# THE EFFECTS OF TEMPERATURES AND SALT SOLUTIONS ON THE GERMINATION OF LETTUCE SEED

by

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# CHAPTER I

## INTRODUCTION

Lettuce is the most important vegetable crop grown in Arizona. A total of 50,000 cars of vegetables was shipped out of Arizona in 1951, and of these 50,000 cars, 25,000 were of lettuce. There are two seasons in which this vegetable crop is grown. Fall lettuce is harvested usually about November 15, and spring lettuce is harvested some time in March or April.

It is the fall crop of lettuce that this paper is concerned with. The fall crop is planted about September 1-5 in the Salt River Valley when the soil and air temperatures are still high. Unsatisfactory stands often are obtained because of low germination. It is believed that this low germination results from high soil temperatures which prevail at germination time (3). Lettuce seeds will not germinate at high temperatures, and this is one of the limiting factors that determine the areas in which fall lettuce can be grown successfully.

The highly saline soils present in some areas of the Salt River Valley, also, have an effect on the germination of seeds. Ayers (1) stated that the critical stage of crop production on saline soil may be germination.

In the experiments which are reported in this thesis, an attempt was made to establish laboratory conditions comparable to the Salt River Valley at the time for sowing the fall crop of lettuce.

## CHAPTER II

## REVIEW OF LITERATURE

Even though the literature on the germination of lettuce seed is plentiful, there is a scarcity of it pertaining to the work done in this thesis. Many of the early varieties of lettuce had a tendency to be dormant, and much of the work was done in breaking the dormancy of the seed. Thompson (8) germinated dormant seed by soaking the seed in water and exposing to diffused light. Borthwick and Robbins (3) did it by pre-chilling moist seed for five days at 4° C. The seed used in the experiments reported in this paper are the 1950 crop of Great Lakes Premier and the 1950 crop of Imperial 44 varieties grown in Central California, and no dormancy problem was encountered.

Various media have been used for germinating seed in the laboratory. The material used must provide adequate aeration and moisture for the seed. Mackeever (6) lined the bottom of covered dishes with one-half inch of sphagnum moss and over it placed a piece of blotter paper cut to fit tightly inside the dishes. Thompson (8) used blotter paper in the bottom of petri dishes. And Davis (5) found absorbent cotton to be a better medium than blotter paper.

Coffeman (4) found that the range of temperatures over which lettuce seed would germinate was from 30-40° F. to 85-90° F. Davis (5) found minimum temperatures for lettuce hypocotyl growth was 34-39° F. and found no germination at 86° F. Borthwick and Robbins (3) germinated lettuce seed at high temperatures (86-104° F.) by removing the endosperm and

integumentary membrane to expose the naked membrane. They state that lettuce seed fail to germinate at high temperatures because the seed coat becomes less permeable to gases at the higher temperatures, and suggested that there may be deleterious products of metabolism in the endosperm or embryo, arising and possibly accumulating only at the higher temperatures, which inhibit the initial germination stages.

Siegel (7) stated that in the field of temperature relations of plants, those aspects dealing with brief treatment of non-dormant seed with heat or cold have hitherto been little investigated.

Ayers (1) has worked on the problem of soil salinity and its effect on the germination of seed. He states that soil salinity may affect germination of seed in two ways: (a) by decreasing the rate of water entry into the seed; and (b) by facilitating the entry of ions in sufficient amounts to be toxic. This results in a slower rate of emergence of seed that do germinate and a decrease in the percentage of germination. Ayers and Hayward (2) state that it is difficult, if not impossible, to evaluate adequately the level of salinity conditioning the germination of seed under field conditions. It is evident that there is no general relationship between the relative salt tolerance of germinating seed and the tolerance during later phases of growth.

## CHAPTER III

## MATERIALS AND METHODS

### I. Temperatures used.

The temperatures used in these experiments and their locations are listed below:

33° ± 2° F. - standard refrigerator in room 28

40° ± 2° F. - standard refrigerator in room 28

60° ± 1° F. - cold storage refrigerator in room 113

70° ± 1° F. - room 14

82° ± 2° F. - thermostatically- led oven in room 28

90° ± 0.5° F. - incubator in room 213

106° ± 0.5° F. - incubator in room 11

The above rooms are all located in the Agriculture Building on the University of Arizona campus.

### II. Salts used.

Salt solutions containing equal amounts by weight of sodium chloride and calcium chloride were used. Concentrations of 2000, 4000 and 6000 ppm. total soluble salts were prepared by using, respectively, 100, 200, and 300 mg. each of sodium chloride and calcium chloride per 100 ml. of distilled water.

### III. Procedure for germination.

The lettuce seed was germinated in standard 9 cm. diameter petri dishes containing an absorbent tissue in the bottom. The absorbent tissue

used was Kleenex folded four times and cut to fit the bottom of each petri dish.

A moisture source was added to each dish, and any excess water was drained out. The lettuce seed was then sprinkled loosely on the Kleenex and the petri dish was covered and placed in the proper temperature. Covering the dishes kept the water content of the different germination dishes reasonably uniform, and helped reduce evaporation. The seeds were germinated in the dark.

IV. Minimum, optimum, and maximum temperatures for germination.

One hundred lettuce seed each of Great Lakes Premier and Imperial 44 varieties was placed in two petri dishes on Kleenex that had been saturated with tap water. The dishes were covered, and the seed was subjected to temperatures of 33°, 40°, 50°, 60°, 70°, 82° and 90° F. Daily observations were made until maximum germination was obtained. This procedure was repeated five times, and each replication was started at a different date.

V. Rate of germination at different temperatures with the addition of sodium chloride and calcium chloride.

Eight petri dishes containing 100 seed each of the two varieties of lettuce were supplied with tap water, 2000 ppm., 4000 ppm., and 6000 ppm. soluble sodium chloride and calcium chloride. Tap water was used as a control in all salt solution experiments. The seed was then subjected to different temperatures, and diurnal observations were made and recorded. This treatment was repeated five times. If added moisture was needed, distilled water was added until the Kleenex was fully saturated again. This prevented the build-up of salt. Only at high temperatures was

moisture a problem.

VI. Effects of an initial high temperature shifted to a lower temperature.

One hundred seed each of the two varieties of lettuce (Great Lakes Premier and Imperial 44) were placed in petri dishes on Kleenex that had been saturated with tap water. The seed was then subjected to a temperature of 106° F. for periods of 2 and 4 hours, after which the seed was shifted to ovens that had temperatures of 70° and 82° F. Daily observations were made and the results were recorded. Five replications were made.

VII. Effects of an initial high temperature with the addition of sodium chloride and calcium chloride shifted to a lower temperature.

Twelve petri dishes were prepared similar to the ones previously described, except that moisture was supplied to the seed in solutions that contained 2000 ppm., 4000 ppm., and 6000 ppm. soluble NaCl and $CaCl_2$. Four more dishes had tap water added to them. The seed was then exposed to a temperature of 106° F. for 2 and 4 hours. They were then transferred to temperatures of 70° and 82° F. Daily observations were made and germination percentages of the seed were recorded. This treatment was repeated five times.

VIII. Rate of growth of lettuce seedlings for all treatments.

As daily observations were made in the preceding experiments, the root and stem growth were measured in millimeters.

## CHAPTER IV

## PRESENTATION OF RESULTS AND DISCUSSION

### I. Minimum, maximum, and optimum temperature for germination.

Germination tests were run using temperatures from 33-90° F. The results are shown in Table I. Since no varietal differences were noticed, the five replications of the two varieties were averaged and this figure was used for the percentage of germination. This method was employed throughout the problem.

The minimum temperature for lettuce seed was between 33° and 40° F., and the maximum temperature at which the seed germinated was 82° F. They failed to germinate at 90° F.

From the literature it was indicated that lettuce seed must have cool temperatures before it will germinate, and the high temperatures will prevent germination. This was brought out during the course of the experiments reported herein. There was a sharp break in the germination curve (Fig. 1) between 33° and 40° F., and also between 82° and 90° F. However, at the lower temperature, there was a delay in germination which was not present at the higher temperatures. This will be discussed more thoroughly later.

The optimum temperature of around 70° F. was indicated by the higher percentage and rate of germination obtained whenever a 70° treatment was used in the experiment. The germination curve was very smooth for temperatures that ranged from 40-82° F.

Lettuce seed when germinated at 70° or 82° F. and the seedlings placed at 90° F. survived as long as moisture was supplied for the ten day period.

II. Rate of germination at different temperatures.

The rate of germination varies at the different temperatures (Table I). Below 60° F., there was a delay of from 4 days (40° F.) to 3 days (40° and 50° F.); while the seed germinated within 24 hours at temperatures of 60-82° F.

From Figure 2 it is noted that as the temperature decreased, the delay in germination increased. But for a higher temperature, this did not hold true. At 82° F. there was no delay in germination, but at 90°, only an 8° increase, there was no germination at all. This indicates that 82° F. was close to the critical temperature for the germination of lettuce seed, and any lettuce sown when soil temperatures are in the 80's will be unlikely to germinate.

The higher temperatures did not kill the seed, as they germinated when put at a lower temperature. This phase will be discussed later in the paper.

III. Effects of the addition of sodium calcium chloride salt solutions at different temperatures.

No change was made in the rate of germination of lettuce seed at temperatures of 40°, 50° and 60° F. with addition of the combination NaCl and $CaCl_2$ solutions. (Table II.) A 97% germination in tap or salt concentrations of 2000, 4000, and 6000 ppm. solutions was obtained at 40° in 5 days, and at 50° in 3 days.

For the 60° temperature, 98% germination was obtained the first day

Table I. The Rate of Germination for Lettuce Seed at Different Temperatures

| Days | 33 | 40 | 50 | 60 | 70 | 82 | 90 |
|---|---|---|---|---|---|---|---|
| 1 | 0* | 0 | 0 | 98 | 99 | 97 | 0 |
| 2 | 0 | 0 | 0 | 97 | 98 | 96 | 0 |
| 3 | 0 | 0 | 97 | 98 | 99 | 99 | 0 |
| 4 | 0 | 62 | 97 | 98 | 99 | 97 | 0 |
| 5 | 0 | 96 | 97 | 98 | 98 | 97 | 0 |
| 6 | 0 | 97 | 97 | 98 | 99 | 97 | 0 |
| 7 | 0 | 97 | 97 | 98 | 99 | 98 | 0 |
| 8 | 0 | 97 | 97 | 98 | 99 | 97 | 0 |
| 9 | 0 | 97 | 97 | 98 | 98 | 97 | 0 |
| 10 | 0 | 97 | 97 | 98 | 99 | 97 | 0 |

*Average percent of germination of the five replications using the two varieties.

Fig. 1. The Germination Curve for Lettuce Seed

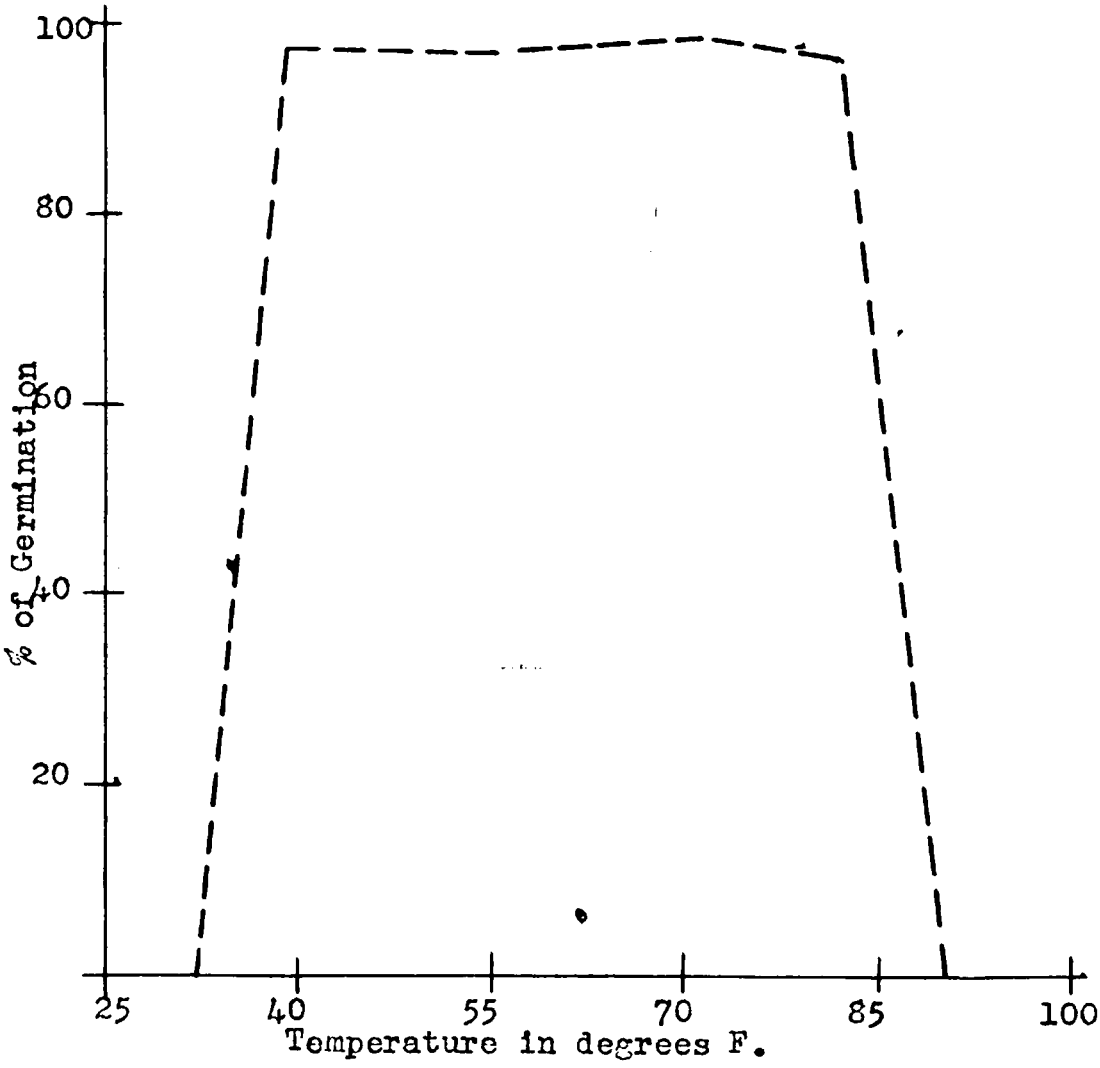
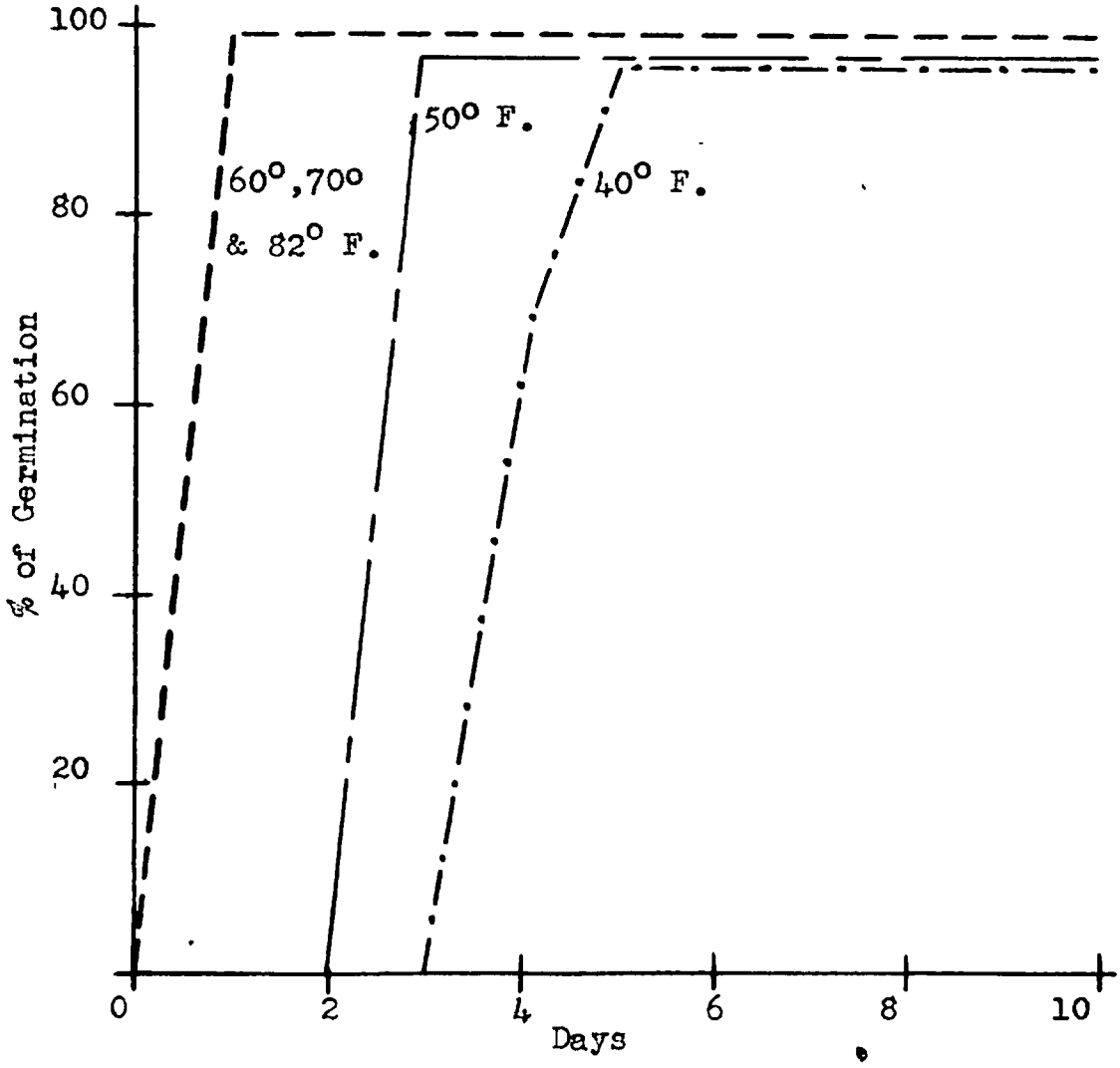


Fig. 2. The Rates of Lettuce Seed Germination at Different Temperatures



for the control and concentrations of 2000 and 4000 ppm. At concentration of 6000 ppm. there was a 78% germination the first day and a 97% germination at the end of the second day.

A 98% germination was obtained at the end of one day for lettuce seed subjected to the 70° F. temperature and using tap water and a 2000 ppm. salt concentration. For the 4000 ppm. concentration an 81% germination occurred the first day and the maximum of 97% the second day. With a 6000 ppm. solution there was a 45% germination the first day and 95% on the second day.

The salt concentrations of 2000, 4000, and 6000 ppm. had little influence on the rate of germination of the lettuce seed at the lower temperatures. At temperatures of 40° and 50°, the rate of germination was not reduced or delayed by the addition of the salt concentrations used in the experiment.

Tap water, which contained about 800 ppm. of total soluble salts, was used for all controls in the experiments reported in this paper. A series of tests were run using tap water and distilled water for all phases of this experiment. No differences were observed in the percentage of germination between the two treatments.

At the 60° F. temperature, the rate of germination was delayed one day with the 6000 ppm. concentration from the control. The total per cent of germination was unaffected.

When the temperature was boosted to 70° F., both the 4000 and 6000 ppm. combinations NaCl and $CaCl_2$ concentrations delayed the germination one day, but the higher concentration caused a greater delay the first day.

At 82° F., the delaying action of the 4000 and 6000 ppm. solutions

Table II. The Rates of Germination for Lettuce Seed at Different Temperatures when Sodium and Calcium Chloride Solutions are added

Concentrations in ppm. ($NaCl:CaCl_2$ = 1:1 ratio by wt.)

| | 40° F. | | | | 50° F. | | | | 60° F. | | | | 70° F. | | | | 82° F. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Days | Tap | 2000* | 4000 | 6000 | Tap | 2000 | 4000 | 6000 | Tap | 2000 | 4000 | 6000 | Tap | 2000 | 4000 | 6000 | Tap | 2000 | 4000 | 6000 |
| 1 | 0** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 98 | 98 | 98 | 78 | 98 | 98 | 81 | 45 | 97 | 96 | 22 | 2 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 99 | 98 | 98 | 97 | 98 | 98 | 97 | 95 | 97 | 97 | 662 | 10 |
| 3 | 0 | 0 | 0 | 0 | 97 | 98 | 97 | 97 | 98 | 98 | 98 | 97 | 98 | 98 | 97 | 97 | 97 | 97 | 65 | 10 |
| 4 | 65 | 60 | 63 | 59 | 98 | 98 | 98 | 97 | 98 | 98 | 98 | 97 | 98 | 97 | 96 | 97 | 97 | 96 | 65 | 10 |
| 5 | 97 | 97 | 96 | 97 | 98 | 98 | 97 | 97 | 98 | 98 | 97 | 97 | 97 | 98 | 98 | 97 | 98 | 96 | 65 | 10 |
| 6 | 97 | 96 | 97 | 96 | 98 | 97 | 97 | 98 | 98 | 98 | 98 | 97 | 98 | 98 | 97 | 97 | 97 | 97 | 65 | 10 |
| 7 | 97 | 97 | 97 | 98 | 98 | 98 | 98 | 97 | 98 | 98 | 98 | 97 | 98 | 98 | 97 | 97 | 97 | 96 | 65 | 9 |
| 8 | 97 | 98 | 96 | 97 | 98 | 98 | 98 | 98 | 98 | 98 | 98 | 97 | 98 | 99 | 97 | 97 | 97 | 97 | 65 | 10 |
| 9 | 97 | 97 | 97 | 96 | 98 | 98 | 98 | 98 | 98 | 98 | 98 | 97 | 98 | 97 | 97 | 97 | 97 | 97 | 65 | 10 |
| 10 | 97 | 97 | 97 | 96 | 98 | 98 | 98 | 98 | 98 | 98 | 98 | 97 | 98 | 98 | 97 | 97 | 97 | 97 | 65 | 10 |

*Salt concentrations in ppm.

**Percent of germination.

was increased considerably over the 70° temperature. It was not until the third day that maximum germination was obtained for the 4000 ppm. concentration; and for 4000 and 6000 ppm. treatment there was a lethal effect, as well as a delaying effect, on germination.

Salt concentrations at low temperatures had little or no effect on delaying and obtaining maximum germination of lettuce seed; but as the temperature increased, there was also an increased delaying effect, and as the temperature reached the critical point, a lethal effect was also observed.

IV. Effects of initial high temperature with a shift to a lower temperature.

The lettuce seed that was put into the 106° F. temperature oven for 2 hours and then shifted to 70° had a germination percentage of 94% in one day and 98% the third day. (Table III.) When the seed was exposed for 4 hours at the high temperature and shifted to 70° F., a 73% germination was obtained the first day and 92% the second day. This was the highest percentage of germination reached.

With the seed exposed to the initial high temperature of 106° F. for 2 and 4 hours and then placed in the oven at 82°, different results occurred. For the 2-hour period at the higher temperature, 76% germination was obtained the first day and the maximum of 92% was reached on the second day. With the initial temperature of 106° F. increased to a 4-hour period, a greater prolongation in germination occurred. At the end of one day, only 12% of the seed had germinated, but at the end of 2 days, 84% showed hypocotyl growth. The maximum of 87% was reached the third day.

When the lettuce seed was exposed to 106° F. for 2 hours and then

Fig. 3. The Rates of Lettuce Seed Germination at Different Temperatures with the Addition of Sodium-Calcium Chloride Salt Solutions

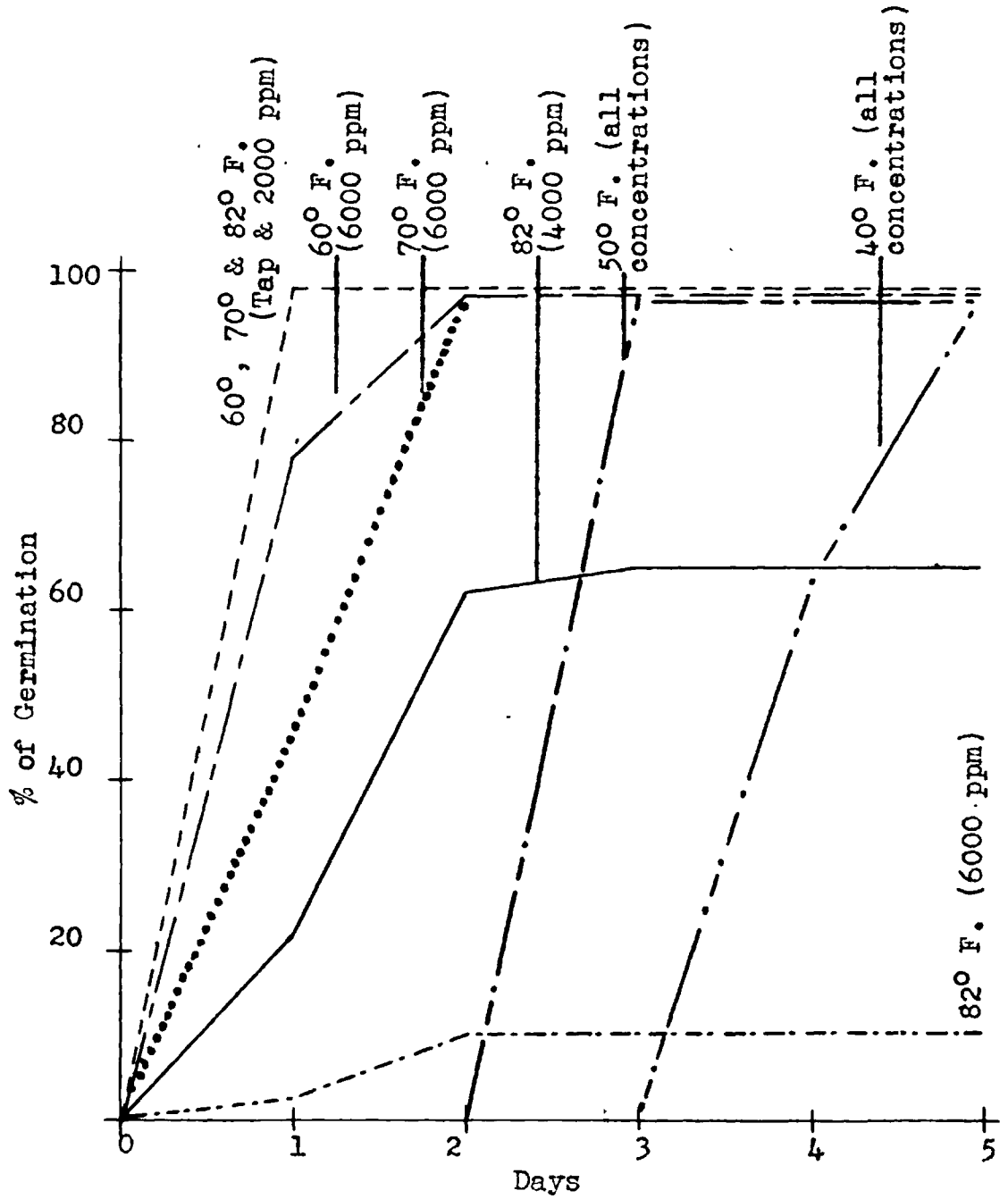


Fig. 4. The Rates of Lettuce Seed Germination when Exposed to an Initial High Temperature with a Shift to a Lower Temperature

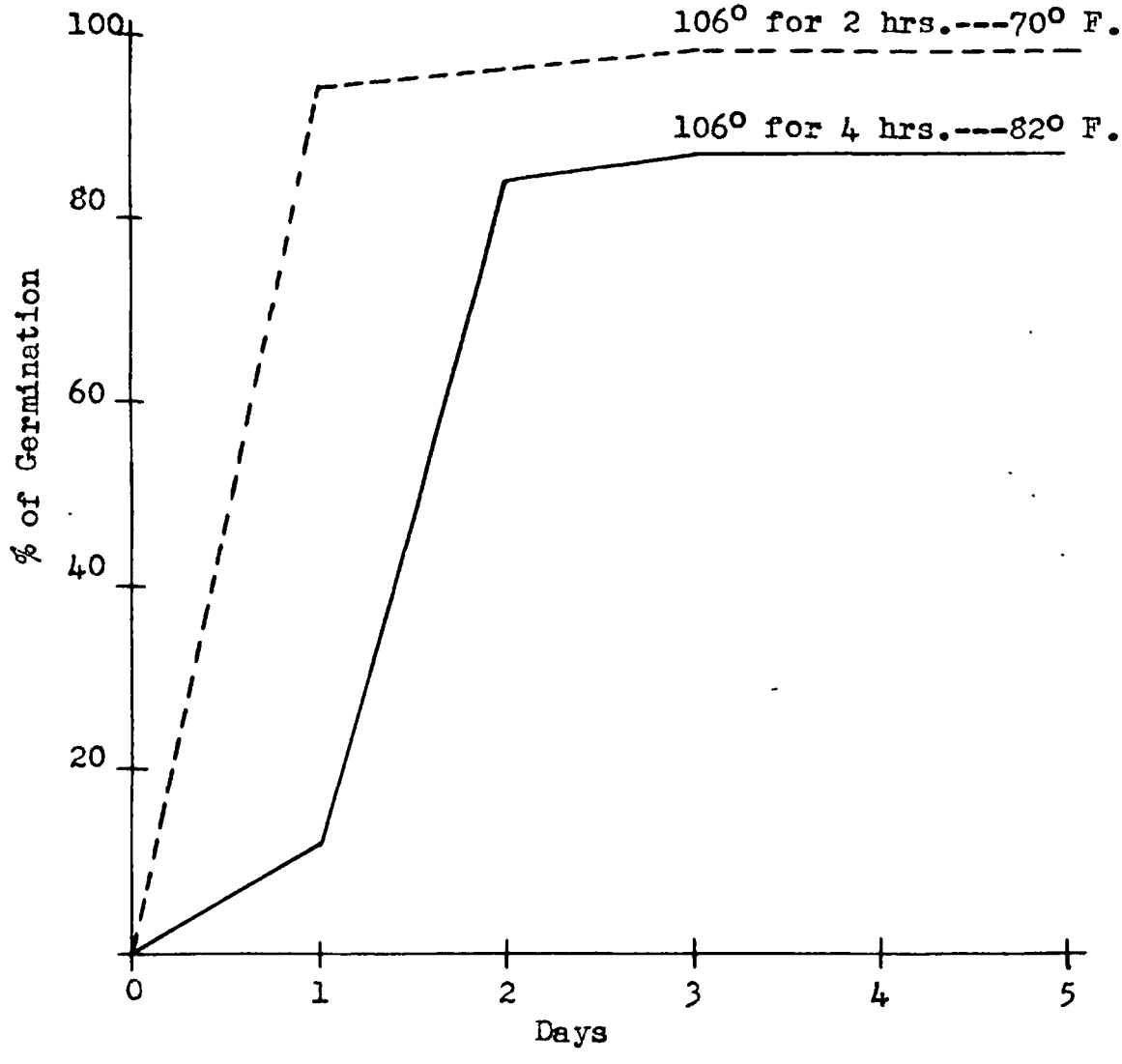


Table III. The Effect of an Initial High Temperature with a Shift to a Lower Temperature

| Initial high temperature | Length of high temp. treatment | Shifted Temperature | Days | % of Germination |
|---|---|---|---|---|
| 106° F. | 2 hr. | 70° F. | 1 | 94 |
| | | | 2 | 95 |
| | | | 3 | 98 |
| | | | 4 | 98 |
| 106° F. | 4 hr. | 70° F. | 1 | 73 |
| | | | 2 | 92 |
| | | | 3 | 92 |
| | | | 4 | 92 |
| 106° F. | 2 hr. | 82° F. | 1 | 76 |
| | | | 2 | 92 |
| | | | 3 | 92 |
| | | | 4 | 92 |
| 106° F. | 4 hr. | 82° F. | 1 | 12 |
| | | | 2 | 84 |
| | | | 3 | 87 |
| | | | 4 | 87 |

placed at 70° F. for the rest of the time, only a slight delaying action occurred; but when the seed was left for 4 hours at 106° F., there was a slight lethal effect, as well as a delaying effect.

Approximately the same results occurred when the seed was exposed to 106° F. for 4 hours and then placed at a temperature of 70°, and when the seed was exposed to 106° F. for 2 hours but placed at 82° and allowed to germinate.

The results of this experiment show that the longer the exposure of seeds to a high temperature, the longer the time required to germinate when placed at a lower temperature. This agreed with the work reported by Borthwick and Robbins (3).

V. Effects of initial high temperature with the addition of sodium and calcium chloride shifted to a lower temperature.

The percentages of germination and the delaying effect of an initial high temperature combined with salt concentrations are tabulated in Table IV. Lettuce seed that had a 2-hour exposure to 106° F. and was then shifted to 70° had a germination of 94% and 95% at the end of one and two days, respectively, when moisture was supplied with tap water (control) and 2000 ppm. salt solution, and a high of 98% at the end of 4 days.

A 4000 ppm. solution resulted in an 89% germination the first day and of 94%, which was the maximum, at the end of 2 days. The 6000 ppm. treatment caused an increased prolongation in germination. Only 35% of the seeds germinated the first day and 89% the second day. The maximum was reached at the end of 3 days when 91% of the seed had germinated.

The length of the initial high temperature (106° F.) period was increased to 4 hours and the following results occurred in the germination percentages when the temperature was reduced to 70° F. With tap water, 73%

Table IV. The Effects of an Initial High Temperature and the Addition of Sodium Chloride and Calcium Chloride Salt Solutions with a Shift to a Lower Temperature

| Initial high temp. | Length of high temp. | Days | Shifted temperatures 70° F. Tap | 2000* | 4000 | 6000 | 82° F. Tap | 2000 | 4000 | 6000 |
|---|---|---|---|---|---|---|---|---|---|---|
| 106° F. | 2 hr. | 1 | 94** | 95 | 89 | 35 | 76 | 66 | 4 | 2 |
| | | 2 | 94 | 95 | 94 | 89 | 92 | 87 | 55 | 27 |
| | | 3 | 97 | 97 | 94 | 91 | 93 | 88 | 55 | 32 |
| | | 4 | 98 | 98 | 94 | 91 | 93 | 88 | 55 | 32 |
| 106° F. | 4 hr. | 1 | 73 | 69 | 4 | 0 | 12 | 9 | 0 | 0 |
| | | 2 | 84 | 86 | 86 | 31 | 84 | 71 | 26 | 1 |
| | | 3 | 84 | 86 | 87 | 45 | 85 | 80 | 36 | 1 |
| | | 4 | 86 | 86 | 87 | 53 | 87 | 80 | 45 | 2 |
| | | 5 | 86 | 86 | 87 | 53 | 87 | 80 | 45 | 2 |

*Salt concentration in ppm.

**Percent of germination.

Fig. 5. The Rates of Lettuce Seed Germination when Exposed to 106° F. for 2 Hours and Shifted to Lower Temperatures with the Addition of Sodium-Calcium Chloride Solutions

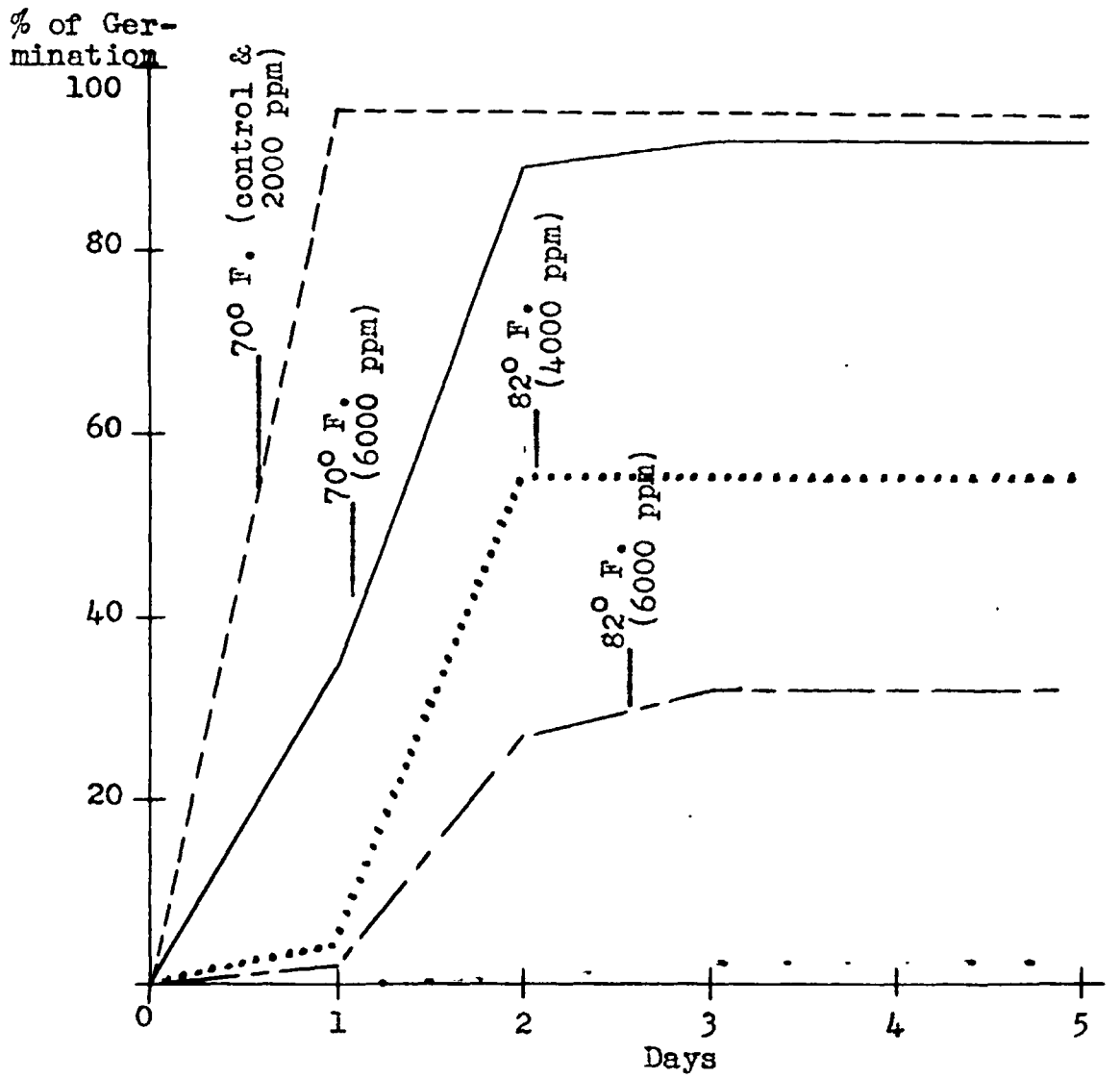
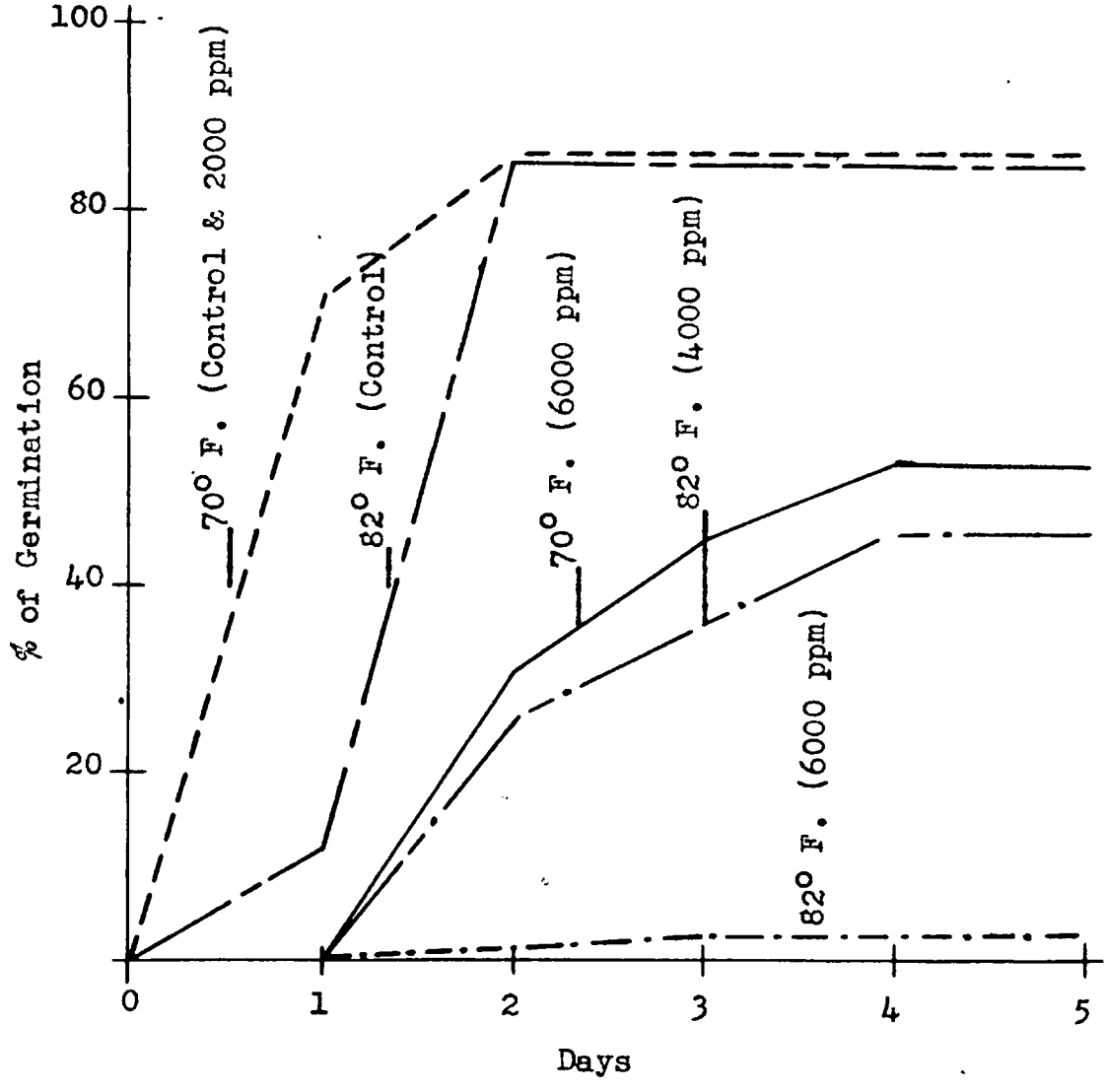


Fig. 6. The Rates of Lettuce Seed Germination when Exposed to 106° F. for 4 Hours and Shifted to Lower Temperatures with the Addition of Sodium-Calcium Chloride Solutions



of the seed germinated in one day, 84% the second day, and the maximum 86% occurred the fourth day. For the 2000 ppm. treatment, 69% germination was reached the first day and 86% at the end of the second day. This was the maximum germination percentage. The results of the 4000 ppm. solution showed only 4% and 86% germination at the end of one and 2 days, respectively; 87%, the maximum, was reached by the third day. With the 6000 ppm. salt concentration, there was no germination the first day and only 31% the second day. By the third day 45% had germinated. The maximum was 53% reached the fourth day.

When salt solutions were added to supply the lettuce seed with moisture for germination, an increased stress on the germinating seed occurred. The seed exposed to 106° F. for 2 hours and then placed at 70° had a 6% decrease in germination with 4000 ppm. solution from the control for the first day. But with a 6000 ppm. there was a decrease of 60% in the germination rate the first day. And there was a very slight lethal effect at the 6000 ppm. level.

When the final temperature was boosted to 82° F. after a 2-hour exposure to 106°, there was a lethal effect encountered at 4000 ppm. which reduced the germination percentage almost one-half (from 93 to 55) and at 6000 ppm. by one-third. The delaying action for all concentrations increased over the 70° F. treatment.

With a 4-hour exposure of the seed to 106° F., there was a lethal effect for all concentrations of the sodium calcium-chloride solutions, even for the control, when the final temperature treatment was 70° and 82°. But the higher final temperature resulted in a lower number of seed that germinated.

VI. Rates of growth of seedlings at different temperatures and salt concentrations.

Root growth measurements were made as the seed germinated. As soon as the radicle appeared through the seed coat, measurements were started. The hypocotyl was divided into the root portion and the stem portion. These measurements are recorded in Tables V, VI, and VII.

At the end of ten days the root and stem of the lettuce seedling grown at 40° F. each had a length of 6 mm. But when grown at 70° and 82°, the roots measured between 51-53 mm., and the stems had a length of 55-56 mm. in 8 days. When the root growth exceeded 50 mm. in length, they became so tangled in the dish and absorbent tissue that it became difficult to remove the seedlings for measurement without breaking off part of the root.

With addition of salts and an initial high temperature for 2 hours at 106° F. reduced to 70°, a root length of 52 mm. and a stem length of 51 mm. were reached by the end of 7 days for the control; for the 6000 ppm. treatment, a root length of 49 mm. and a stem length of 47 mm. were measured for the same period of time.

The temperature below 60° F. had a retarding effect on the growth of lettuce seedlings. At very low temperatures, 40-50° F., once the seeds had germinated, growth almost was at a standstill; but as the temperature approached 70° F., the rate of growth was increased and very few differences were observed in the growth rate of the seedlings at 70° and 82° F.

The root section of the hypocotyl grows rapidly at first, and as it begins to taper off the stem growth begins to increase and finally equals

or overtakes the root growth by the end of 10 days.

The salt solutions and high initial temperatures did not greatly affect the growth of the lettuce seedlings; as long as the seed was able to germinate, growth was made. Only when the salt concentration was 6000 ppm. and an initial high temperature of 106° was maintained for 4 hours before reducing it to 82° was there an appreciable reduction in root and stem growth.

In addition to the seedlings grown at 40° and 50° F., having their growth retarded, masses of root hairs appeared on the roots (Fig. 9). Only a few, if any, root hairs were present on the seedlings grown at the higher temperatures.

Table V. Rate of Growth for Lettuce Seedlings at Different Temperatures

| Days | Temperature | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 40° F. | | 50° F. | | 60° F. | | 70° F. | | 82° F. | |
| | Root | Stem | Root | Stem | Root | Stem | Root | Stem | Root | Stem |
| 1 | 0* | 0 | 0 | 0 | 1 | 0 | 3 | 0 | 5 | 0 |
| 2 | 0 | 0 | 0 | 0 | 2 | 0 | 7 | 5 | 7 | 12 |
| 3 | 0 | 0 | 2 | 0 | 4 | 1 | 20 | 20 | 21 | 19 |
| 4 | 1 | 0 | 3 | 1 | 6 | 3 | 31 | 29 | 28 | 23 |
| 5 | 3 | 1 | 3 | 1 | 9 | 8 | 33 | 31 | 30 | 31 |
| 6 | 3 | 1 | 5 | 2 | 13 | 13 | 38 | 44 | 41 | 37 |
| 7 | 4 | 3 | 6 | 4 | 17 | 15 | 47 | 48 | 42 | 41 |
| 8 | 5 | 5 | 8 | 5 | 19 | 20 | 53 | 56 | 51 | 55 |
| 9 | 6 | 5 | 13 | 9 | 20 | 23 | | | | |
| 10 | 6 | 6 | 14 | 12 | 23 | 28 | | | | |

*Length in mm.

Table VI. Rate of Growth of Lettuce Seedlings when Germinating Seed was Exposed to 106° F. for 2 and 4 Hours and Shifted to 70° F. with the Addition of Sodium-Calcium Chloride Solutions

| | Treatment | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 106° F. for 2 hrs. then 70° F. | | | | | | | | 106° F. for 4 hrs. then 70° F. | | | | | | | |
| | Tap | | 2000* | | 4000 | | 6000 | | Tap | | 2000 | | 4000 | | 6000 | |
| Days | R | S | R | S | R | S | R | S | R | S | R | S | R | S | R | S |
| 1 | 3** | 0 | 4 | 0 | 3 | 0 | 2 | 0 | 2 | 0 | 1 | 0 | 0.5 | 0 | 0 | 0 |
| 2 | 8 | 2 | 7 | 4 | 7 | 7 | 7 | 6 | 8 | 6 | 7 | 5 | 6 | 0.5 | 5 | 0 |
| 3 | 17 | 12 | 15 | 14 | 19 | 17 | 22 | 17 | 22 | 17 | 25 | 15 | 21 | 6 | 14 | 4 |
| 4 | 27 | 25 | 29 | 30 | 28 | 27 | 36 | 29 | 27 | 25 | 25 | 28 | 32 | 21 | 21 | 12 |
| 5 | 32 | 33 | 30 | 35 | 32 | 36 | 45 | 34 | 31 | 32 | 33 | 33 | 35 | 30 | 34 | 23 |
| 6 | 44 | 46 | 38 | 38 | 42 | 47 | 48 | 44 | 34 | 38 | 34 | 41 | 36 | 32 | 37 | 28 |
| 7 | 52 | 51 | 47 | 50 | 45 | 48 | 49 | 47 | 37 | 48 | 36 | 47 | 36 | 33 | 38 | 30 |
| 8 | | | | | | | 50 | 50 | 43 | 59 | 38 | 48 | 37 | 36 | 43 | 36 |
| 9 | | | | | | | 51 | 52 | 45 | 62 | 38 | 51 | 41 | 39 | 45 | 38 |
| 10 | | | | | | | 53 | 53 | 46 | 62 | 44 | 55 | 42 | 43 | 47 | 38 |

*Salt concentration in parts per million (ppm.).

**Length in mm.

Table VII. Rate of Growth of Lettuce Seedlings when Germinating Seed was Exposed to 106° F. for 2 and 4 Hours and Shifted to 82° F. with the Addition of Sodium-Calcium Chloride Solutions

| | Treatment | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 106° F. for 2 hrs. then 82° F. | | | | 106° F. for 4 hrs. then 82° F. | | | |
| | Tap | 2000* | 4000 | 6000 | Tap | 2000 | 4000 | 6000 |
| Days | R S | R S | R S | R S | R S | R S | R S | R S |
| 1 | 3** 0 | 2 0 | 5 0 | 3 0 | 1 0 | 2 0 | 0 0 | 0 0 |
| 2 | 7 6 | 8 5 | 13 11 | 12 4 | 8 5 | 7 3 | 6 2 | 2 0 |
| 3 | 19 15 | 12 11 | 23 17 | 24 21 | 16 12 | 19 11 | 19 17 | 5 2 |
| 4 | 28 21 | 20 18 | 25 23 | 31 30 | 21 17 | 20 14 | 27 21 | 9 6 |
| 5 | 36 27 | 31 31 | 28 29 | 37 35 | 32 24 | 29 27 | 39 30 | 12 14 |
| 6 | 44 33 | 41 33 | 34 31 | 41 36 | 33 30 | 31 28 | 39 29 | 12 14 |
| 7 | 53 49 | 50 41 | 38 31 | 52 41 | 37 32 | 34 33 | 40 31 | 13 14 |
| 8 | | | 43 32 | | 37 33 | 36 35 | 42 30 | 13 14 |
| 9 | | | 48 41 | | 39 35 | 39 36 | 44 32 | 15 14 |
| 10 | | | 52 42 | | 41 40 | 42 37 | 44 33 | 15 14 |

*Salt concentration in ppm.

**Length in mm.

Fig. 7. The Rates of Root Growth for Lettuce Seedlings at Different Temperatures

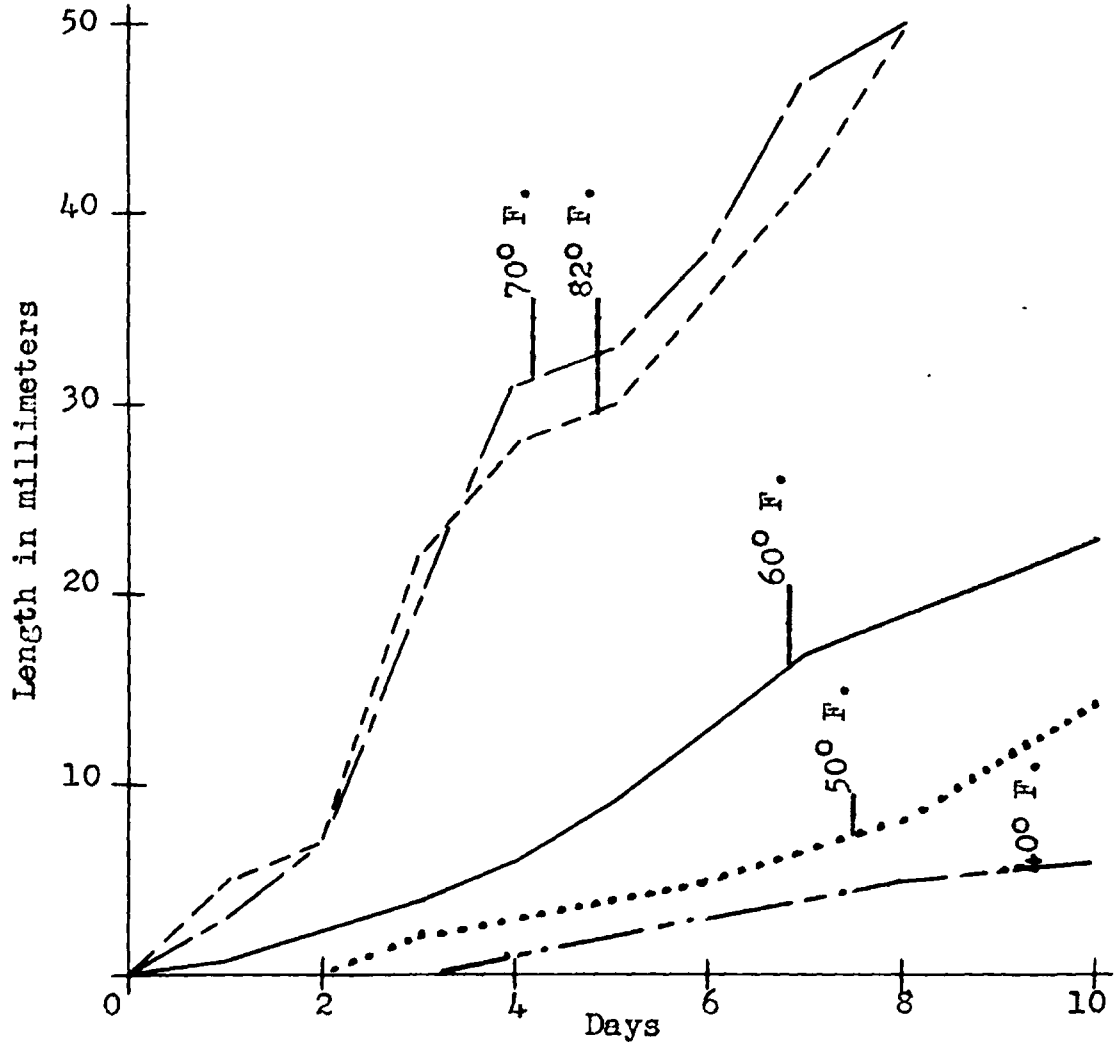


Fig. 8. The Rates of Stem Growth for Lettuce Seedlings at Different Temperatures

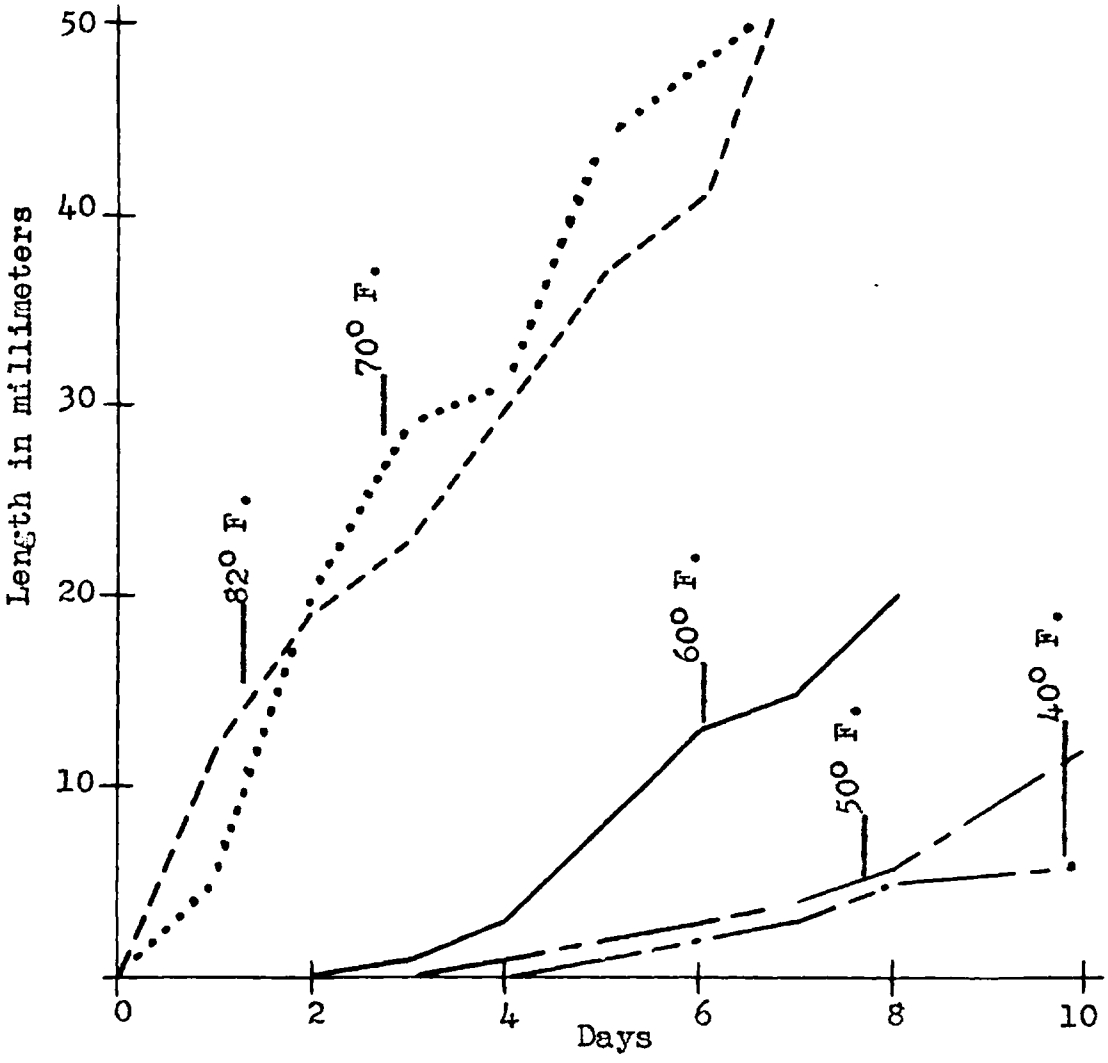


Fig. 9. Comparative Sizes of Lettuce Seedlings Grown at 70° F. (left) and 40° F. (right)

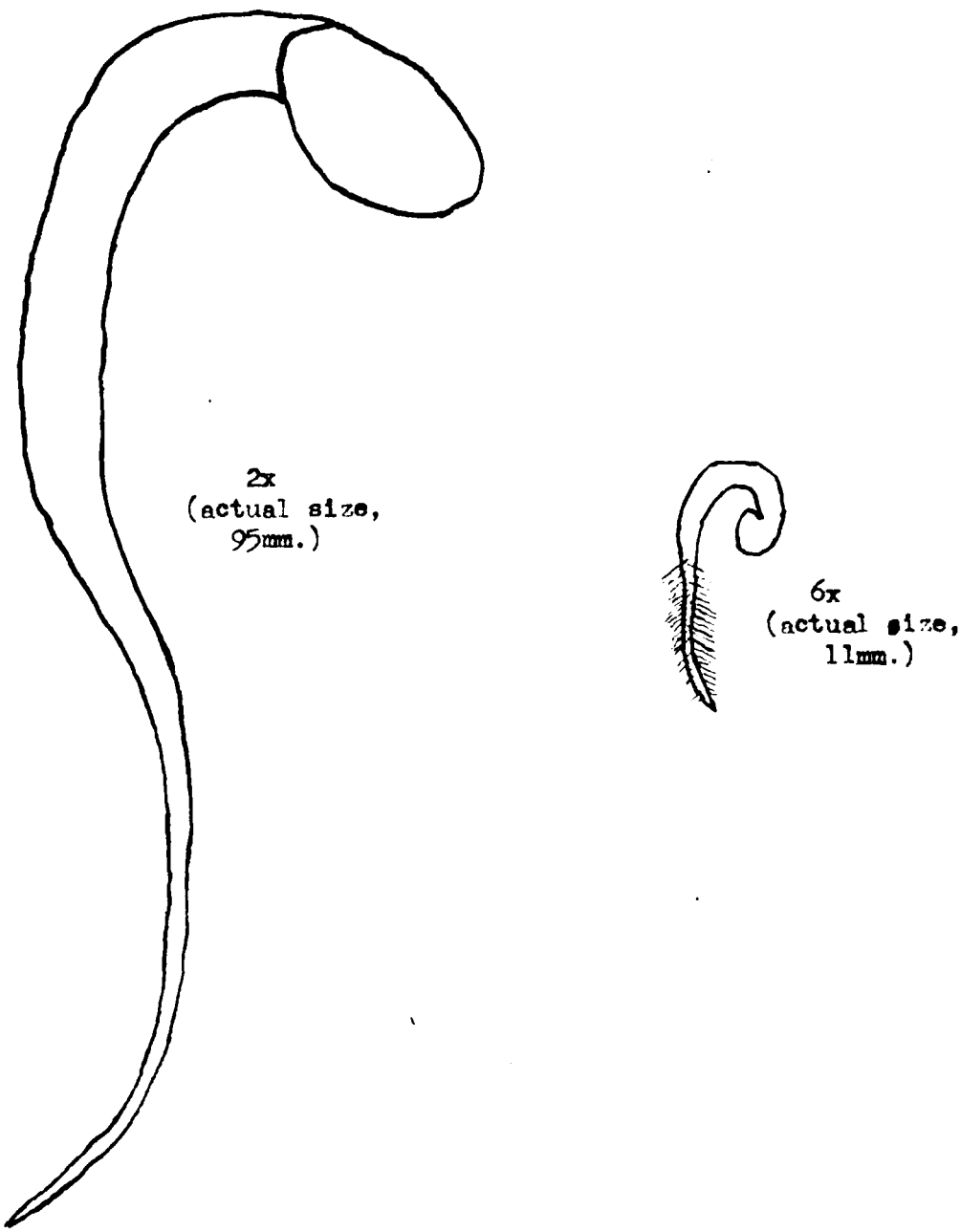


Table VIII. Analysis of Initial High Temperature and Salt Concentrations Experiment

| Source of Variation | F |
|---|---|
| Total Varieties | Less Than 1 |
| Salts | 38.37 |
| Temperature | 24.51 |
| V x S | Less Than 1 |
| V x T | Less Than 1 |
| S x T | 53.99 |
| Error | |

# CHAPTER V

## SUMMARY

1. No differences were observed in the two lettuce varieties used.

2. The minimum temperature for lettuce seed germination was between 33-40° F., and the maximum temperature was between 82-90° F.

3. The optimum temperature for lettuce is near 70° F.

4. Low temperatures, 40-60° F., delay the germination of lettuce, but do not reduce the percentage of seeds that will germinate.

5. A temperature of 82° F. is approaching the critical point for the germination of lettuce seeds.

6. Salt concentrations used had little effect in delaying lettuce seed germination at the lower temperatures; but at higher temperatures the 4000 ppm. and 6000 ppm. sodium-calcium chloride solutions had a lethal effect, as well as a delaying effect.

7. The longer the period that lettuce seeds are exposed to an initial high temperature, the greater the prolongation of germination when they are placed at a lower temperature that will permit germination. And the closer this final temperature is to the critical temperature for lettuce seed germination, the more lethal effect is introduced.

8. The salt concentrations added to an initial high temperature cause a corresponding increased prolongation and lethal effect on germinating lettuce seeds.

9. Temperatures below 60° F. reduced the rate of growth of lettuce seedlings.

10. Rate of growth for lettuce seedlings at 70° and 82° F. closely paralleled each other.

## LITERATURE CITED

1. Ayers, A. D.
1952 Seed germination as affected by soil moisture and salinity. Agron. J. 44:82-84, Feb.

2. Ayers, A. D., and Hayward, H. E.
1949 A method for measuring the effects of soil salinity on seed germination with observations on several crop plants. Soil Sci. Soc. Amer. Proc. (1948), 13:224-226.

3. Borthwick, H. A., and Robbins, W. W.
1928 Lettuce seed and its germination. Hilgardia 3:275-305.

4. Coffman, E. F.
1923 The minimum temperature of germination of seeds. Agron. J. 15:266-267.

5. Davis, W. E.
1924 The germination of lettuce seed. Proc. Assoc. Off. Seed Analysts No. Amer. 16:71-73.

6. Mackeever, F. C.
1951 Seeds and their germination. Gard. J. 1:6, 23, Jan-Feb.

7. Siegel, S. M.
1950 Effects of exposure of seeds to various physical agents. I. Effects of brief exposure to heat and cold on germination and light-sensitivity. Bot. Gaz. 112:57-60, Sept.

8. Thompson, Ross C.
1938 Dormancy in lettuce seed and some factors influencing its germination. U.S.D.A Tech. Bull. 655.