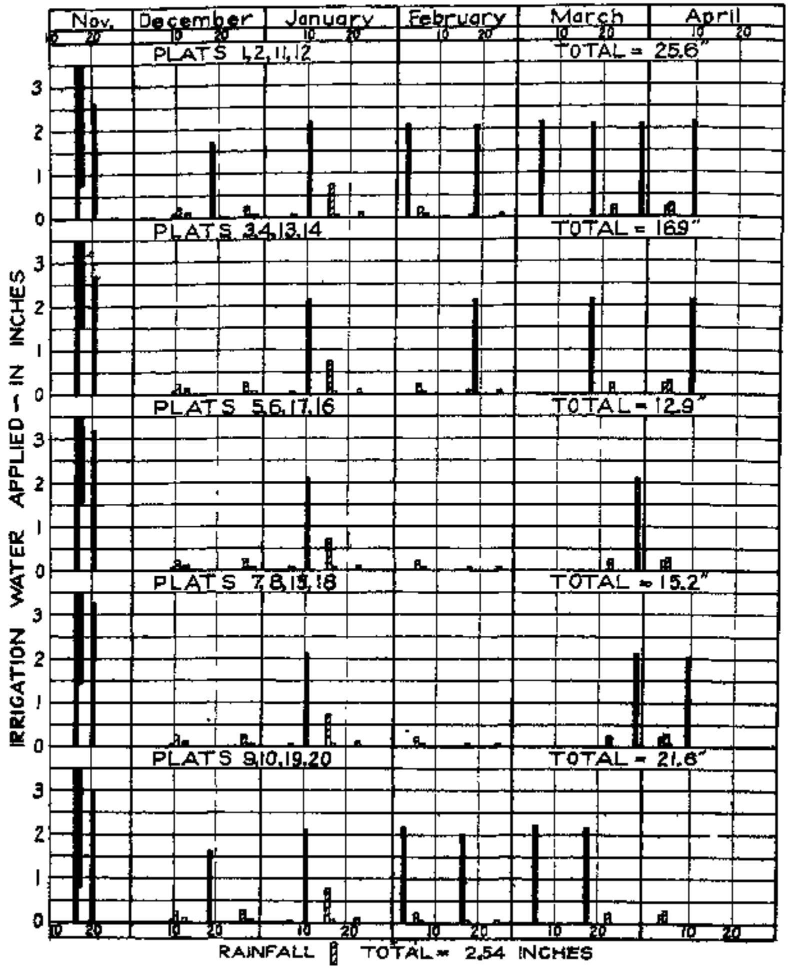

Fig. 16.—Irrigation schedule by treatments, and rainfall, Salt River Valley Experiment Farm, 1928-29.

15 for the Davis ranch. Each point that is plotted on these charts is an average of six samples. An examination of these figures brings out many interesting facts that are consistent for both years. The moisture content of this soil from 3 to 4 days after irrigation consistently shows between 18 and 19 percent of moisture in the upper 3 feet of soil. Seven days to 2 weeks after irrigation it will be noted that the soil moisture content has dropped to between 17 and 18 percent at a time early in the growing season when transpiration and evaporation were negligible.

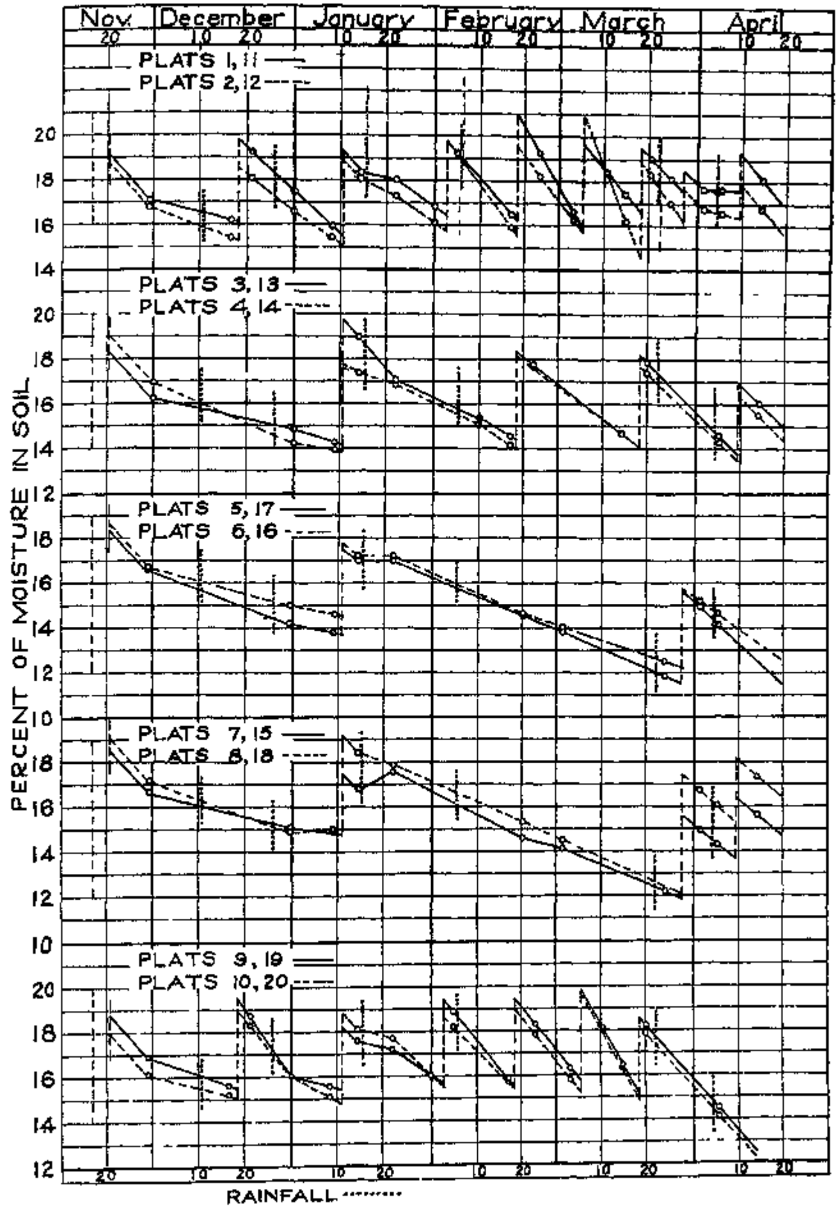

Fig. 17.—Soil moisture determinations 0-1 foot, Salt River Valley Experiment Farm, 1928-29.

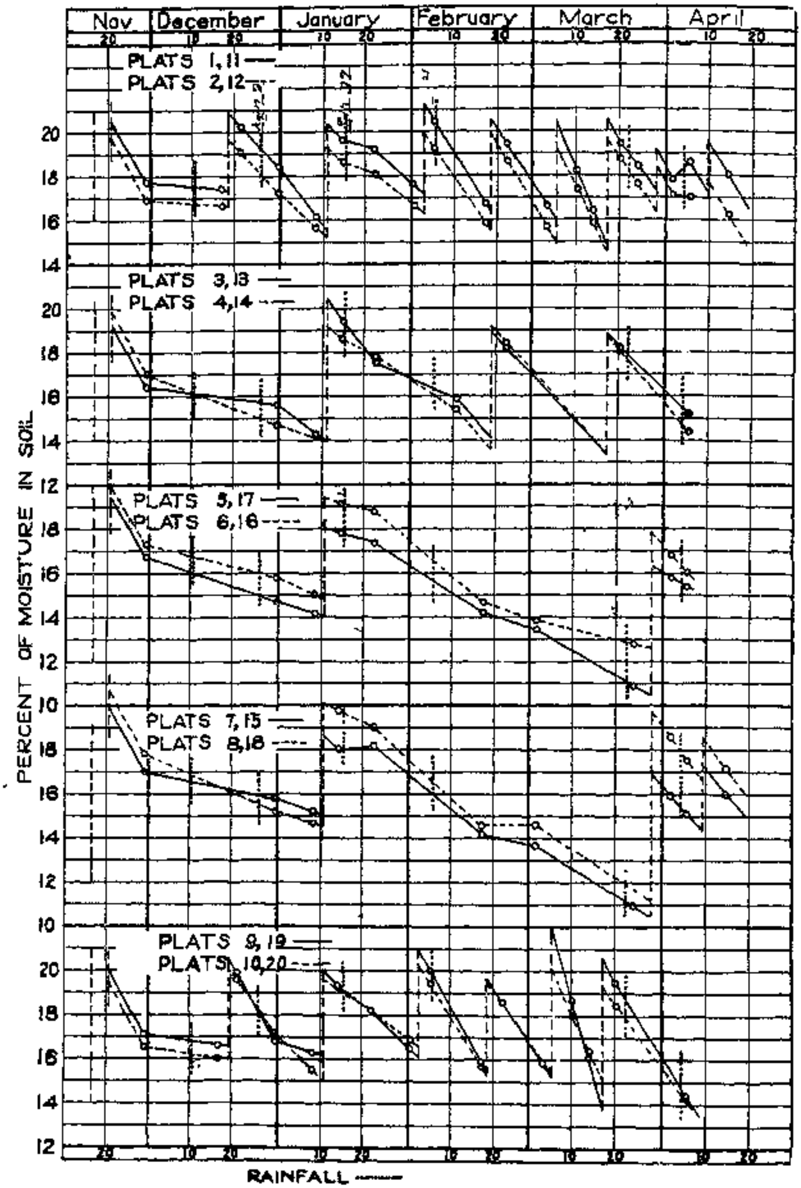

Fig. 18.—Soil moisture determinations 0-3 feet, Salt River Valley Experiment Farm, 1928-29.

The moisture content in both years is higher in the first foot than the average of the 3 feet. The difference is greater in 1927-28 than in 1928-29 and is consistent with the moisture equivalents for the 2 years as given in tables III and IV. It is found that the average moisture equivalent of the first foot on the Davis ranch is 1.5 percent greater than the average for the first 3 feet, whereas on the Experiment Farm the difference is only 0.6 percent. This is at least partially explained as being due to the previous cropping practice on the two locations. The Davis ranch which had been in alfalfa for 5 years was in all probability higher in organic matter than the Experiment Farm which had been cropped heavily, and was given a dressing of manure and a plowing-under of a light crop of peas. Later in the season as the root system of the lettuce plant develops, soil samples taken previous to irrigation show a lower moisture content than the average of the 3 feet as might be expected with this type of a surface feeding crop.

Irrigation schedules in figures 13 and 16 show that treatments I and II are directly comparable for both years. Treatment III, however, should not have been irrigated on December 23 in the 1927-28 season following the heavy rain of December 10, in order to be directly comparable with the following year. Treatments IV and V are not directly comparable for the 2 years due to the difference in planting dates, since the treatments are based on the stage of growth. The length of interval between successive stages of growth is determined for the most part by the existing climatic conditions, the most important factor of which is the temperature. This factor is largely responsible for the difference in treatments IV and V for the 2 years. The maximum, minimum, and mean daily temperatures are plotted in figures 19 and 20 for 1927-28 and 1928-29 respectively, by 5-day intervals. It is noted here that in 1927-28 the mean daily temperature from the date of planting to December was, with the exception of a few days, above 55° F. The plants grew rapidly and were thinned October 21, an interval of 23 days from planting. The lettuce continued to make rapid growth until December 5, when the bunching stage was reached, 45 days from thinning. From this time on the mean daily temperature was, with the exception of 7 days, well below 55° F. and the lettuce matured very slowly to the first cutting on January 20, 46 days after bunching. From seeding to the first cutting required a time interval of 114 days under the growing conditions that existed.

The temperature conditions during 1928-29 differed considerably from those of the previous year. Growing conditions were in reverse order to the previous season with low temperatures during the earlier periods of growth and comparatively higher temperatures in the harvest period.

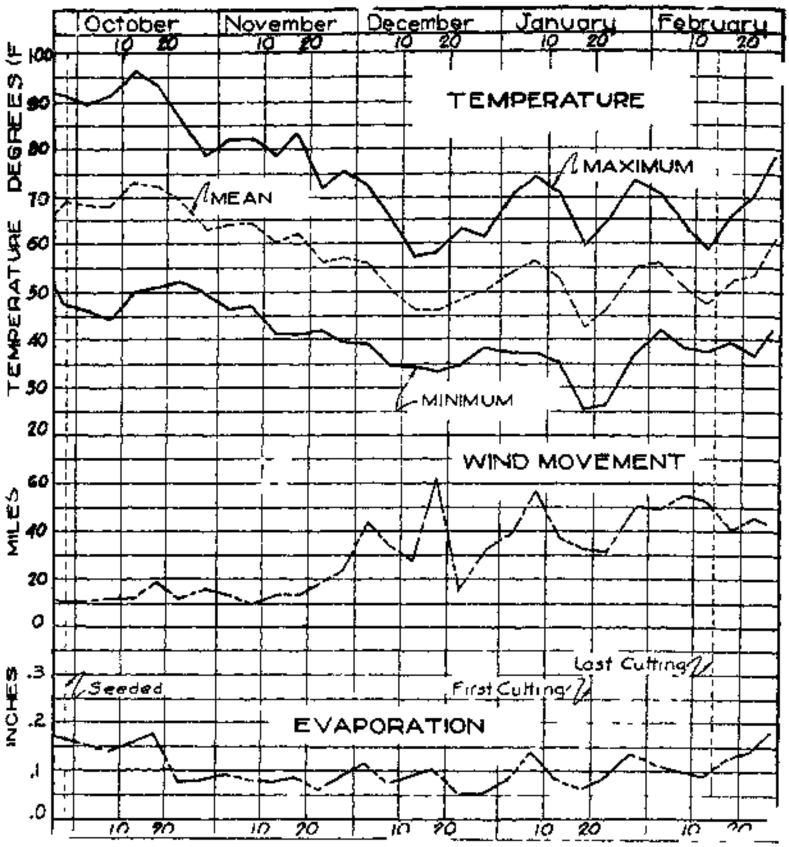

Fig. 19.—Maximum, minimum, and mean temperatures with evaporation and wind movement by 5-day periods, 1927-28.

During the 53-day period from seeding to thinning, on January 7-9, there were only 14 days in which the mean daily temperature was over 55° F. with more than half of these occurring during the first 2 weeks immediately following planting. The lettuce grew very slowly during this period and continued to make little growth until the bunching stage was reach on March 10. Thus 61 days were required from thinning to bunching, during which time the mean daily temperature was below 55° F. excepting during 8 days, 6 of which occurred immediately previous to bunching Growing conditions were apparently more favorable from this stage to harvest on April 4, as only 24 days were required during which the mean daily temperature was approximately 60° F. During this season 135 days were necessary to grow the crop to the first cutting.

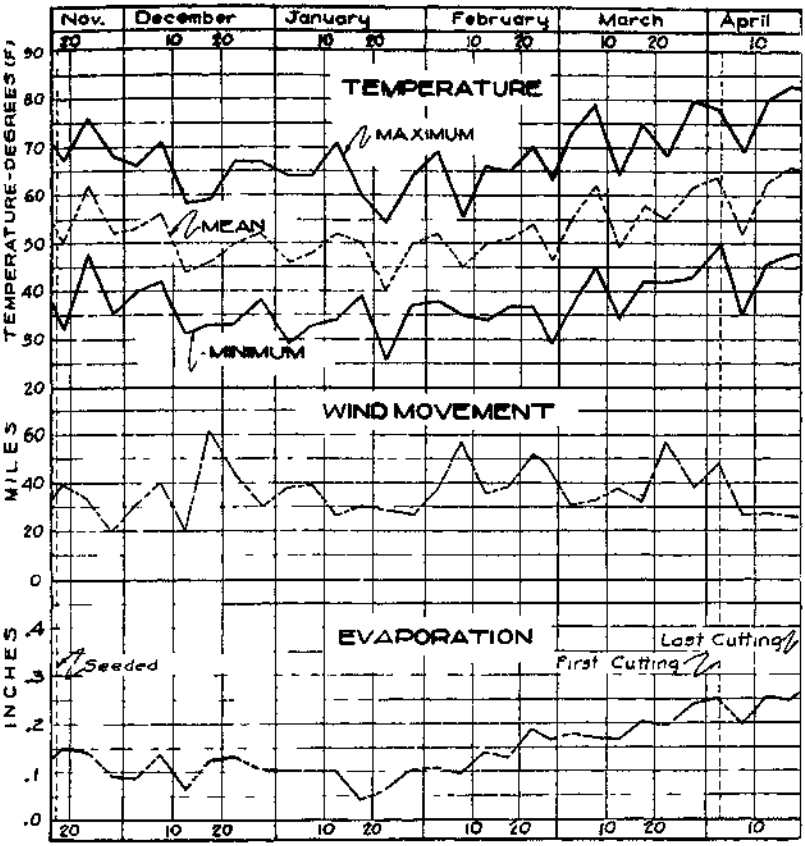

Fig. 20.—Maximum, minimum, and mean temperatures with evaporation and wind movement by 5-day periods, 1928-29.

Although sufficient data is not available to arrive at a definite conclusion it appears, from a comparison of the lettuce growth and temperature records in figures 19 and 20, that lettuce makes little or no growth below a mean daily temperature of between 50° and 55° F., under Salt River Valley climatic conditions. It is possible that with a smaller range between maximum and minimum daily temperatures that this figure might not hold true.

ROOT DEVELOPMENT

Plants were washed out on each of the five treatments in an endeavor to determine the penetration, distribution, and characteristic rooting habit under these conditions. Trenches were dug in an "L" shape across the bed and along the furrow to a depth of 6 feet, within 4 inches of the lettuce plants. A power orchard sprayer, with garden hose and adjustable nozzle was used. The nozzle was adjusted to a fine spray with comparatively low pressure which was found most effective as the roots are exceedingly delicate. Ice picks were employed to loosen the soil along the roots as it was found impossible to make any progress with the spray alone in this type of soil without damaging the root or losing its course. Many roots were lost and again picked up as the washing progressed. It was impossible to retain roots intact due to their extremely delicate structure and in order to properly designate their location they were charted on graph paper as the washing progressed.

No significant difference was noted in the extent or distribution of the root systems between the different irrigation treatments with the possible exception of treatment III. Here it was observed that both the extent and distribution of upper feeder roots and the deeper penetrating roots were slightly less than in the other plants washed out. A typical cross section of a bed showing the lettuce plants in position and their root systems as they were found, is shown in figure 21.

The tap root of most of the plants had a diameter of approximately 1 inch at the surface of the soil, tapering to about 3/16 of an inch

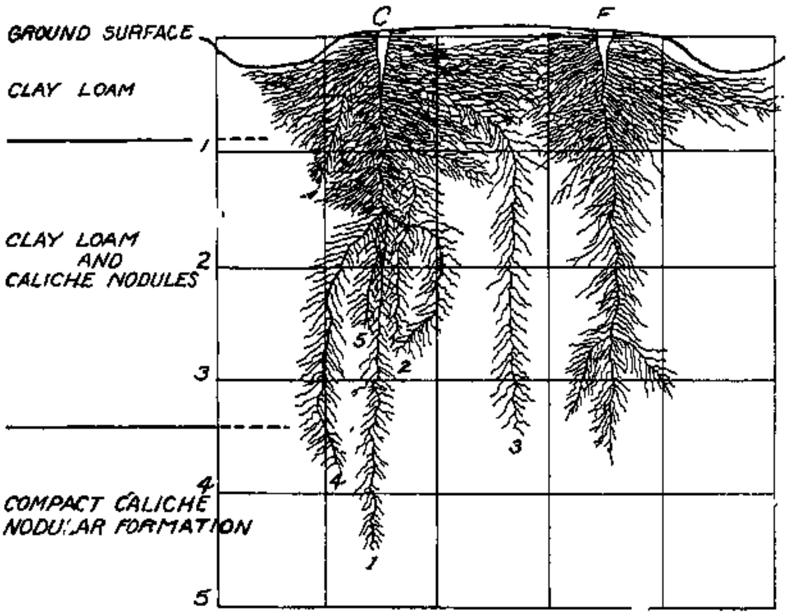

Fig. 21.—Sketch of root system of two mature lettuce plants on Davis ranch, 1927-28.

at a depth of 6 inches. From this point downward the diameter decreased until it was slightly more than a sixteenth of an inch at a depth of from 12 to 15 inches. The root continued from this point to a total depth of from 40 to 55 inches with an average thickness of slightly over a sixteenth of an inch. Where a single taproot was observed its path was ordinarily vertically downward with numerous and tortuous windings, deviating from the straight path to avoid groups of compact caliche nodules. The contact of the tip of this root with these caliche nodules on its growth downward caused many small swellings where the root tip had attempted to penetrate the nodule and then turned aside. In many cases where the taproot was unable to force its way through or around the nodule it apparently branched and in some cases as many as four or five large lateral roots took the place of the taproot. The direction of these branches was usually diagonally downward turning vertically downward from 6 to 15 inches away from the projected path of the taproot. The taproot and these branches were ordinarily of the same diameter throughout.

The first 12 to 15 inches of the taproot was densely covered with fine feeder roots that gradually diminished in number from the surface 8 to 10 inches downward. A count of the feeder roots on the first 4 inches of the taproot of a typical plant totaled approximately 200 lateral feeder roots. The course of these feeder roots near the surface of the soil, in the beds, was downward at an angle of approximately 30° for the first 4 or 5 inches from the taproot, then turning more nearly horizontal and upward an inch or so and turning downward in the zone of competition between adjacent plants. These roots, on the furrow side, leave the taproot at approximately the same angle and flatten out under the furrow with the upper roots within an inch of the soil surface. Few feeder roots were found closer than 2 inches to the surface under the beds proper. Many of these surface roots overlap the root zone of the adjacent plants to a distance of 3 or 4 inches. These roots branch and re-branch until a heavy mat is formed throughout the upper 12 to 15 inches of soil. The volume occupied by these feeder roots is roughly that of an inverted cone 30 inches in diameter and 15 to 18 inches in depth.

In this upper zone of concentrated root growth, from five to ten large feeder roots branched from the taproot at an angle of from 30° to 45° downward and out from 5 to 15 inches from the taproot. Their course was vertically downward from this point and they were similar in appearance to the taproot and its lower branches in both size and branching. The ultimate depth of these large laterals very closely approximated that of the taproot and the lower branches. In a few cases these laterals were found in the root zone of adjacent plants. Very often one or more of these roots from the same plant or adjacent plants followed the course of an old alfalfa root. It was observed also that most of these roots maintained a diagonal course across the bed or furrow, thus occupying a less competitive soil area.

The laterals from the taproot and large branches were as a rule not over 6 inches in length and were sparsely branched below this upper zone.

HARVEST DATA

The lettuce was harvested during both seasons at the same stage of maturity as in commercial fields with the exception that a larger number of cuttings was made to insure more uniform and comparable conditions of maturity. During 1927-28, one man did all of the cutting while during the following year the increase in crop necessitated two men on this work as the plats matured quite rapidly. These men worked together in each plat rather than each one harvesting separate plats. This care was taken in both seasons to eliminate the variability of human judgment as much as possible. The stage of maturity at which the plants were harvested was indicated by a change in color of the heads from a dark green to a light silver shade and a blanching of the midvein of the wrapper leaf to a clear white.

The lettuce heads were cut flush with the ground surface and were carried carefully in crates to a central grading and weighing station where one man classified them. The classes into which the heads were separated are designated as follows: "commercial" those heads ranging in size from 4 to 7 dozen sizes for a commercially packed standard crate, the heads to be solid, well formed, and mature; "unmarketable," into which class all small, soft, and undesirable heads were placed; "bursted" included those heads that had definitely split and bursted before they could be harvested; and "slimed" heads were those showing a definite infection of the rot. All classes were counted and weighed separately. After the last cutting all plants remaining in the plat were counted to determine the total number of plants.

A composite sample of 50 heads was taken from the commercial class of each plat during the second cutting in 1927-28 and during the following year this sample was taken in the first as well as the second cutting. These heads were stripped of wrapper leaves, measured and weighed, and the results were used in computing a factor of solidity or compactness. The harvest data for 1927-28 and 1928-29 are shown in tables X and XI.

TABLE X.—HARVEST DATA ON LETTUCE IRRIGATION PLATS 1927-28.

Plat	Total plants	Average weight all plants	Average weight commercial	Average stripped weight	Percent heading	Percent commercial heads	Percent slime	Average compactness
1 & 11	1988	.89	.93	.62	81.5	56.0	2.5	.64
2 & 12	2474	.86	.90	.61	81.1	55.8	1.8	.65
3 & 13	2025	.97	.98	.65	82.8	38.0	0.8	.65
4 & 14	2064	.95	.96	.62	84.3	40.2	1.1	.67
5 & 15	2524	.81	.87	.57	77.5	42.0	0.6	.65
6 & 16	2568	.80	.87	.57	80.3	48.8	0.2	.63
7 & 17	2448	.82	.90	.61	70.0	36.0	2.2	.59
8 & 18	2341	.86	.90	.62	68.2	34.2	0.8	.59
9	1313	.87	.91	.63	80.4	41.7	0.3	.65
10	1371	.83	.89	.57	89.3	48.6	0.2	.65

TABLE XI.—HARVEST DATA ON LETTUCE IRRIGATION PLATS 1928-29.

Plat	Total plants	Average weight all heads	Average weight commercial	Average stripped weight	Percent heading	Percent commercial heads	Percent bursted	Percent slimed	Average compactness
1 & 11	2346	.91	.96	.55	84.2	59.8	6.25	0.40	.62
2 & 12	2471	.86	.93	.56	78.0	51.2	5.8	0.7	.61
3 & 13	2616	.94	1.01	.56	77.8	44.2	11.0	0.2	.58
4 & 14	2417	.99	1.04	.58	69.0	37.2	10.8	0.3	.59
5 & 17	2248	.97	1.02	.48	63.7	30.5	21.2	0.0	.55
6 & 16	2268	.97	1.02	.51	60.3	24.3	21.5	0.0	.56
7 & 15	2189	1.06	1.10	.53	69.3	25.7	29.8	0.10	.58
8	1180	1.02	1.10	.52	62.2	24.2	23.4	0.0	.54
9 & 19	2043	.91	.97	.53	83.7	56.1	7.8	1.00	.59
10 & 20	2279	.86	.91	.56	79.7	57.5	6.7	0.7	.63

Plats 19 and 20 were discarded early in the season of 1927-28 due to the poor stand of plants secured. The harvest data from plat 18 in the 1928-29 season were discarded as this plat accidentally received a heavy irrigation just previous to the first cutting.

WEIGHT OF HEADS

A comparison of the average weight per head of total heads cut, and of the average weight of the commercial heads, is shown in figure 22 for 1927-28 and in figure 23 for 1928-29, under each irrigation treatment. The correlation of total head weights with commercial head weights is so consistent that no distinction is made in the following discussion.

It will be noted from the charts that consistent results were obtained from irrigation treatments I and II during both years. The average weight of total heads as well as the average weight of commercial heads

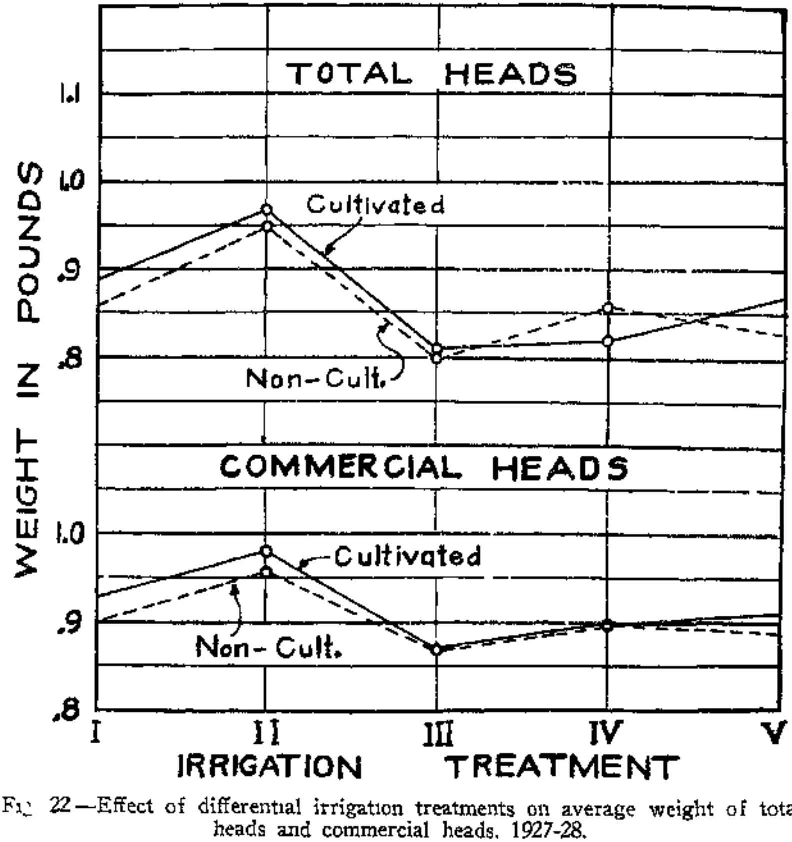

Fig. 22—Effect of differential irrigation treatments on average weight of total heads and commercial heads, 1927-28.

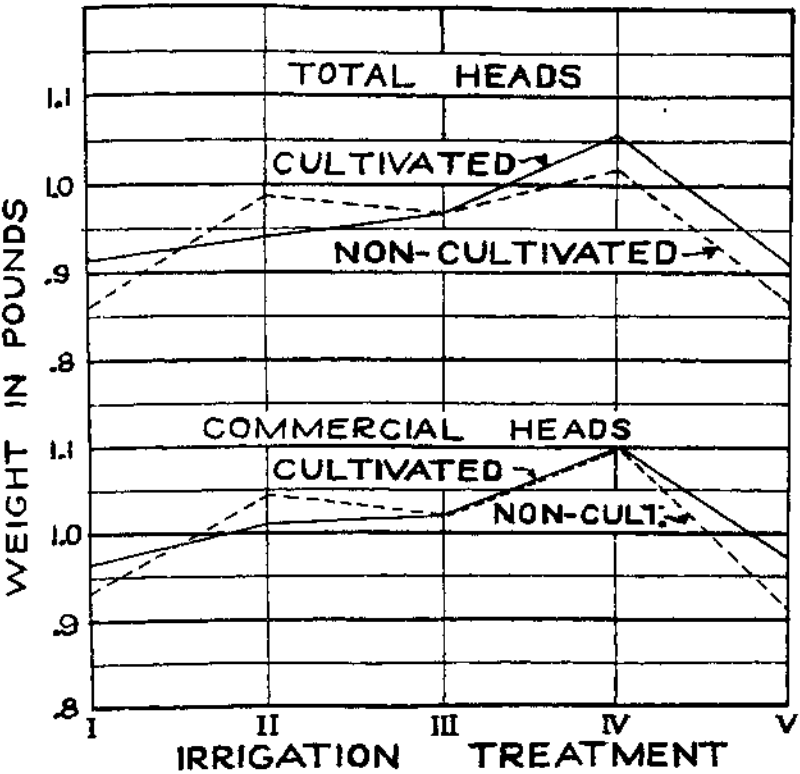

Fig. 23.—Effect of differential irrigation treatments on average weight of total heads and commercial heads, 1928-29.

is greater in both seasons for treatment II. This would indicate that carrying the soil moisture at approximately the field water-holding capacity or above, as in treatment I, throughout the growing season is not favorable to the production of the heaviest heads, where as the maintenance of soil moisture, as in treatment II, with a wider range produced consistently heavy heads during both seasons.

Treatment III, the driest of the group, produced the lightest weight heads in 1927-28. The following year approximately the same amount of water was applied in this treatment and resulted in heads weighing practically as much as those in treatment II for that season. This apparent discrepancy is explained by the fact that in 1927-28 the plants were subjected to a water stress early in the growing season when temperature conditions were favorable to rapid growth (Fig. 14). A heavy rain December 10 and a subsequent irrigation in the latter part of the month together with rains during harvest kept the soil moisture sufficiently high to prevent water stress during the remainder of the season. In 1928-29, however, no water stress occurred until the latter part of March, which was followed by an irrigation on March 30 as temperatures became favorable to rapid growth. This late irrigation caused rapid development of the lettuce plants which had been previously noted as smaller and slightly more mature.

Treatment IV shows a lack of comparability for the 2 years in that the total water applied in 1927-28 was 20.7 inches and only 15.2 inches in 1928-29. As has been explained previously this was due to difference in temperature conditions affecting the growth of the plants on which the irrigation treatment was based. In 1927-28 this treatment shows very little effect of the water applied by irrigations during December and January. This leads to the conclusion that due to the unfavorable temperatures for growth in this period and at maturity the plants were able to make use of compartively little of the available soil moisture. An examination of soil moisture charts for this year reveals that the moisture content of this treatment, during the earlier periods of growth under favorable temperature conditions, and that of treatment III are almost identical. The heavy rain on December 10 offset to a large extent any differences in soil moisture content that might have resulted from the irrigation of treatment IV on December 8. Thus it would appear that lack of abundant soil moisture early in the season, when temperature conditions were favorable for growth, decreased the weight of heads in treatment IV the same as in treatment III, nothwithstanding the fact that adequate moisture was available for the entire balance of the growing season. In 1928-29 this same treatment is directly comparable to treatment III of the same year with the excetpion of an additional irrigation given in the early part of harvest, under temperature conditions such that the plant was able to utilize this abundant soil moisture. This additional water supply had the effect of increasing the head weight to such an extent that the heads from this treatment were the heaviest of all.

Treatment V in 1927-28 produced heads slightly heavier than did treatments III and IV, with abundant soil moisture early in the season at a time when growing temperatures were favorable and with an evident shortage in the first part of the harvest season. This water shortage during maturity is apparently responsible for lighter heads than those in treatments I and II. In 1928-29 treatment V is more nearly comparable to treatment I of this year and is not comparable with treatment V of the preceding year, due to difference in growth of plants, as influenced by temperature, and upon which the treatment is based. The weight of heads this season is heavier than those of treatment I and the average weight of commercial heads is greater than either treatment I or II. This would seem to show the advantages of bringing the crop to the harvest season with an abundant supply of available soil moisture to be used during this period.

The results of cultivation versus non-cultivation, or very shallow cultivation, are shown in figures 22 and 23. It is noted from these charts that consistent differences are not manifest between these cultural treatments and that it is not possible to draw definite conclusions as to their value.

HEADING

The percentage of total plants heading and the percentage of commercial heads are shown in figures 24 and 25, and are based on the number of heads cut plus the number of plants remaining in each treatment after harvest. The results for both seasons show that there is a consistent relationship existing between the percentage of plants heading and the commercial heads for all treatments. In view of this fact these two values will not be discussed separately, with the exception of treatment I, in the 1927-28 season. It is felt that this exception is caused by worm injury early in the season in plats 1 and 2 resulting in injury to many plants that prevented them forming heads.

Again it is noted that treatments I and II are consistent for both seasons, the highest percentage of heading in all plats is found in treatment I. Treatment II is somewhat lower in percentage heading, which is just the reverse of the order in the weight of head figures. It is evident that an abundance of soil moisture carried throughout the season, as is found in treatments I and II, is conducive to a high percentage of heading.

Treatment III is not comparable for the two seasons in the percentage of heads formed. In 1927-28 the moisture content of the soil wes reduced to its lowest point early in the season whereas during the heading period, although the moisture content was not high, sufficient moisture was present to allow the heads to mature. However a low percentage of heading resulted from this treatment. In 1928-29, in contrast to the previous year, the moisture content was reduced to a low point where a definite water stress was observed in the plants a week before the first cutting was made. An irrigation at this time, when favorable temperature conditions for growth existed, produced heavier plants of which a large proportion opened up and failed to make heads. From this it appears irrigation at maturity following a definite water stress may be expected to lower the percentage of heading materially.

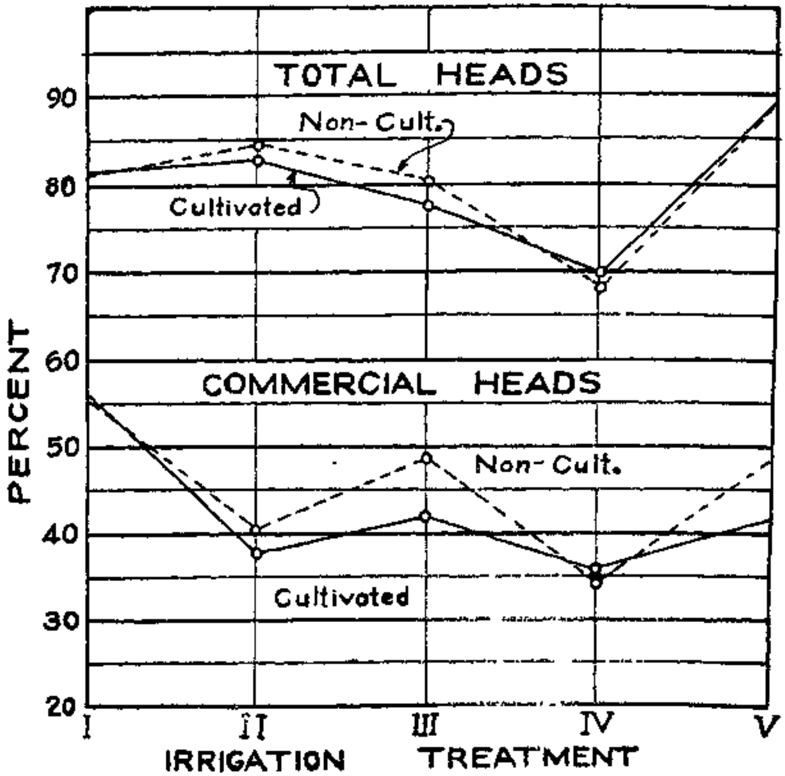

Fig. 24.—Effect of differential irrigation treatments on percentage of plants heading and percentage of commercial heads, 1927-28.

Treatment IV in 1927-28 is comparable with treatment III of the same year in that the lowest moisture content of the soil occurred early in the season. Frequent irrigations throughout the latter part of the growing period failed to increase the percentage of heading as compared with treatment III. This treatment in 1928-29 differs only from treatment III of that year in that an additional irrigation was given during harvest. No material difference in percentage of heading between them is found.

Treatment V in 1927-28 shows the effect of abundant water supply during the early period of growth, under favorable growing temperature conditions, with a gradual reduction in soil moisture content during the slow growing weather of December and January to maturity. This condition resulted in a high percentage of comparatively small heads. The irrigation given on February 7 occurred late in the harvest period after the major portion of the crop had been cut and during weather un-

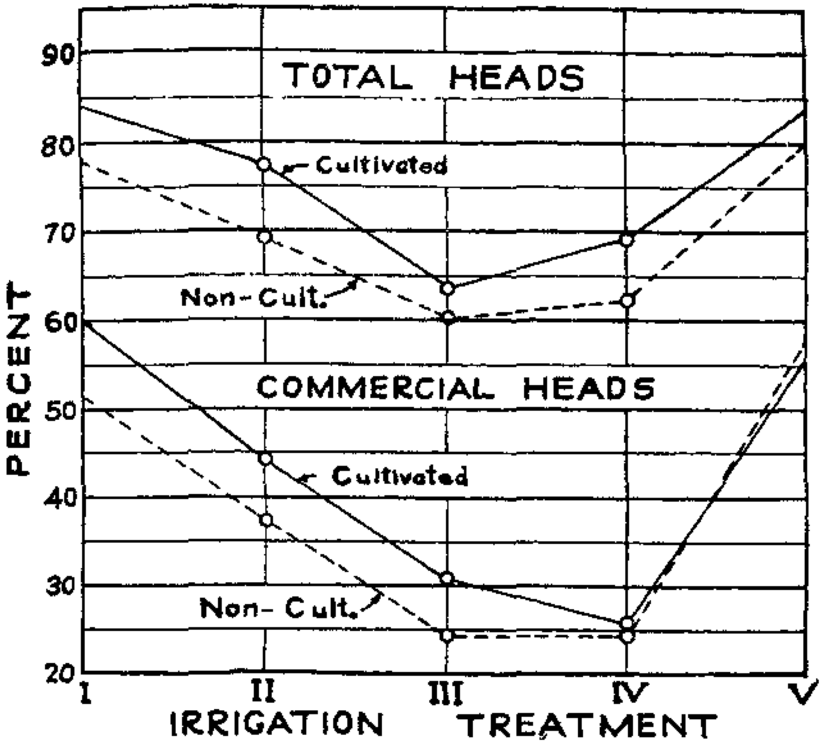

Fig. 25.—Effect of differential irrigation treatments on percentage of plants heading and percentage of commercial heads, 1928-29.

favorable to rapid growth. This irrigation had no appreciable effect on the percentage of heading. During 1928-29 this treatment is more nearly comparable to treatment I, the only difference being that it was not given the irrigations just previous to and during harvest. This resulted in a high percentage of heading almost identical to that of treatment I.

Cultivation treatment during 1927-28 resulted in no outstanding difference, due, no doubt, to the shallow nature of the cultivation carried on. In 1928-29 however, where the cultivation was maintained to a depth of 3 inches following each irrigation, it is noted that consistent favorable results in heading were obtained in comparison with the shallow cultivation for weed elimination.

MATURITY

In order to study the comparative time of maturity under the various irrigation treatments it was necessary to determine a mean date of maturity based upon harvest data. An index for the mean date of maturity was secured for each set of duplicate plats by the summation of the values obtained, by multiplying the percentage of heads harvested at each cutting by the number of days between each and the first cutting. This index of maturity divided by 100 then gives the number of days between the first cutting and the mean date of maturity. The percentage heading for each cutting and the index of maturity for the individual treatments are given in table XII. The mean date of maturity is graphically shown in figure 26.

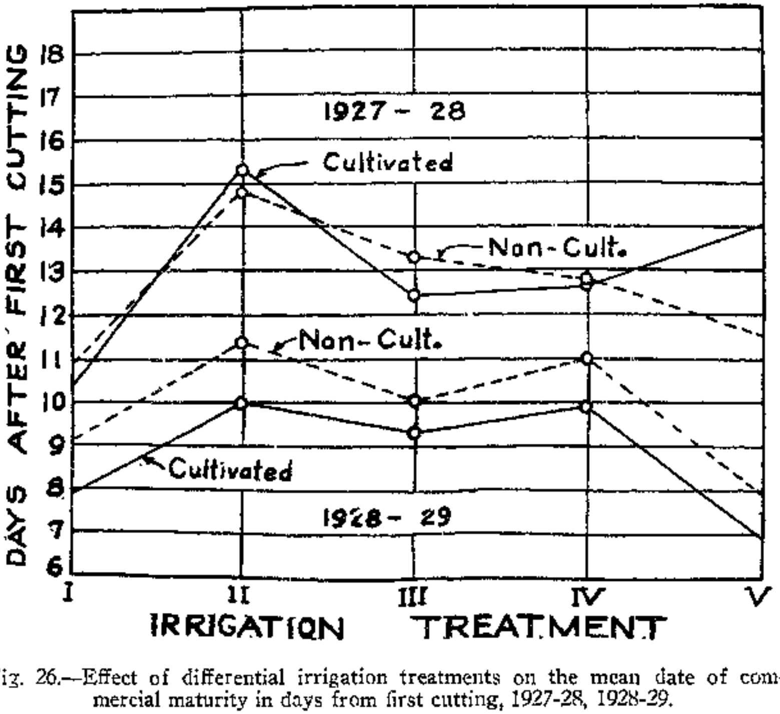

Fig. 26.—Effect of differential irrigation treatments on the mean date of commercial maturity in days from first cutting, 1927-28, 1928-29.

The effect of different weather conditions during the harvest period is reflected in the consistently longer interval between the average date of maturity and the first cutting in 1927-28, as compared to 1928-29, the difference being 5 or 6 days.

A further examination of figure 26 shows a consistent early maturity in irrigation treatments I and V for both years, however treatment V has a somewhat earlier maturity than treatment I due in all probability to the gradual reduction of soil moisture just previous to and during harvest. The difference in field water-holding capacity of plants 9 and

TABLE XII.—DATES, AND YIELD OF LETTUCE IN PERCENT, FOR EACH CUTTING BY PLATS, 1927-28 AND 1928-29.

1927-28	1 and 11		2 and 12		3 and 13		4 and 14		5 and 15		6 and 16		7 and 17		8 and 18		9		10	
	Date	Pct.	Date	Pct.	Date	Pct.	Date	Pct.	Date	Pct.	Date	Pct.	Date	Pct.	Date	Pct.	Date	Pct.	Date	Pct.
1st. cutting	1/25	17.0	1/25	19.3	1/25	11.0	1/25	19.0	1/25	9.0	1/25	7.4	1/25	2.8	1/25	1.8	1/25	9.6	1/25	16.5
2nd. cutting	1/31	34.6	1/31	25.5	1/31	16.4	1/31	9.8	1/31	13.2	1/31	15.9	1/31	12.5	1/31	12.2	1/31	27.7	1/31	36.4
3d. cutting	2/11	48.4	2/11	55.2	2/14	72.6	2/14	71.2	2/10	72.8	2/10	76.7	2/8	84.7	2/8	86.0	2/14	62.7	2/14	47.1
Maturity Index	1030.4		1091.4		1530.4		1482.8		1244.0		1334.6		1260.8		1277.2		1400.2		1150.4	
1928-29	1 and 11		2 and 12		3 and 13		4 and 14		5 and 17		6 and 16		7 and 15		8		9 and 19		10 and 20	
	Date	Pct.	Date	Pct.	Date	Pct.	Date	Pct.	Date	Pct.	Date	Pct.	Date	Pct.	Date	Pct.	Date	Pct.	Date	Pct.
1st. cutting	4/3	27.1	4/3	11.9	4/5	23.6	4/5	13.4	4/5	28.6	4/5	22.8	4/5	17.8	4/5	14.5	4/3	26.7	4/3	22.2
2nd. cutting	4/9	27.8	4/9	39.1	4/10	16.6	4/10	14.8	4/12	33.2	4/13	46.5	4/13	48.6	4/13	49.8	4/10	40.2	4/10	36.8
3d. cutting	4/15	29.4	4/15	30.8	4/15	36.4	4/15	42.8	4/18	38.2	4/19	30.4	4/19	29.6	4/19	35.7	4/13	21.2	4/14	30.9
4th cutting	4/20	15.7	4/20	18.2	4/20	23.4	4/20	29.0									4/20	11.9	4/20	11.2
Maturity Index	786.5		913.6		998.0		1137.0		929.1		998.0		995.2		1098.2		695.7		787.9	

10, 1927-28, as shown in figure 14, is reflected in this chart with plat 10 showing a 2½-day earlier average date of maturity. Treatment II which is comparable for both years and has a wider range in soil moisture, is approximately 2 days later in maturity, than treatment I.

Treatments III and IV, which are not comparable as to soil moisture conditions through the growing season, had each been subjected to a low soil moisture content when temperture conditions were favorable for growth early in the season in 1927-28 and late in the 1928-29 season. In 1928-29 this condition occurred just previous to harvest, the plants showing a definite water stress which was followed by an irrigation that evidently prolonged the growth of the plants and delayed maturity.

Cultivation during 1927-28 had no consistent effect upon the mean date of commercial maturity whereas during 1928-29 the mean date of maturity is definitely earlier in the cultivated plats. During this season cultivation influenced the mean date of maturity speeding it up approximately a day in all treatments.

A study of the spread of commercial maturity was made for both years and the results are shown in figure 27, which has been plotted from the data on the five different treatments as given in table XII. In this chart no differentiation is made between cultivated and non-cultivated plats as there was so little difference between them. Each curve represents an average of the harvest data from four plats under each treatment. An arbitrary allowance of 5 days was made before the first cutting and after the last cutting in plotting these charts. This figure was selected as being relatively near the actual one for completing the maturity period.

During 1927-28 the harvest was seriously interfered with by rains considerably delaying the last cutting. Treatments I, II, and V show reasonably consistent curves for both seasons whereas treatments III and IV differ considerably due to the difference in irrigation treatment for these two seasons. Treatments I and II show a fairly uniform rate of maturity with a harvest period varying from 15 to 20 days. It is apparent that sufficient data on the spread of maturity was not secured to arrive at definite conclusions. This was due in large measure to rains occurring in the harvest season, particularly affecting the number of and intervals between cuttings in 1927-28.

BURSTED AND SLIMED

The data on bursted heads was not recorded separately in 1927-28, these heads being included in the unmarketable class. During 1928-29 these data were recorded separately and are shown in table XI. Inasmuch as there was no significant difference between the cultivated and

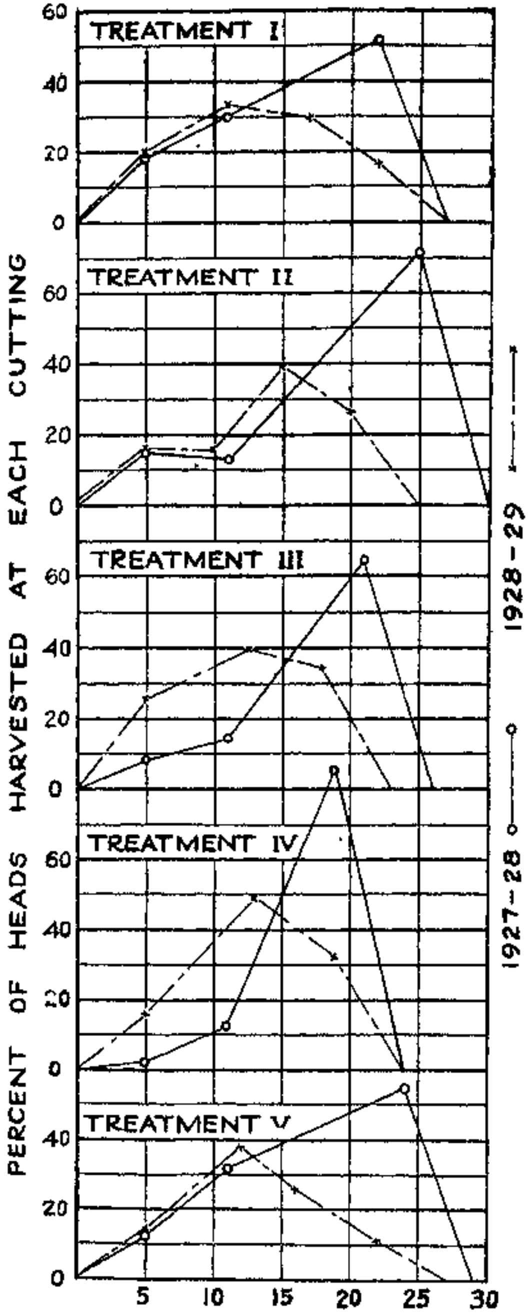

Fig. 27.—Effect of differential irrigation treatments on the spread of commercial maturity in days, 1927-28 and 1928-29.

non-cultivated plats in either slimed or bursted heads these data are presented as an average for the separate treatments in figure 29. It is noted here that treatments I and V are the lowest in percent of bursted heads indicating that a high uniform soil moisture content throughout the season is conducive to the formation of solid heads. Treatment II following directly in line with irrigation treatment I is also low in this respect. In contrast with these three treatments it is observed that treatments IV and V, in which the soil moisture has been reduced to a low point just previous to harvest and followed by irrigation, produced plants that developed heads rapidly which bursted before they could be harvested.

A correlation is observed between the amount of irrigation water applied and the percent of slimed heads developed. These results are consistent in both seasons. In 1928-29 treatments III and IV show no increase in slime from irrigation just previous to and during harvest. It is also observed that treatment V, in which water was withheld just previous to and during harvest, shows a slightly greater percentage of slimed heads than treatment I which was carried through the season with a high soil moisture content. From these results it may be concluded that the susceptibility to slime is affected by the seasonal soil moisture content and that the modification of irrigation treatment during harvest has little effect.

A comparison of the percentage of bursted and slimed heads in 1928-29 shows that they are in inverse proportion. Both of these may be correlated with the amount of irrigation water applied during the season.

COMPACTNESS

A study was made of the relative solidity of the commercial heads under each treatment. A composite sample of 50 heads was selected from the commercial heads of each plat during the second cutting in 1927-28 and the same number from both the first and second cuttings in 1928-29. An arbitrary measurement of the solidity or compactness of the individual heads was obtained in the following manner.* All loose leaves were carefully stripped from the head as in preparation for table use and the stem cut off flush with the head. (Fig. 28.) The transverse and longitudinal circumference of each head was measured in inches and the head carefully weighed in ounces. The compactness factor was then determined by dividing the weight by the product of the circumferences and multiplying by 10. The stripped weights and

*This method was developed and suggested by Charles Hobart, Research Assistant in Horticulture and Agronomy, Arizona Agricultural Experiment Station.

compactness factors for the second cutting of 1927-28 are given in table X and of 1928-29 in table XI.

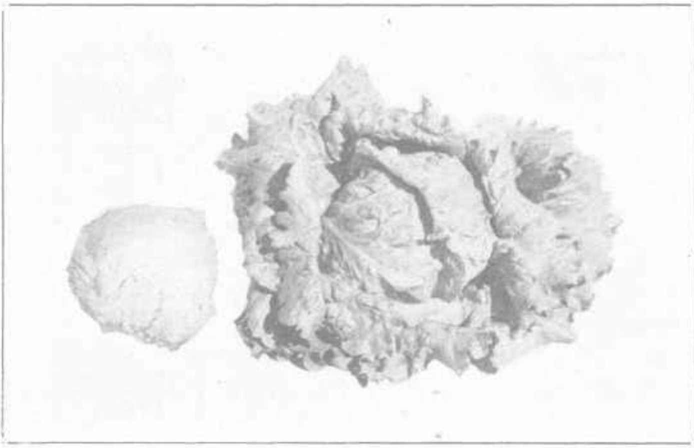

Fig. 28.—Lettuce head stripped of leaves for compactness measurements, compared with normal head.

The compactness factors are charted by irrigation treatments, for the second cutting for both year, in figure 29, inasmuch as no significant differences were observed between cultivated and non-cultivated plats. Treatments I and V of both years produced heads of highest average compactness with the single exception of treatment II in 1927-28. In 1928-29 it is noted that the compactness is in direct relation to the amount of irrigation water applied. In view of this it may be assumed that a high uniform soil moisture content throughout the season is desirable in the production of solid compact heads of lettuce.

A higher compactness is evident in 1927-28 which is due in all probability to the slower maturing temperatures of that year. Differences in the comparative compactness of treatments III and IV between the two seasons may be attributed to a difference in the irrigation treatments. No reason is apparent for the behavior of treatment II in this regard.

In 1928-29 an inverse relation exists between compactness and the percentage of bursted heads. There is a direct realtionship however between the percentage of slimed heads and the average compactness. It would thus appear that the solid heads are more susceptible to this disease than the more open and less compact type.

During 1928-29 a study was made between the compactness of the first and second cuttings. From the data presented in Table XIII it will be noticed that there is a lowering of the compactness of the later cuttings.

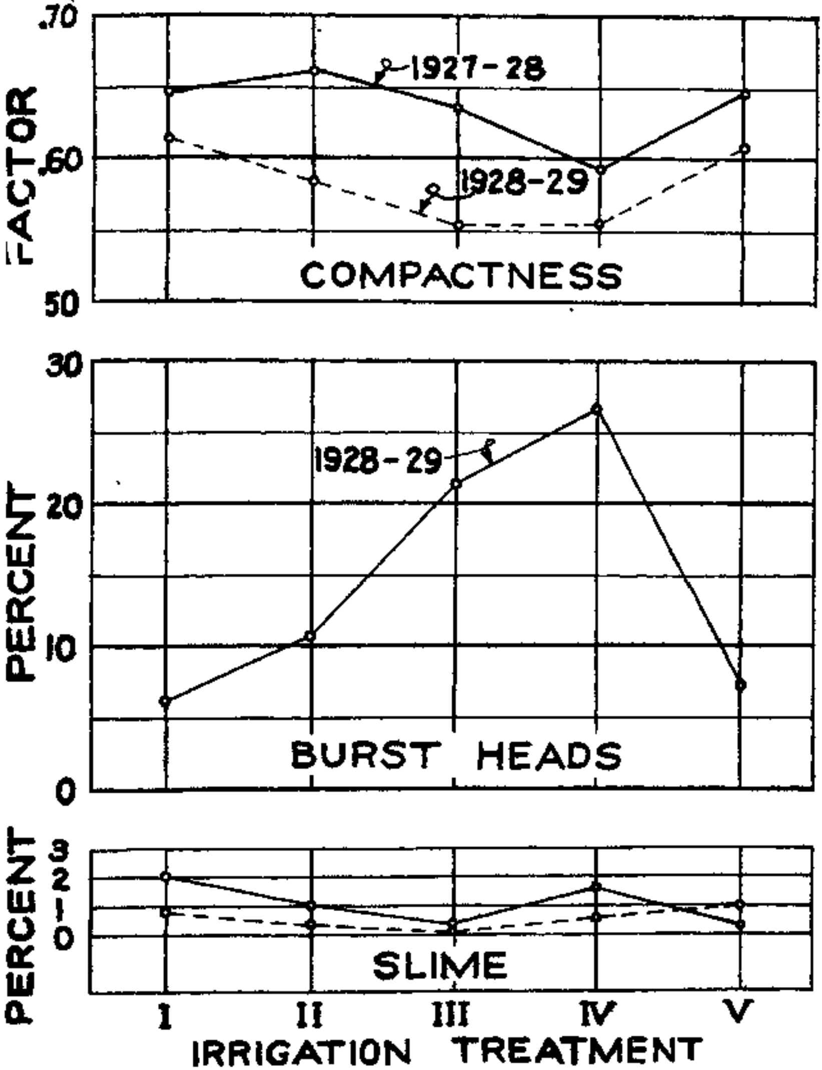

Fig. 29.—Effect of differential irrigation treatments on the compactness, percentage of bursted and percentage of slimed heads, 1927-28 and 1928-29.

TABLE XIII.—AVERAGE COMPACTNESS OF FIRST AND SECOND CUTTINGS OF LETTUCE BY IRRIGATION TREATMENTS 1928-29.

Treatment	I	II	III	IV	V
1st Cutting	.66	.635	.651	.588	.68
2nd Cutting	.61	.583	.553	.556	.61
Average	.64	.609	.602	.572	.64

The effect of irrigation treatment on the leafiness of lettuce plants is shown graphically in figure 30 and the data are given in table XIV for both seasons. The average weight of commercial heads for the second cutting was used each year as a basis for comparison with the average weight of stripped heads, for the same cutting, as used in the study of compactness. Inasmuch as no consistent difference was evident between the cultivated and non-cultivated plats the data are shown by irrigation treatments.

The treatments having consistently abundant soil moisture during the early growing season and up to bunching are the lowest in percent of wrapper leaves, during both years. Treatment II, with fluctuating but ample soil moisture throughout the season, is slightly higher in this respect.

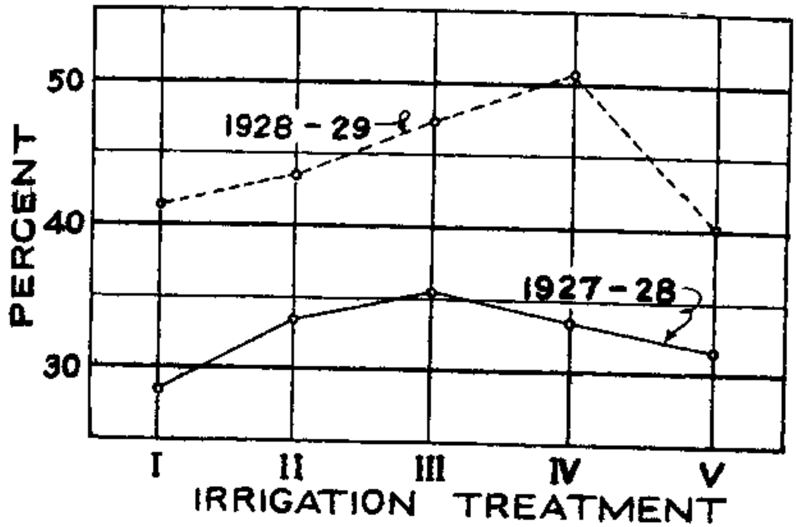

Fig. 30.—Effect of the differential irrigation treatments on the percent of wrapper leaves developed about the lettuce head, 1928-29.

TABLE XIV.—COMPARISON OF TOTAL AND STRIPPED HEAD WEIGHTS.

Treatment	I	II	III	IV	V
1927-28					
Av. wt. head......lbs.	.87	.96	.88	.93	.88
Stripped wt. heads......lbs.	.62	.64	.57	.62	.60
Wt. wrapper leaves......Pct.	28.0	33.3	35.2	33.3	31.8
1928-29					
Av. wt. head......lbs.	.96	1.01	.95	1.08	.92
Stripped wt. heads......lbs.	.56	.57	.50	.53	.55
Wt. wrapper leaves......Pct.	41.6	43.6	4.74	50.9	40.2

The remaining treatments III and IV which are not consistent in irrigation for the 2 years also show an inconsistency as regarding leafiness. These plats during 1927-28 were low in soil moisture at different times, but rains occurring during the growing season prevented an actual water stress. Their leafiness for this year is only slightly higher than the other plats. These treatments in 1928-29 present a different picture and they are much the highest of the group in leafiness with an extreme condition in treatment IV. Both of these plats reached a definite water stress just previous to harvest and were then irrigated just prior to the first cutting. Treatment IV, the highest in wrapper leaf percent, received another irrigation just prior to the second cutting. Temperature conditions were favorable for rapid growth and it is believed that the shock received from the water stress followed by abundant soil moisture is responsible for the rapid increase in production of wrapper leaves.

SUMMARY AND CONCLUSIONS

Results of these experiments indicate significant effects of differential irrigation treatments on the growth of the lettuce plant. Variability of seasonal temperatures, soil types and other environmental factors will no doubt influence these effects to some extent and a long time experimental project on various soil types would be necessary for conclusive data. It is not known that the effects here given will be found applicable to the fall season crop since it endures extremely high air and soil temperatures during its early growth. This phase is projected in another experiment and will be carried to completion at a later date.

The use of the moisture equivalent as an index of the field water-holding capacity of the Laveen clay loam is misleading unless corrections are made for the effect of calcium carbonate or caliche nodules contained in the soil. The average field water-holding capacity of the first 3 feet of this soil is shown to be approximately 17 percent and the moisture equivalent is found to be between 19 and 20 percent. Most of the difference is due to the practically impervious character of these caliche nodules, the low moisture content of which under saturated soil conditions indicates that their soil moisture content does not change materially with the fluctuations in soil moisture.

The expermental work done on the bare plats in an attempt to secure additional information as to the movement of soil moisture in the Laveen clay loam is considered to be of a preliminary nature and not conclusive. It is believed, however, that the results of this work do indicate that there is an effect due to the increased pressure of the soil-trapped air on both the rate of movement of soil moisture downward and the character of this movement. The result is a delayed movement of the water downward and an increasing length of time between irrigation and the establishment of equilibrium in the soil water in the first case, and a movement of soil water by displacement of soil water in the second.

Soil-moisture capacity was found to be consistently higher in the first foot of soil, due in all probability, to the greater amount of organic matter present.

Temperatures for favorable growth of the lettuce plant were observed to be above a mean daily temperature of between 50 and 55 degrees Fahrenheit under Salt River Valley conditions.

The feeder root system of commercially mature lettuce plants on this soil are in the shape of an inverted cone 30 inches in diameter and from 15 to 18 inches in depth. This area is densely occupied by fine feeder roots leaving the taproot at an angle of about 30 degrees from horizontal and turning to a horizontal line of growth when from 4 to 5 inches away. Below 18 inches there are four or five large lateral roots in addition to the taproot. These large roots penetrate to a depth of from 40 to 55 inches and branch when stopped by caliche nodules. These large roots develop many fine feeder roots ranging from 1 to 4 inches in length.

Harvest data have shown that the maintenance of a high uniform soil moisture content at or above the field water-holding capacity is favorable for production of heavy lettuce heads, however, a soil moisture content slightly below this does not materially reduce the head weight. Further reduction of the soil moisture content, early in the growing season, greatly decreases the head weight. This same reduction late in the season does not produce this effect if followed by an irrigation. Irrigations during harvest, following a definite water stress prior to this time, result in a material increase of head weight, particularly when temperature conditions are conducive to rapid growth.

An abundance of soil moisture at or near the field water-holding capacity of the soil produces the maximum number of plants heading. Irrigation at maturity immediately following a definite soil moisture deficiency results in a low rate of heading. Aboundant soil moisture during the growth period with soil moisture reduction during harvest is favorable for a high rate of heading. Deep cultivation is favorable for a high rate of heading as compared to shallow cultivation.

Early maturity of lettuce is definitely a result of uniformly high soil moisture conditions throughout the growing season and the maturity is somewhat earlier if the soil moisture content is lowered during harvest.

Conditions of soil moisture deficiency during growth, when followed by irrigation, result in a prolonged growth period and correspondingly later maturity. Consistent cultivation of 3 inches in depth throughout the season hastens maturity somewhat over shallow cultivation.

The percentage of bursted heads is found to be the lowest under conditions of uniformly high soil moisture conditions throughout the season. Any definite soil moisture deficiency during the growing season is favorable to a high rate of bursted heads. This is especially true when the deficiency occurs just previous to harvest and is followed by an irrigation under temperature conditions favorable for rapid growth.

The production of heads affected by slime increased in proportion to the amount of irrigation water applied. The withholding of irrigation water previous to and during harvest does not decrease this tendency.

Solidity or compactness of the lettuce head is directly affected by irrigation treatment with the maximum solidity resulting from a uniformly high soil moisture content throughout growth. The more compact the lettuce head the less is the tendency toward bursting but the more susceptible it is for slime infection. Early maturing heads are more compact than those maturing later from the same planting.

The leafiness about the lettuce head proper is lowest in those plats of high moisture content. The maximum percent of wrapper leaves occurs in those plats undergoing a definite water stress just prior to harvest followed by frequent irrigations. These heads are loose, lack solidity, and are generally undesirable for marketing.

It is concluded, from the results shown, that the highest yield of quality lettuce is produced with a uniformly high soil moisture content throughout the season for either the winter or spring crop of lettuce in the Salt River Valley .