Technical Bulletin No. 33 September 1, 1931

University of Arizona

College of Agriculture

Agricultural Experiment Station

STUDIES IN LETTUCE SEEDBED IRRIGATION UNDER HIGH TEMPERATURE CONDITIONS

By

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and

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PUBLISHED BY

University of Arizona

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RESPONSIBILITY AND ACKNOWLEDGMENTS

The senior author is responsible for the pot studies, analysis of all the data and preparation of the manuscript. The junior author made the initial suggestion for this study and assisted in the organization and execution of the field work.

Grateful appreciation is expressed to Professor A. F. Kinnison, Dr. J. G. Brown, and Mr. C. J. Wood for their kindly criticism and helpful advice.

CONTENTS

PAGE

Introduction 283

The Experiment 285

Procedure 285

Irrigation Treatments 285

Temperature Studies 287

Root Studies 294

Weak and Strong Seed 298

Summary 302

ILLUSTRATIONS

PAGE

FIG. 1.—Ten year (1920-1929) averages of temperature, wind movement and evaporation at University Experiment Farm, Mesa, Arizona 284

FIG. 2.—Field investigation plots showing low and high bed. Temperature records taken at stakes 287

FIG. 3.—Surface soil temperatures of low beds under irrigation treatments I, V and VI 289

FIG. 4.—Low and high bed surface soil temperatures. Each curve is an average for that bed under irrigation treatments I, V and VI 291

FIG. 5.—Surface soil night temperatures. These are averages of temperatures from all beds under irrigation treatments I, V and VI 292

FIG. 6.—Three inch soil temperatures in low beds under irrigation treatments I, V and VI 293

FIG. 7.—Low and high bed three inch soil temperatures. These are averages for each type of bed under irrigation treatments I, V and VI 295

FIG. 8.—Total root measurements, by days, of lettuce plants grown under irrigation treatments I, V and VI 297

FIG. 9.—Plants grown under irrigation treatment I. Left to right the first two are from weak seed, the next two from strong seed and the last is a standard for comparison 300

FIG. 10.–Plants grown under irrigation treatment II. Left to right the first two are from weak seed, the next two from strong seed and the last is a standard for comparison 301

FIG. 11.–Plants grown under irrigation treatment III. Left to right the first two are from weak seed, the next two from strong seed and the last is a standard for comparison 302

STUDIES IN LETTUCE SEEDBED IRRIGATION UNDER HIGH TEMPERATURE CONDITIONS

By

M. F. Wharton, Department of Horticulture,

and

Charles Hobart, Department of Agronomy

INTRODUCTION

The production of head lettuce during the fall season in the Salt River Valley of Arizona is accomplished under climatic conditions that are abnormally severe at planting time. The seed must be sowed in September, usually between the tenth and fifteenth, in order to mature the crop at a time when market conditions are normally satisfactory.

Borthwick and Robbins * have shown in their recent work that lettuce does not germinate well at temperatures above 77° F. The daily air temperatures during the month of September in this region are sufficiently high to keep the soil surface temperature above this critical point except for a few hours during the night. The average for the past 10 years (Fig. 1.) shows a maximum temperature range above 90° F. for this period and a minimum range between 60° F. and 70° F. The mean daily temperature is found to be near 80° F. for the first half of the month and diminishes gradually during the latter half. This temperature picture presents a climatic condition that is dangerously near the critical point for lettuce seed germination. The climatic situation is particularly menacing when the method of planting the seed is considered. Lettuce seed is planted commercially with drills only one-quarter of an inch deep and much of it is even nearer the surface.

Commercial lettuce growers have recognized high temperature as a serious handicap and have attempted to modify it by irrigation. The customary practice has been to maintain a continual irrigation for a period varying from 72 hours to as much as 10 days following seeding, in the hope that the cool irrigation water in the furrows would in a measure reduce the soil temperatures to the range of germination. Frequent follow-up irrigations have been given at short intervals after the initial irrigation, with the thought that a continuously wet soil above the seed would

* Lettuce seed and its germination, H. A. Borthwick and W. W. Robbins. Hilgardia, Vol. 3, No. 11, May 1928.

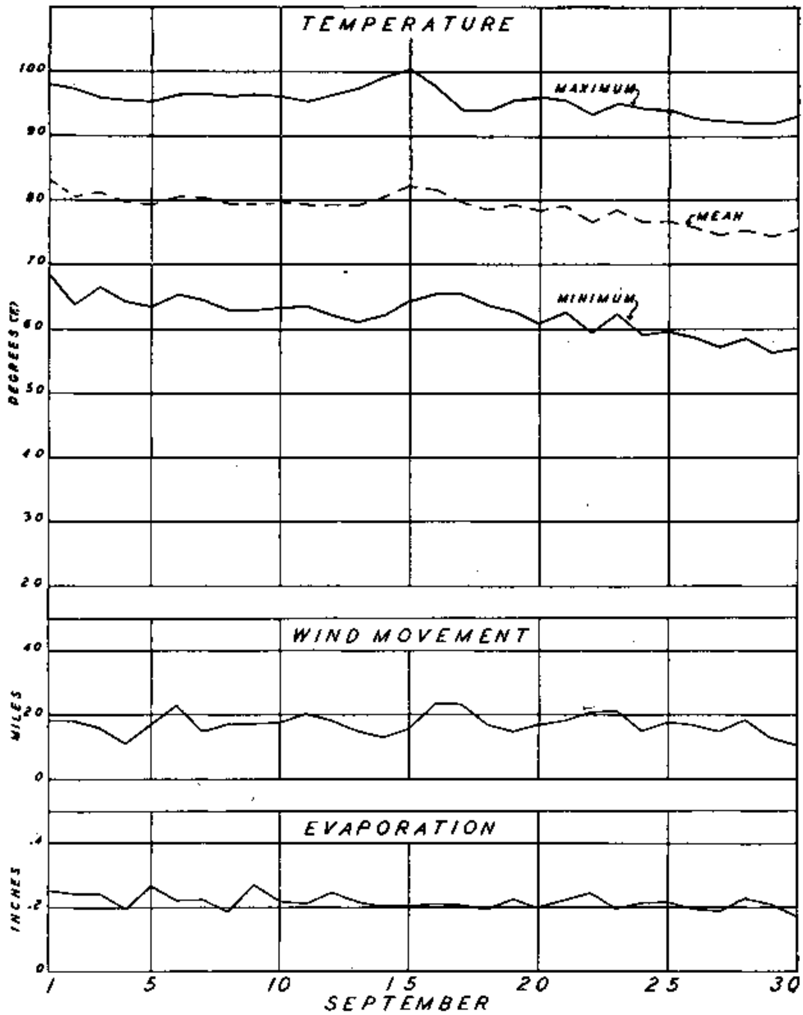

Fig. 1.—Ten year (1920-1929) averages of temperature, wind movement and evaporation at University Experiment Farm, Mesa, Arizona.

assist the plant in breaking through the soil surface. It was also believed that these frequent irrigations would tend to maintain a cool soil temperature.

The soils adapted to lettuce culture in this valley are of a clay loam type and this irrigation practice has resulted in a great deal of puddling with its deteriorating effect on soil texture. It is thought that this has been a factor of major importance in rendering land unsuited to further production of lettuce after a 2-year period of cropping.

Considerable difficulty has been experienced in obtaining and maintaining commercial stands of plants during the fall. Many growers have not been able to obtain favorable stands consistently and others have reported that the lettuce started well but a high percentage of the plants died within a few days after emerging from the soil. The sickly condition of lettuce on soil subjected to this irrigation program, and the loss of early plantings, have been directly attributed by Brown * to impaired æration from puddling and over irrigation.

The prevailing fall lettuce irrigation schedule has developed an economic problem in water usage as well as a problem in the efficient distribution of irrigation water over a large acreage at the same time. The greater part of fall lettuce acreage is seeded within a 10-day period and requires irrigation water over this entire acreage for several days. This has severely taxed the capacity of the distribution system. The waste in run-off water from continual irrigation during this time has greatly increased the cost of production. The 3 acre-feet allotment of irrigation water for the entire year is often completely used up on lettuce and additional water must be purchased for the cantaloupe crop that normally follows.

These conditions suggested the need of investigation, and the following experiment was initiated in September, 1928, to study the effects of various irrigation treatments on soil temperature and on the root growth of lettuce seedlings.

THE EXPERIMENT

PROCEDURE

The field studies were made during the first 10 days of September 1928 and 1929 on the Salt River Valley Experiment Farm, one mile west of Mesa, Arizona. The soil here has been classified as Laveen clay-loam by the United States Bureau of Soils † and is representative of a considerable acreage devoted to fall lettuce production.

IRRIGATION TREATMENTS

1. Plots 1 and 1a. First irrigation for 72 hours, water was then off for 12 hours, on for 24 hours, off for 24 hours, on 24 hours, off 48 hours,

* What makes young lettuce die, J. G. Brown. Arizona Producer, Vol. 9, No. 18, December 1, 1930.

† Soil Survey of the Salt River Valley Area, Arizona, by W. G. Harper, in charge, F. O. Youngs and A. T. Strahorn, U. S. Department of Agriculture and S. W. Armstrong and H. C. Schwalen, University of Arizona. U. S. D. A. Bur. Chem. & Soils, No. 32, Series 1926.

and on 24 hours. This treatment was modified during the 1929 season as follows: An initial irrigation of 72 hours and following irrigations were applied at intervals short enough to insure a thoroughly wet soil surface to the end of the experiment.

II. Plots 2 and 2a. First irrigation for 72 hours and then allowed to go without further irrigation until the soil surface over the seed had dried enough to start crusting. A 48-hour irrigation was then applied. No further irrigation was given.

III. Plots 3 and 3a. First irrigation for 24 hours, the soil surface over the seed was allowed to dry until it started to crust and then 24 hours of irrigation was given. This treatment was repeated to the end of the experiment.

IV. Plots 4 and 4a. The first irrigation was applied until the beds were thoroughly soaked. The soil surface of the beds was kept wet with frequent irrigations until the end of the fourth day. No further irrigation was applied for the rest of the experiment.

V. Plots 5 and 5a. First irrigation for 12 hours, the soil surface over the seed was allowed to dry until it started to crust and then was irrigated until the bed was soaked through. This treatment was repeated until the end of the experiment.

VI. Plots 6 and 6a. First irrigation was applied until the beds were soaked through. The soil surface of the beds was kept wet by frequent short irrigations until the end of the experiment.

Each experimental plot consisted of two beds, one high and one low, 48 inches in width from furrow to furrow, and 20 feet long. The soil surface of the high bed was approximately 2 inches above the water level in the furrows, when they were filled for irrigation, and the surface of the low bed was just high enough above this level to prevent flooding. Borders, 4 feet in width, separated the plots to prevent lateral irrigation effect and served as walks when recording data. (Fig. 2.)

The irrigation water was distributed to the individual furrows by lath spiles from the head ditch. Similar spiles were set in the ends of the furrows to maintain a uniform water level and also to provide run-off for excess water. The plots were small, as it was impossible always to obtain ditch water when needed, and several times it was necessary to use the domestic supply.

The seedbeds were planted with 2-year-old seed of the New York Market variety, commercial strain, of head lettuce. The seed was drilled into the soil in the regulation commercial manner to a depth not exceeding one-quarter of an inch. Two rows, 24 inches apart, were planted on each bed.

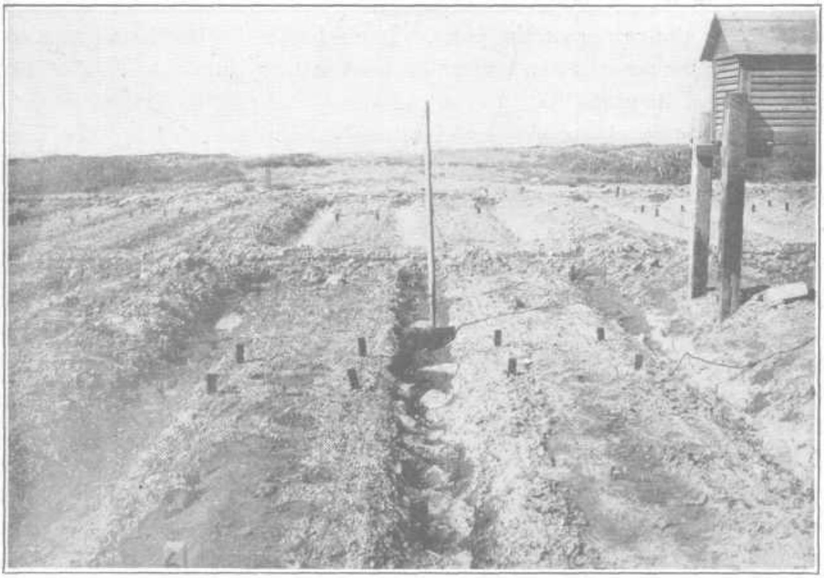

Fig. 2.—Field investigation plots showing low and high bed. Temperature records taken at stakes.

TEMPERATURE STUDIES

The soil temperature readings were taken in the seed row in the center of the plots (Fig. 2.) by inserting calibrated thermometers into the soil to the designated depths. The readings were all taken in approximately the same location, but care was taken to place the thermometers in undisturbed soil for each reading. Three sets of thermometers were used in rotation during the recording of the readings and each set was left in place until the absolute reading was assured. Soil temperatures were recorded every four hours from six o'clock in the moning on September 1, during the first four days and nights, after which the night recordings were discontinued.

The surface soil temperature was obtained by inserting a standard laboratory mercury thermometer into the soil until the mercury bulb was covered. In reality this temperature reading is a record of the one-half inch surface temperature. The 3-inch temperature was obtained in a like manner by inserting a copper-jacket soil thermometer into the soil to this depth. Temperature readings were made in the high and low beds of all plots and their duplicates and the respective duplicate readings were averaged. Irrigation-water and air-temperature readings were recorded at the same time.

A continuous air-temperature record was obtained from a thermograph installed in the center of the plots. Humidity and wind readings were taken from the records of a United States Weather Bureau station located 50 feet from the plots.

The temperature records of treatments I, V, and VI * have been selected as representative of the mean and extremes of irrigation practices employed. The temperature records taken at 6 a.m., 2 p.m., and 6 p.m. are used in the charts as these present the relative maximum, minimum, and approximate mean of the readings during the day. The readings at 10 a.m. follow those at 6 p.m. very closely and the night temperatures are near those of the air. It is practically impossible to include all temperature readings on one chart, for comparison, as it becomes too involved for accurate analysis and ease of reading. The charts as presented are by days, beginning and ending at 6 a.m., and the temperture points are in their respective locations of time. Air temperatures are shown by temperature readings of 2-hour intervals from the thermograph records. The initial irrigation started on the day previous to the chart, and only the irrigations applied after 6 a.m. on September 1 are shown.

Air temperatures and evaporation records for September 1928 (Fig. 3) show that this season was abnormally warm and dry when compared with the 10-year average for this month (Fig. 1). Records for the following September (1929) indicate that this month was considerably below the average in temperature and evaporation. It is believed that the experimental data here presented for these 2 years are typical of the relative extremes of climatic conditions in the Salt River Valley during September. These data should then be applicable to all conditions within these limits, varying proportionately with climatic changes.

Surface-soil temperatures of the low beds (Fig. 3) during 1928 maintained a maximum above 90° F. until the last day of the experiment. It is interesting to note that there is little consistent difference between the maxima of the irrigation treatments. Treatment I, the very wet or long irrigation treatment, shows a slightly higher maximum during the first half of the experiment. The irrigation water during this period ranged in temperature from 70° F. to 80° F. and evidently had little effect on the surface-soil temperature in the seed row of this plot. The temperature of the soil surface in treatment V, increased rapidly as the surface started to dry. This is particularly noticeable on September 7 and 10, but quickly returns in line with other treatments when the soil is again wetted by irrigation. During this year the temperatures of the soil surface were depressed well below maximum air temperatures. The evaporation was uniformly high, being well over one-quarter of an inch

* Irrigation treatments are shown in the charts as plots I, V and VI.

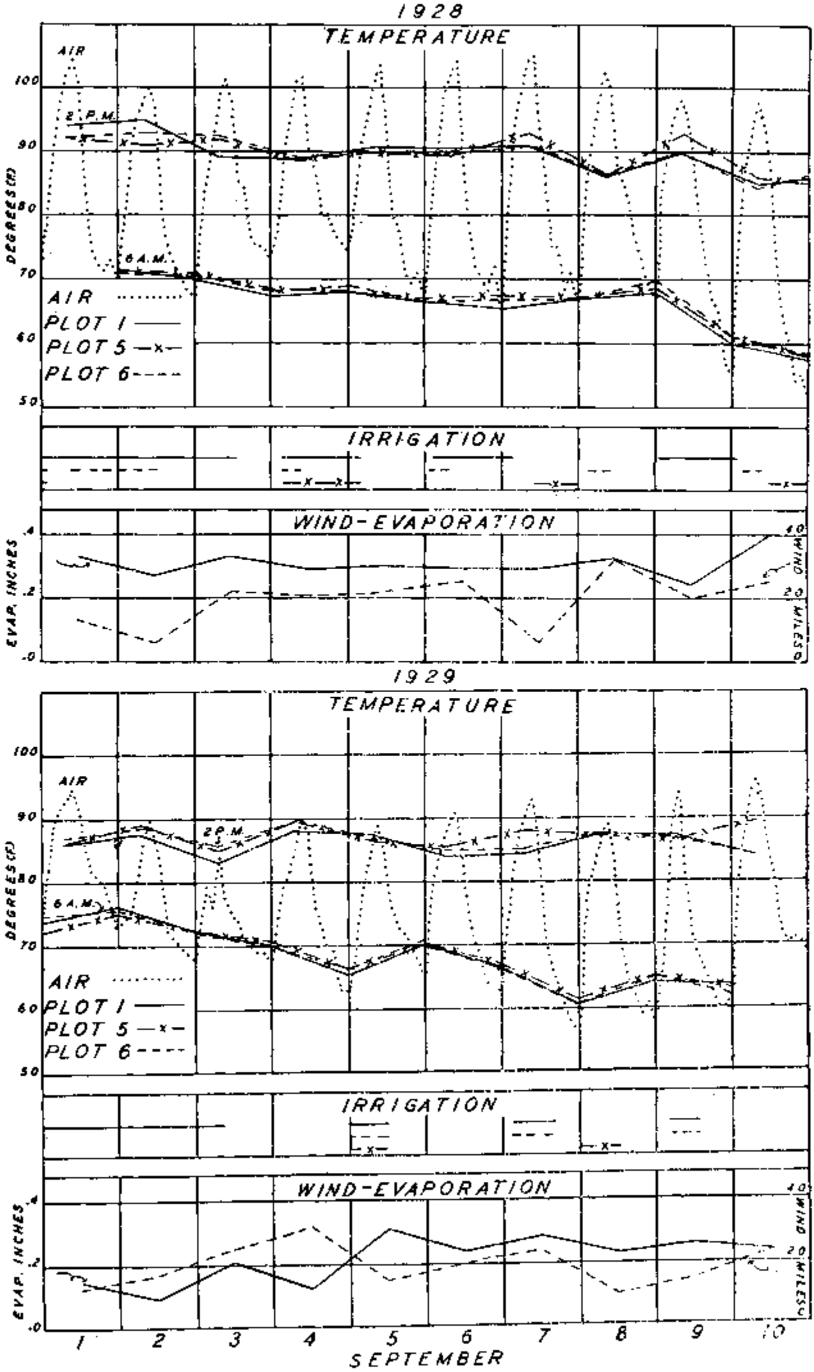

Fig. 3.—Surface soil temperatures of low beds under irrigation treatments I, V, and VI.

per day. The maximum soil temperatures varied inversely with the evaporation rate in a consistent manner throughout, being most noticeable during the period of September 2 and 3 and again from September 8 to 10 inclusive. This correlation holds true between temperature and wind movement, but not to such a marked degree.

The climatic situation during September of the following year (1929) presents a somewhat different set of conditions. There was considerable rainfall and much cloudy weather during the first 4 days and the evaporation rate during this time was exceptionally low. The weather cleared after the fourth day and the temperature and evaporation both increased rapidly and were quite high to the end of the experiment.

Surface-soil temperatures during the 1929 season were uniformly quite close together as in 1928 for all treatments. During the first 4 days, when the evaporation rate was low, the surface-soil temperatures were consistently higher than those of the air. This was no doubt due to a building up of heat without the cooling effect of normal evaporation. During this period there was evidenced a slight cooling effect from the irrigation water in treatment I, as this was the only treatment with water running in the furrows, and the maximum temperatures were consistently lower than the other irrigation treatments. During the latter half of the experiment, the evaporation and air temperature rose steadily and the soil temperatures were considerably depressed below those of the first half, and were somewhat below that of the air. The cooling effect from evaporation was not as much in evidence during this season, but the relation between evaporation and soil surface temperatures was again in evidence for the periods of September 2 and 3, and September 6 and 7. The increase in soil temperature coincident with surface drying was again noted on September 7 and 10 in treatment V. These temperatures quickly returned to normal with the other treatments as soon as the soil was wetted.

The soil surface temperatures at 6 p.m. showed little differences that might be related to irrigation treatment, excepting in those instances where the soil in treatment V showed evidence of drying. All three irrigation treatments were in such close agreement that they may be considered uniform for both seasons at this time of day.

The minimum temperatures recorded at 6 a.m. for the surface soil are in consistently close agreement for all treatments and are considered to be without significant difference during either season. The minimum temperature closely follows the air temperature regardless of irrigation treatment or evaporation except for a period of 3 days, September 4, 5, and 6 in 1928. This discrepancy can be accounted for only in the possibility of a dry, warm desert night wind that may have materially in-

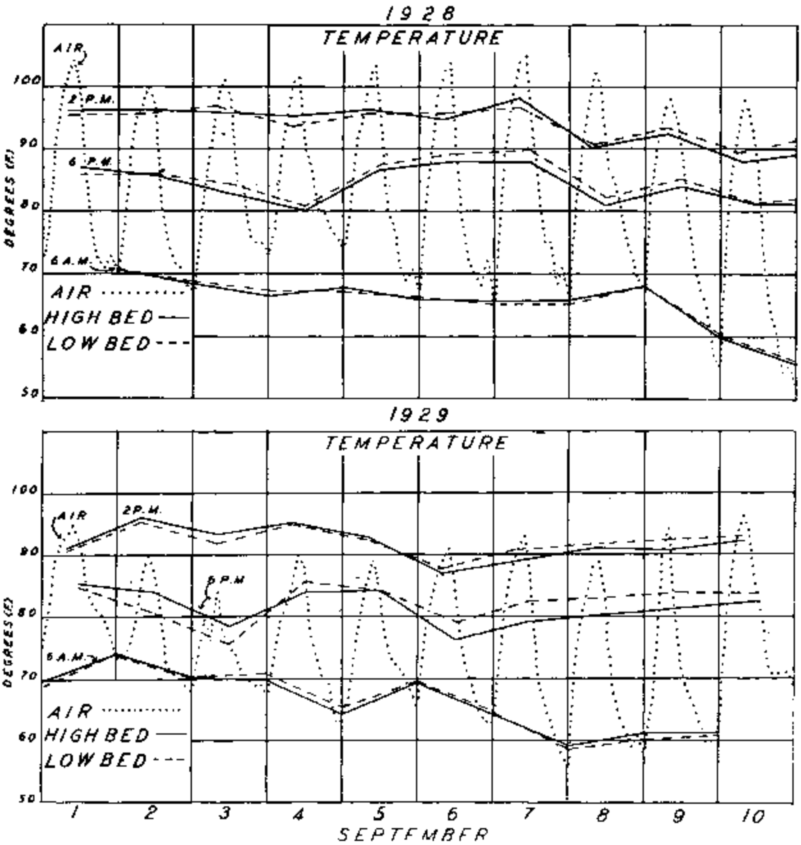

Fig. 4.—Low and high bed surface soil temperatures, each curve is an average for that bed under irrigation treatments I, V and VI.

creased the evaporation for a short time. The possibility of error in reading temperatures is minimized as the thermograph readings check accurately with the U. S. Weather Station records, 50 feet away. It is evident from the consistency of these curves and their close agreement that irrigation has no significant effect in altering the soil minimum temperature from that of the air. The close agreement between the driest treatment (V) and the wettest (I) serves as a basis for this conclusion.

Temperature differences between the respective irrigation treatments on the high beds were found to be directly comparable to those for the low beds. Inasmuch as there is no consistent significant difference between the irrigation treatments they were averaged for each type of bed and are shown in figure 4.

There was little difference in the maximum soil surface temperatures between the respective beds in the 1928 season. However, in 1929 it was

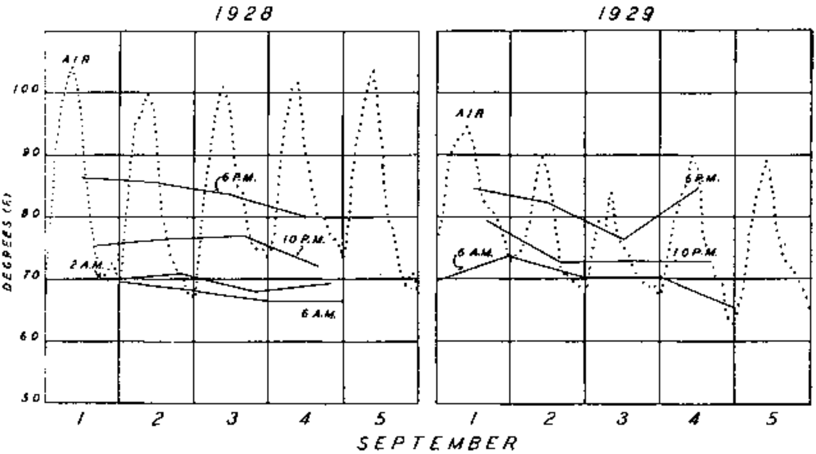

Fig. 5.—Surface soil night temperatures. These are averages of temperatures from all beds under irrigation treatments I, V and VI.

noted that the low bed was consistently cooler during the first five days when the evaporation rate was low. During the latter half of the experiment when the evaporation rate had materially increased, the reverse was true. The differences are so slight as to be considered of minor importance in cultural practice.

The minimum temperatures are in close agreement and significant differences are not in evidence.

There is a consistent difference in favor of the high beds in that they cool off more rapidly toward evening as shown in the temperature records at 6 p.m. (Fig. 4). This cooling effect in favor of the high beds is coincident with a high evaporation rate as the low beds were somewhat cooler during the first 3 days of the 1929 season when the humidity was quite high and the evaporation rate was exceptionally low.

The temperature differences between low and high beds are not sufficiently great to warrant the use of high beds as a cultural practice. The additional cost of the extra irrigation water necessary to wet the high beds and to keep the surface of them wet is not compensated for by a sufficiently favorable difference in temperature.

The soil surface temperatures are extremely important for the night hours as during this time the temperature of the seed must be low enough to allow moisture and oxygen absorption for germination. Borthwick and Robbins (1) have stated that 8 hours below the critical temperature of 77° F. is sufficient for this action provided there is a normal supply of oxygen and moisture about the seed. Figure 5 shows that this interval of time below the critical temperature was present even in the abnormally warm season of 1928. The evaporation rate during the night is so

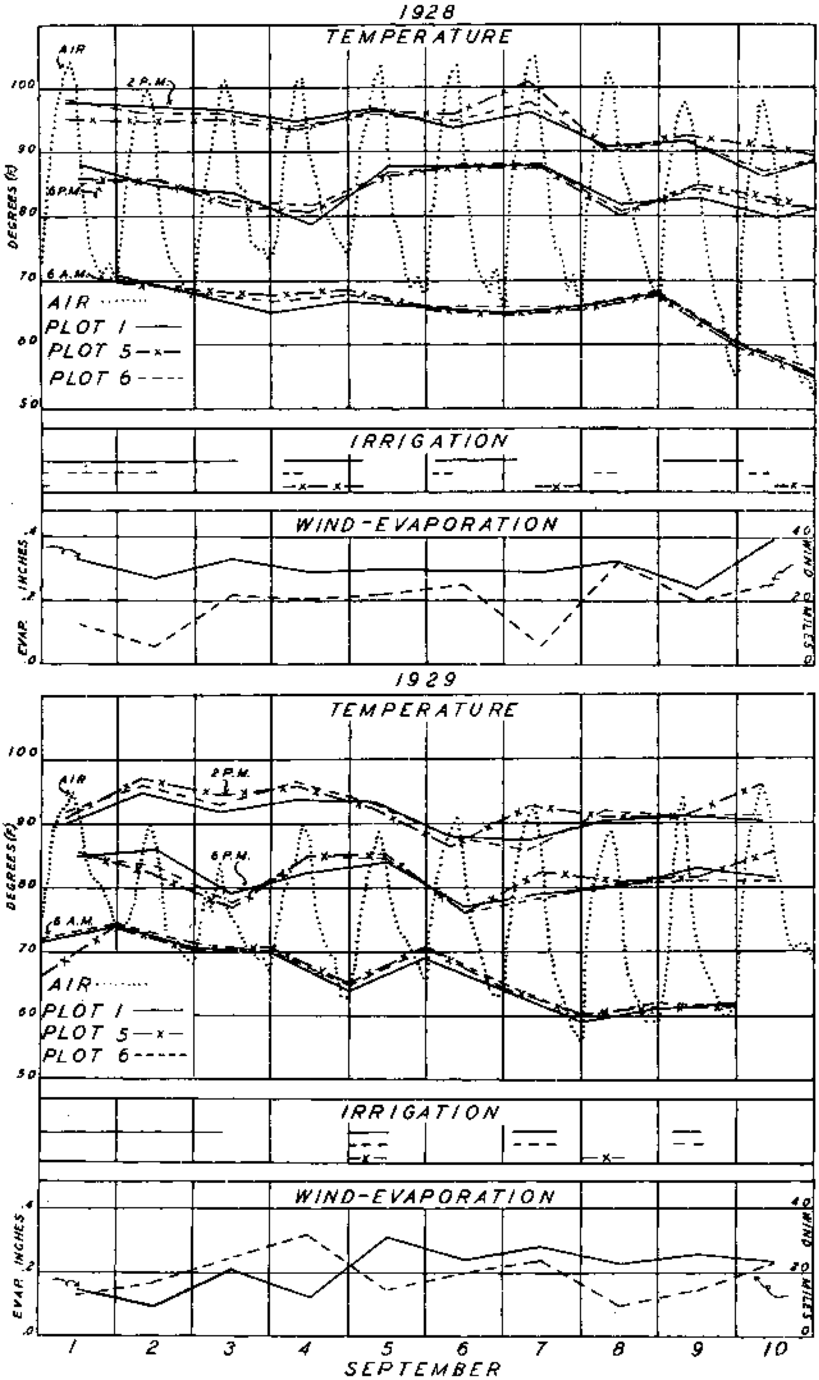

Fig. 6.—Three inch soil temperatures in low beds under irrigation treatments I, V and VI.

low that no significant difference could be expected or was noted between any of the irrigation treatments or between the different types of beds and they are averaged and so presented in the chart.

A study was made of the temperatures at 3 inches as it is known that extremely high temperatures are inhibitory to favorable root growth in the seedling lettuce plant. These temperatures for the low beds are shown in figure 6. Only maximum and minimum temperatures are given, as the range is so narrow that the other readings would make analysis difficult. Here again it is noted that there were no consistent differences between treatments excepting in those instances where the soil of treatment V began to dry out with its accompanying rapid rise in temperature due to the reduced evaporation from the surface. A slight difference is noted in favor of treatment I, the heaviest irrigation treatment, early in the season of 1929 when the evaporation rate was low. With these minor exceptions the maximum temperatures are in close agreement.

Minimum soil temperatures at the 3-inch depth are uniformly so close together for both seasons that no significant difference could be ascertained. Here again, the minimum readings fluctuate with, and are very close to, the minimum air temperatures.

The temperatures at 3 inches were averaged for the low bed and for the high bed, and these averages are shown in figure 7. No consistently significant difference is in evidence.

The 3-inch temperatures were in the root zone of the young seedling lettuce plants. Although the favorable temperature range for germination is below 77° F., Borthwick and Robbins (1) report that lettuce seedlings will grow favorably at temperatures up to 100° F., and that the first indication of root growth retardation is noted at 104° F. The soil temperatures in this experiment have all been well below this point under all types of irrigation.

ROOT STUDIES

Root measurements were used to study the response of lettuce seedling growth to different soil moisture conditions. An attempt was made to remove a representative number of typical plants from each plot by carefully washing out the root systems. The heavy texture of the soil and the fragile nature of the lettuce roots soon demonstrated that this procedure could not be relied upon for accurate data. It was impossible to obtain even a single complete root system as many of the small roots were broken and lost. This phase of the experiment was postponed for later study where more effective means of root removal could be employed.

Outstanding differences could be noted in the effect of the irrigation treatments on the soil texture and plant growth. Observational notes were taken at the end of the experiments and a composite report for both seasons is here presented.

Treatment I. The germination was seriously affected under this treatment and the estimated commercial stand was only 10 percent on the low bed and 50 percent on the high bed. The soil was badly melted down and waterlogged with the low bed in the poorer condition. The plants were small, yellow, and of a general sickly appearance.

Treatment II. The stand of plants on the low bed was only slightly better than that of the previus treatment but the high bed was much better with a fair commercial stand. The soil condition of both beds was slightly better than that of treatment I. Little difference could be noted in the general vigor of the plants.

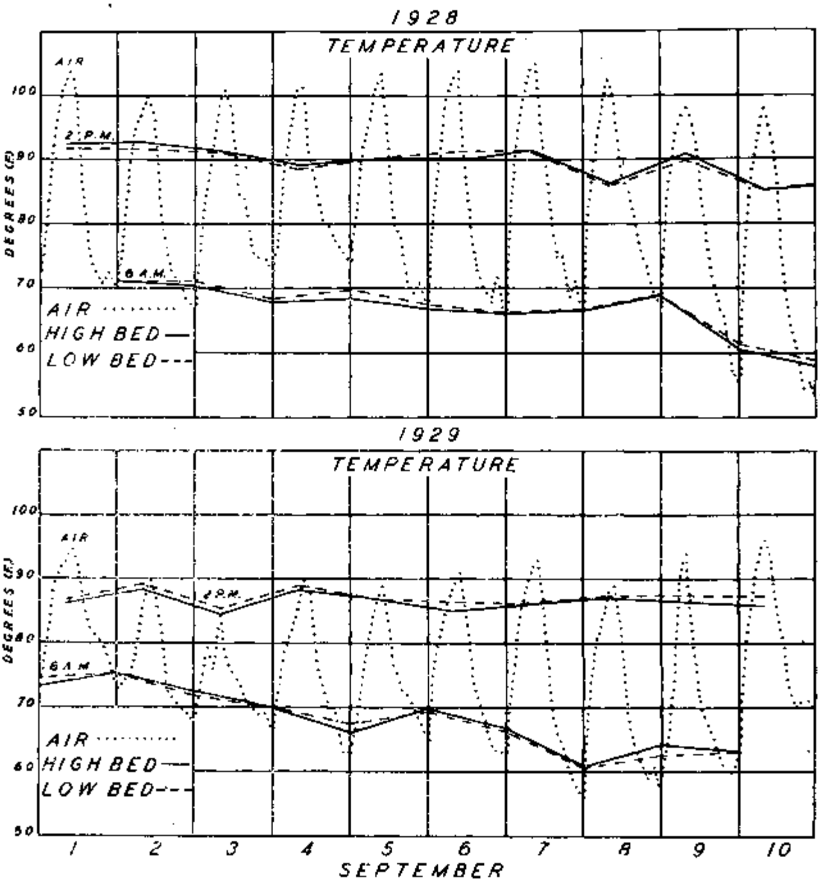

Fig. 7.—Low and high bed three inch soil temperatures. These are averages for each type of bed under irrigation treatments I, V and VI.

Treatment III. High and low beds had a favorable commercial stand of plants that were much sturdier, particularly along the soil cracks, and of better color than those of the above treatments. The soil condition was also improved materially although there was a considerable amount of surface cracking.

Treatment IV. An excellent commercial stand was produced on both beds. The soil condition was good but badly cracked. The plants were of good color and vigorous growth.

Treatment V. The plants under this treatment were decidedly retarded in growth but of good color and numerous enough to be estimated as a perfect commercial stand. Soil conditions were excellent with a minimum amount of surface cracking.

Treatment VI. A perfect commercial stand of thrifty vigorous plants was present on both beds. The soil condition was good with a moderate amount of surface cracking along the plant rows.

The effect of the frequent and continued irrigations was to puddle the soil badly with resultant cracking. The surface texture was in very poor condition at the end of the experiment. Plants produced from these treatments did not have a vigorous or healthy appearance and the stand was too scattered to be considered favorable for a commercial crop.

The driest treatment (V) was the least harmful to the surface soil texture as there was a minimum amount of puddling and cracking. The plants were somewhat retarded in growth from the wide range in soil moisture, but were healthly in appearance. The soil moisture condition was evidently favorable to germination as a perfect commercial stand of plants was secured.

Treatments IV and VI are considered to be the most desirable from a commercial standpoint. Although the soil texture was slightly impaired by these irrigation treatments, a commercial stand of vigorous, healthy plants was secured. The water required was reasonable in amount and in number of applications and it was felt that the excellent condition of plants and soil texture warranted the selection of one of these as the preferable treatment.

A series of pot studies was conducted at Tucson immediately following the field experiments. The air and soil temperatures were somewhat lower and more favorable for germination and growth of lettuce than those of the field trials. Twenty clay pots of the 12-inch size were seeded to lettuce for each of the irrigation treatments. These pots were buried in the soil until the soil surface within them was approximately an inch above the normal water level when they were irrigated. Treatments I, V, and VI were used in this root study. Two representative pots were

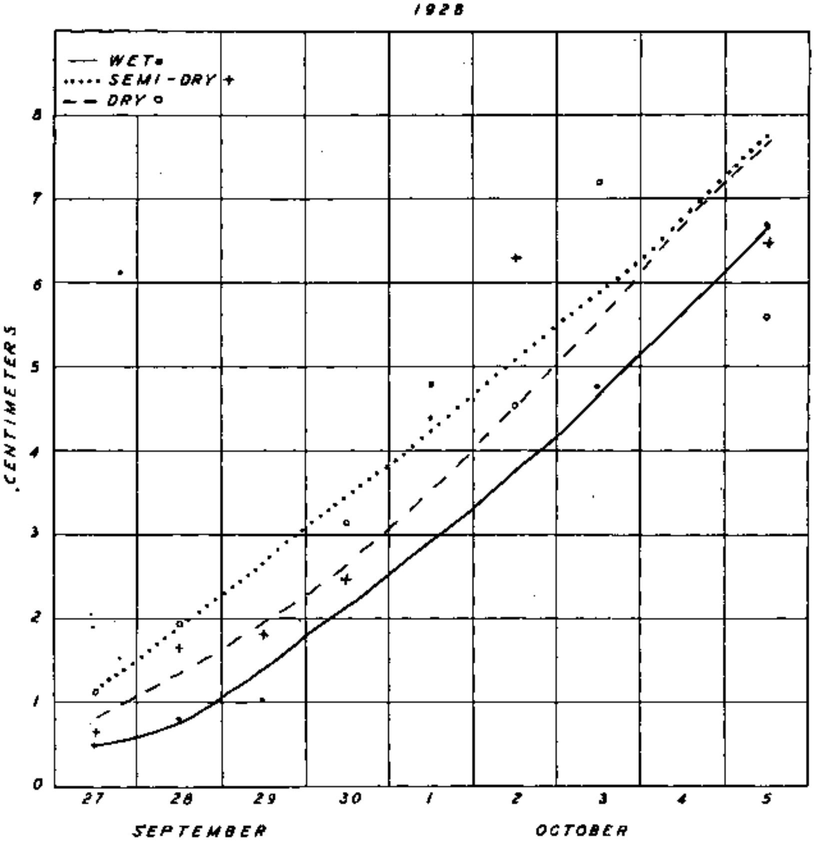

Fig. 8.—Total root measurements, by days, of lettuce plants grown under irrigation treatments I, V and VI.

selected daily from each treatment and the plants were carefully washed from the soil. The root systems were measured by floating them out on a glass plate over centimeter cross-section paper.

Root measurements of the pot studies are shown in the chart of figure 8. The slowest root development is found under treatment I with its excess of soil moisture during the first several days. The plants from treatment V, which alternates from wet to dry, are somewhat further advanced in root development. The root development from plants under irrigation treatment VI is consistently greater than those of the other treatments. It is interesting to note that the differential between treatments I and VI is consistent throughout. From this it may be assumed that the retarding effect of excess soil moisture occurs early in the life of the lettuce plant. This is further confirmed by the root development under treatment V where it is noticed that the retardation is considerably overcome as the soil dries out. The optimum condition is found in the irrigation practice of treatment VI where only enough water is applied to wet the soil and free drainage assures favorable æration.

WEAK AND STRONG SEED

A laboratory test of the vigor and viability of several lots of lettuce seed suggested a study of their response to these different irrigation treatments. The vigor of the seed had been ascertained by germination and growth rate tests under controlled conditions.

Four samples of seed were selected from each class with the following germination records:

Weak seed — 55.2%, 59.5%, 84.0%, 88.0%
Strong seed — 95.7%, 98.0%, 99.5%, 99.5%

One hundred seeds were planted, one-quarter of an inch deep, in each 12-inch clay pot and each seed sample was replicated in quadruplicate for each irrigation treatment. The pots were buried in coarse sand that filled a three compartment zinc lined table. Each compartment was equipped with drainage control and water supply and during the irrigation periods the water level was maintained at a constant as the water ran into and out of the compartment.

The irrigation treatments were modified somewhat from those used in the field as the humidity and temperature were such as to prevent rapid drying of the surface soil. The modified irrigation treatments were:

Treatment I. Free water was kept in the soil constantly for 6 days by maintaining continuous irrigation throughout this period. The water level in the compartment was maintained one-half inch below the soil surface within the pots.

Treatment II. The irrigation treatment here was identical with I. The water level was maintained 2 inches below the soil surface within the pots.

Treatment III. Irrigation water was applied until the soil was thoroughly wetted within the pots. Free drainage was established immediately following the irrigation and was maintained to the end of the experiment.

Two representative pots were selected from each seed sample and irrigation treatment and the plants were completely removed from the soil by careful washing. Twenty typical plants were saved from each two pots for root measurement.

A composite weighed average of the root measurements from two different series was made and is shown in Table I.

TABLE I.—AVERAGE ROOT GROWTH IN CENTIMETERS OF 2-WEEKS-OLD LETTUCE PLANTS FROM WEAK AND STRONG SEED UNDER IRRIGATION TREATMENTS I, II, AND III.

	Irrigation treatment		
	I	II	III
Weak seed	2.3 cm.	2.9 cm.	3.3 cm.
Strong seed	4.9 cm.	5.8 cm.	5.8 cm.

The root development of the plants from the weak seed shows a consistent increase from the saturated soil, treatment I, through to treatment III which has a sufficient amount of soil moisture as well as proper æration. The wet treatment has a decided effect of retarding root growth in plants from the strong seed. Treatment II which is at field carrying soil moisture capacity from capillary action does not exhibit any detrimental effect on the root growth of the seedlings from strong seed as compared with the more favorable soil, air, and moisture conditions found in treatment III. The increased vigor of the plants from strong seed was evidently able to overcome the unfavorable conditions found in treatment II but not fully able to combat the severe condition of treatment I. These plants from strong seed were able to grow to much better advantage even in the severe conditions than were the plants from the weak seed as shown by their greater root development.

The distribution of the plants by root measurement is shown in Table II, as composite totals of weak and strong seed by irrigation treatments.

This distribution further confirms the average root measurement data as there is a concentration of plants, from the weak seed, within a very narrow range as compared to the range of distribution found in the plants from the strong seed. The same relative effect of the irrigation treatments is found to be somewhat more striking in this table when the regions of concentration are considered. The detrimental effect of the irrigation treatments on germination may be more fully realized from this table as it was impossible to obtain the required number of plants from two pots of the weak seed. There is marked evidence in favor of irrigation treatment III as it was possible to obtain a greater number of plants for study from the two pots of weak seed.

TABLE II.—DISTRIBUTION OF PLANTS, FROM WEAK AND STRONG SEED, ACCORDING TO TOTAL ROOT GROWTH IN CENTIMETERS. THIS IS A COMPOSITE TABLE OF TWO SERIES OF GROWTH STUDIES UNDER IRRIGATION TREATMENTS I, II, AND III.

Irrigation treatment:	I		II		III	
Length of roots in centimeters	Weak	Strong	Weak	Strong	Weak	Strong
1- 2	12		2		3	
2- 3	22	1	24	2	24	
3- 4	12	13	11	3	23	3
4- 5		20	4	20	13	14
5- 6	1	36	1	17	1	28
6- 7		9		18	3	27
7- 8		1		8		8
8- 9				8		1
9-10						1
10-11						1
Number of plants washed	47	80	42	80	67	80

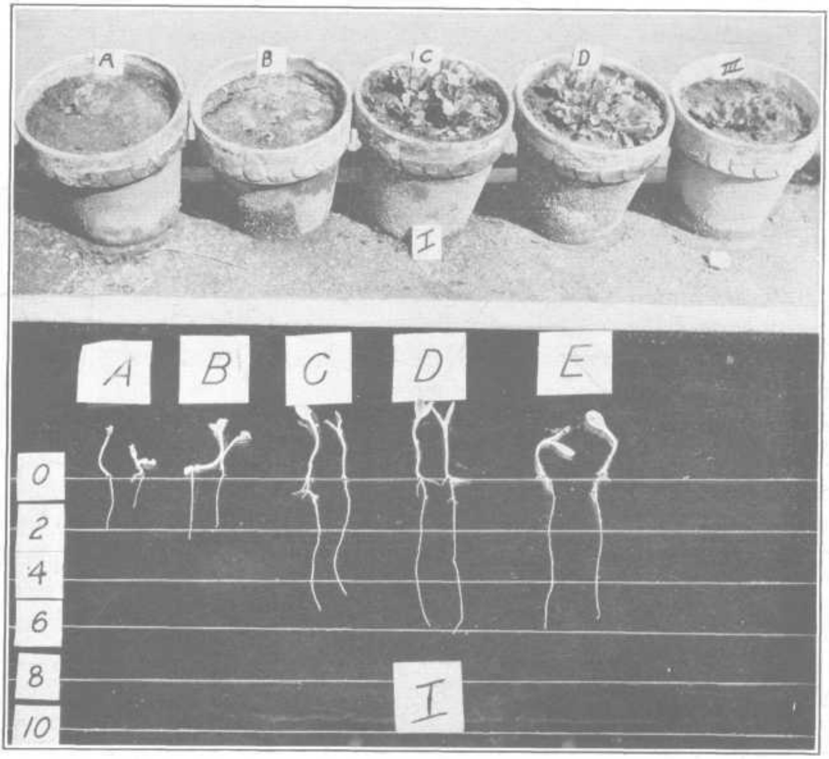

Fig. 9.—Plants grown under irrigation treatment I. Left to right the first two are from weak seed, the next two from strong seed and the last is a standard for comparison.

The effect of these irrigation treatments is further illustrated in figures 9, 10, and 11. Reading from left to right the first two pots and plants in each picture are from weak seed, the next two are from strong seed, and the last is from a standard strain of seed used as a basis of comparison. These pictures were obtained several days after the root measurements were taken which acounts for the greater root growth.

The poor germination from the weak seed is much in evidence in the pots from treatments I and II and the germination in treatment III is considerably below that of the strong seed. The germination rate of the strong seed does not seem to be greatly affected by the irrigation treatments.

The root and top growths of the weak seed, under the first two treatments were decidedly weak compared to the plants from the same seed under treatment III. The roots were spindly with very few laterals. The tops were yellow, the leaf margins had started to curl inward and turn brown and the entire appearance was that of a plant just barely alive. The plants from the same seed, under treatment III, had developed much better root and top systems and gave every evidence of continuing growth

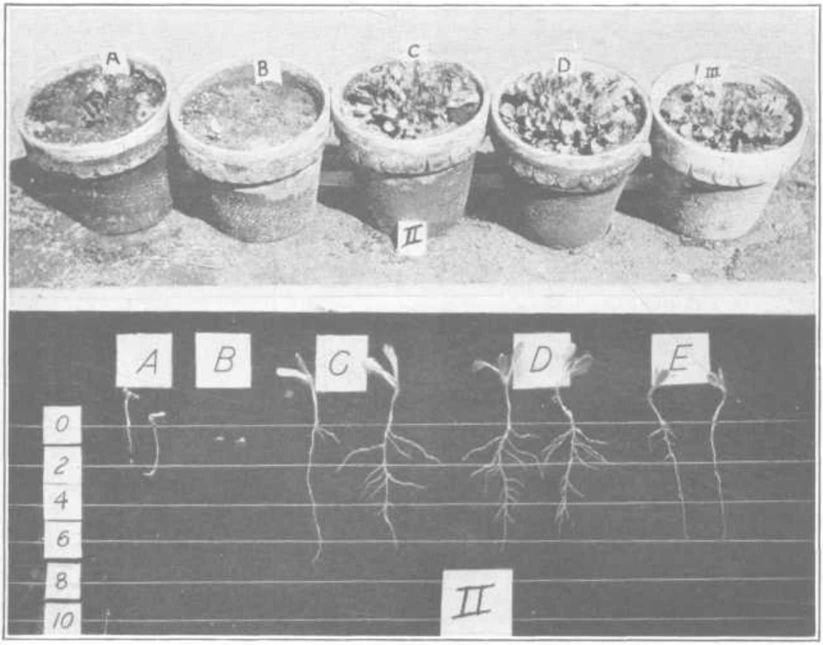

Fig. 10.—Plants grown under irrigation treatment II. Left to right the first two are from weak seed, the next two from strong seed and the last is a standard for comparison.

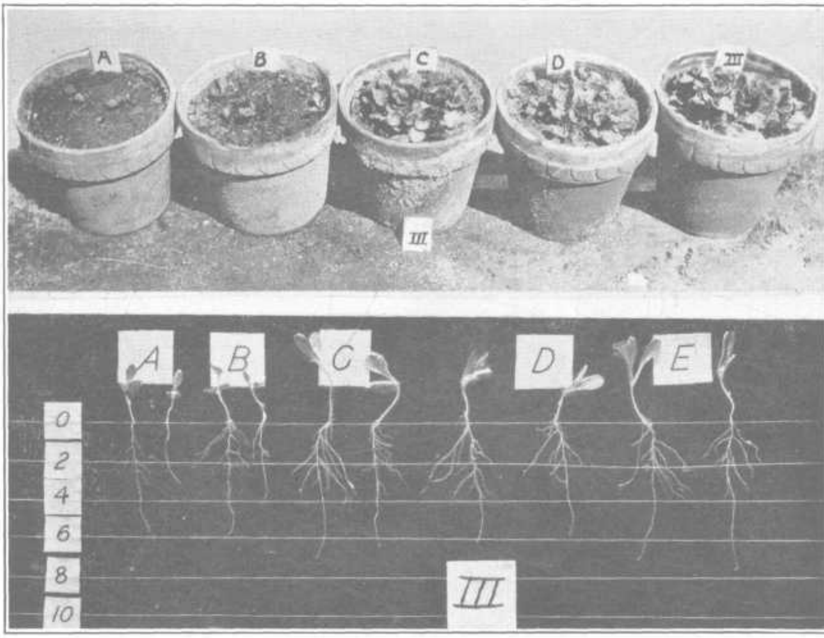

Fig. 11.—Plants grown under irrigation treatment III. Left to right the first two are from weak seed, the next two from strong seed and the last is a standard for comparison.

although they did not compare favorably with plants from the strong seed. There was a distinct effect of root and top retardation in the plants from the strong seed under irrigation treatment I. Little difference could be noted in the root systems of the plants from the other two treatments except that the laterals were somewhat suppressed, below the water level of 2 inches from the surface in treatment II. The plants from treatment III were vigorous and had an extensive, well-developed root system with a uniform distribution of laterals the entire length of the tap root.

SUMMARY

1. The evaporation of moisture from a wet soil surface is the major factor influencing the temperature of the surface 3 inches of soil during the hot weather of early fall in the Salt River Valley.

2. Continual irrigation with cool water has an insignificant influence on soil temperature, under hot weather conditions, as the cooling effect is lost by the time the irrigation water reaches the plant row through lateral penetration.

3. The cooling effect of moisture evaporation from a wet soil is proportional to the evaporation rate and wind movement.

4. Night soil temperatures, during September in the Salt River Valley, are within the range favorable for lettuce seed germination for a sufficient period to insure commercial stands of plants in the warmest weather.

5. The irrigation program that insures a continuous moist soil surface with a minimum amount of water has been found to be most desirable in producing favorable temperatures and soil conditions for germination of lettuce seed and for subsequent growth of the young seedlings.

6. Continuous or heavy irrigations are detrimental to soil texture as they are conducive to puddling, cracking, and poor æration.

7. The presence of excess moisture, above the field-carrying capacity of the soil, retards root development and growth of the lettuce plant due to its impaired æration.

8. Lettuce plants from strong, vigorous seed are able to overcome unfavorable soil-moisture conditions although their growth is greatly retarded.

9. Lettuce plants from weak seed are unable to develop and grow except under the most favorable conditions of soil moisture and æration.

10. The germination of strong lettuce seed is not adversely affected by poor æration to the extent of commercial loss. Germination of weak seed is suppressed to the point of almost complete failure except under the most favorable conditions.

11. It is believed that only the strongest and most vigorous lettuce seed should be used in commercial plantings to insure a stand of vigorous plants able to overcome minor unfavorable soil conditions.