THE EFFECT OF SOIL MOISTURE AND COMPACTION
ON SUGAR BEET EMERGENCE

By

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AN ABSTRACT

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Approved by Walter M. Carleton

A very serious problem that must be solved before complete mechanization of sugar beet production is possible is that of obtaining high percentages and uniform emergence. In order to obtain maximum yields when using mechanical thinners it is necessary to have a uniform stand of beets.

A great deal of research has been directed toward determining the basic factors which affect germination of seeds, and developing the machinery and techniques for placing the seed in the proper environment for best emergence. Because many facts about germination and emergence are still not fully known this study was undertaken.

The review of literature pointed out that there are a large number of factors affecting emergence and indicated that there may be other factors that are yet unknown. The effect of soil moisture and compaction, two of the more important factors discussed in the literature were chosen for further study.

In a laboratory experiment designed to determine the range of soil moisture which would produce satisfactory emergence it was found that soil moistures ranging from 12 to 21 percent produced emergence of approximately 90 percent. In soil drier than 12 percent or wetter than 21 percent the emergence dropped sharply.

In a number of samples planted in soil ranging from 6 to 9 percent moisture no emergence was observed 11 days after planting. At this time one or two cubic centimeters of water were added to certain seeds in the boxes. Four days later two-thirds of the seeds which had added water had emerged while none of the non-treated seeds emerged.

Another laboratory study was made to determine the effect of soil compaction on sugar beet emergence. Compaction pressures ranging from zero to thirty psi were applied to soil at three moisture percentages in which sugar beet seeds had been planted. In general, compaction pressures of two and five psi produced the fastest emergence. In soil of low and medium moisture content any compaction above two psi was detrimental, while in soil of high moisture content the various pressures from zero to thirty psi had very little effect on emergence.

A field study was made to determine if the results of the laboratory investigation would hold true under field conditions. A stream of water was directed into the furrow just before the seed was placed, and various forces were applied to the press wheels. Also, data on the interrelation between fertilizer and moisture and the effect on emergence was obtained. Because of extreme weather conditions the results of two field plantings were somewhat inconclusive. In one planting 200 pounds of 10-10-10 fertilizer placed with the seed produced a significant increase in emergence while none of the other factors were significant. In a later planting the effect of fertilizer was not significant, but water added at a rate of 100 gallons per acre and a force of 150 pounds on the press wheels both produced a significant increase in emergence.

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INTRODUCTION

The Problem

In the past few years great strides have been made toward mechanization of the production of sugar beets. Up until about 1930 hand labor was used almost entirely for thinning, weeding, and harvesting (18).[1] At that time about 118 man-hours were required to raise an acre of beets.[2]

Since 1930 a great deal of research has been directed toward seed bed preparation, precision planters, emergence problems, weed control, blocking and thinning equipment, and harvesting equipment. As a result the labor requirement has been reduced to 62 man-hours per acre and in some cases as little as 30 man-hours per acre.

Hand labor connected with harvesting has nearly been eliminated by equipment developed in the last ten years (22). Techniques of seed bed preparation have been improved in order to provide a better seed bed in which to get the plants started. Machinery for blocking and thinning of beets has been developed satisfactorily. Planters have been designed that accurately place the seed at the proper depth and spacing.

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[1]Numbers in parenthesis refer to literature cited.

[2]Labor requirements statistics compiled by R. B. Gray and S. W. McBirney of the United States Department of Agriculture (18).

A serious problem still unsolved is that of low percentage and erratic emergence. Sugar beet seed is not as vigorous as most field crop seeds such as corn or wheat and in order to obtain an adequate stand it is necessary to plant an excess of seed. This requires that the beets be thinned in order to have the proper spacing for maximum yields.

The problem of erratic emergence cannot be blamed entirely on the seed for germination tests show that the seed will germinate when placed in the proper environment. The problem then develops into one of determining the proper environment to produce uniform and high percentage emergence in the field.

It is hoped that with the development of a highly viable single germ seed, precision planters, and a more complete knowledge of the factors affecting seedling emergence that the thinning operation can be completely eliminated by planting the final desired stand.

The Objective

The objective of this investigation was to obtain more basic data on the factors affecting sugar beet seedling emergence. After making a review of literature it was decided because of time limitations to investigate only two of the factors that are known to affect emergence.

Many references were found in the literature pointing out the great influence of soil moisture on the percentage and rate of emergence. Further investigation of this factor seemed necessary.

The other factor chosen for study was the effect of soil compaction on emergence. Although much applied research has been accomplished, very few references could be found giving basic data on the effect of soil compaction on germinating seed.

The ultimate goal of this project is to completely mechanize the production of sugar beets and at the same time increase the yield.

REVIEW OF LITERATURE

Many factors affect germination and emergence of seeds. In order to analyze the emergence problem of sugar beets the following is taken from an outline presented by Snyder (29).

A. Pre-emergence losses or delays due to
   1. Germination
      a. Lack of sufficient water
      b. Lack of aeration
      c. Low temperature
      d. Contact with fertilizer
      e. Unknown factors in seed
   2. Emergence
      a. Disease (Black root, damping-off)
      b. Lack of sufficient water to survive once germinated
      c. Crusting of soil surface
      d. Deep planting
      e. Soil erosion burying seed too deep to emerge
      f. Fertilizer injury

B. Post-emergence losses

Soil Moisture

It is well known that moisture is an important factor in the germination of seeds. Hunter and Erickson (16) found that in order for seeds to germinate each species had to attain a specific moisture content. They found this minimum moisture content was approximately 31.0 percent for U.S. 215 X 216 segmented sugar beet seed as compared with 30.5 percent for corn, 26.5 percent for rice, and 50.0 percent for soybeans. Moisture contents in seeds were expressed on a wet weight basis and in soils on a dry weight basis. They found the minimum soil moisture required for sugar beet seed to attain the 31.0 percent moisture content required for germination was between 4.41 and 5.45 percent in Miami silt loam, 8.84 and 9.47 percent in Nappanee clay loam, 10.2 and 12.0 percent in Brookston sandy clay loam, and 16.8 and 17.7 percent in Clyde clay.

Moisture tension curves for each soil were plotted on one graph. The soil moisture percentages required for germinating the various species of seed were then placed on the moisture tension curve for each particular soil and it was found that a line of constant moisture tension was formed for each species. The maximum moisture tension for sugar beets was 3.5 atmospheres as compared with 12.5 atmospheres for corn, 7.9 atmospheres for rice, and 6.6 atmospheres for soybeans. These results of Hunter and Erickson show that other species of seed have the ability to germinate in soils considerably drier than those required by sugar beets. They concluded that considerably more care should be paid to soil moisture conditions when sugar beets are planted due to their inability to germinate in dry soils.

Leach _et al_ (21) found only a slight difference between the rate of emergence of whole, segmented, and decorticated sugar beet seed in soils at high moisture contents. However, at low soil moistures they found decorticated seed germinated faster and showed a higher percentage of potential emergence than whole seed. They theorized that the corky material

surrounding the whole seed tended to impede the absorption of water by the seed, thus slowing the germination process. At high soil moistures this effect was apparently negligible.

Working in soils of various moisture contents with no compaction, Hunter and Dexter (17) found that a soil moisture content of 14 percent was sufficient to supply enough moisture to air dry segmented sugar beet seed to permit germination. They had previously found that the seed moisture content had to be 31 percent or greater to permit germination. Air dry seeds germinated in Brookston sandy clay loam only between 12 and 20 percent soil moisture. Germination did not occur in air even at 100 percent relative humidity because the seeds attained a moisture content of only 29 percent. They concluded that sugar beet seeds draw moisture more readily by coming in contact with a free film of water and that a free water surface is necessary for sugar beet seed germination. A limit was reached when too much moisture was present and lack of oxygen apparently caused decreased germination.

Hunter (15) did considerable work to determine the effect of soaking segmented sugar beet seeds in various solutions before planting. After soaking the seed in water for four hours it had reached the moisture content required for germination. Tests were also run to determine the effect of alternate periods of soaking and drying the sugar beet seeds. The results indicated that this treatment in some manner stimulated germination. As many as five alternate periods of soaking and drying did not harm the germination potential of the segmented sugar beet seed. No treatment was found, chemical or otherwise which helped to speed up the emergence of sugar beet seeds as much as soaking the seed in water for at least four hours prior to planting and planting the seed wet.

Tolman and Stout (31) reported that a water soluble inhibitory substance was present in the corky material surrounding the seed. They concluded that the beneficial effects of washing or soaking sugar beet seed may be due to the removal of this substance.

Aeration

Several researchers have found that sugar beets must have good aeration in order to germinate. For example, Farnsworth (9) found that in soils with an air capacity of less than 12 percent, decreased germination was due to poor aeration. Greenhouse studies conducted by Cook (4) have shown that sugar beets are very sensitive to excessive soil packing and conditions of poor aeration. He reported, "Soil compaction slowed up the growth greatly. Forced aeration was beneficial in both the normal and packed cultures."

In contrast, Barmington (1) drew the following conclusion from his study of press wheels. "Anything that can be done to increase the unit pressure on the soil in the immediate vicinity of the seed is good if the device does not tear up the seedbed as it moves on down the row." It would seem, however, that a practical limit would be reached above which decreased emergence would result due to poor aeration.

Aeration studies on Xanthium seed made by Shull (26, 28) and Crocker (7) indicated that failure to germinate was due to lack of oxygen.

Hunter (15) using U. S. 215 X 216 segmented sugar beet seed found that the seeds would not germinate under water unless an additional supply of oxygen was added to the water.

In a laboratory experiment using U. S. 215 X 216 segmented seed in Brookston clay loam Carleton (3) found that compaction pressures of two, three, and four pounds per square inch produced significantly higher emergence than one pound per square inch. Within this range the higher pressures produced higher percentages of potential emergence.

It is clear that aeration is an influential factor in germination and emergence of sugar beets. However, no reference could be found which gave a full report on the effect of soil compaction as it affects aeration and emergence in sugar beets.

Temperature

Since germination is essentially a series of chemical and physical reactions Hunter (15) concluded that there is little doubt that temperature has an effect on the rate of these reactions within the seed. He investigated the effect of temperature on germination of U. S. 215 X 216 segmented sugar beet seed by placing one hundred seeds in a petri dish containing ten cubic centimeters of water. The results of this experiment in which five temperatures were used are shown in Table I.

TABLE I[15]

GERMINATION OF SUGAR BEET SEED ON MOIST BLOTTERS AT A VARIETY OF TEMPERATURES

Days After Planting	Temperature of Experiment				
	5°C	8°C	10°C	15°C	20°C
5	0	0	0	12%	64%
10	0	0	8%	27%	78%
15	0	3%	43%	52%	82%
20	0	24%	68%	73%	82%

Table I shows that this particular variety would not germinate at temperatures less than five to eight degrees Centigrade. Wood (33) reports that the development of varieties of sugar beets capable of germinating at low temperatures and also being frost resistant now seems possible. He lists the advantages of such development as follows:

a. Lengthening of the effective growing season in both spring and fall

b. Prevention of replanting or loss of fields due to frost damage in seedling stage

c. Indications of association of cold resistance with greater sucrose content.

Leach et al (21) working with Yolo fine sandy loam found that lowering the temperature from 70 to 50 degrees Fahrenheit more than doubled the time required for emergence and affected emergence rates in a similar manner. Data given by Crabb and Smith (6) for soil under small grain-meadow cover indicated an average soil temperature in early May near East Lansing of 50 to 60 degrees Fahrenheit. These low temperatures explain why sugar beets planted early in the planting season may not germinate and emerge for a period of ten days to two weeks.

The interrelation between temperature and moisture and the effect on the rate of moisture intake in seeds was studied by Shull (27). Such factors as this are complicated and not fully understood.

Harrington (14) and Morinaga (25) found that some seeds germinated better when subjected to fluctuating temperatures. The following procedure is the method used by the Farmers and Manufacturers Beet Sugar Association in germinating sugar beet seeds.[1]

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[1]From correspondence with Mr. Mark R. Berett, Research Agronomist, Farmers and Manufacturers Beet Sugar Association, Saginaw, Michigan.

1. Soak seeds for two hours in distilled water.
2. Soak seed for 10 minutes in Lignasan. If the seed has previously been treated with an insecticide and fungicide, step #2 is omitted.
3. Place seeds between two sheets of blotter paper moistened with distilled water.
4. Put seeds in germinator. Temperature in germinator is maintained at 86°F for eight hours and 76° for 16 hours.
5. Moisten top sheet of blotter paper daily with distilled water.
6. After three days in the germinator the seeds are counted and number of seeds with single, double, triple, or quadruple sprouts is determined.
7. The seeds are replaced in the germinator and counted again after four days. The percentage of seed which has germinated at the seven day count is the recorded germination.

Fertilizer

Statistics given by Brown (2) in 1940 indicate that since the development of the combined seed and fertilizer drill, fertilizer has been applied with the seed on at least 90 percent of the acreage receiving any fertilizer. He stated that the beet drills used by most Ontario growers deliver the seed and fertilizer into one tube and let them mix while dropping into the furrow. While this method assured the young seedling of adequate nutrients in the early stages of growth numerous cases have shown injury to seedlings by the fertilizer. He explained, "If the rainfall is just sufficient to cause a very concentrated nutrient solution the tender seedlings may be injured or killed. Rates must be held to 250 pounds per acre or less even under favorable moisture conditions to avoid injury when the fertilizer is placed with the seed."

From his study of six methods of applying fertilizer Jensen (19) reported that optimum yields were obtained using only 50 pounds per acre with the seed and 100 or 150 pounds per acre side-dressed or broadcast. No comment was made on the effect of fertilizer on emergence.

Jones (20) recommended the application of a small amount of fertilizer with the seed at planting time followed by side dressing with heavier amounts after thinning.

Later experiments have shown more and more the harmful effects of placing fertilizer with the seed. Mellor _et al_ (24) in an investigation of fertilizer efficiency as affected by placement over a three-year period reported that fertilizer drilled in the same furrow with the beet seed in 1948 resulted in a 54.7 percent stand reduction as compared with the unfertilized check. They explained:

> This was an effect which did not occur in 1947 and probably would occur only under conditions of insufficient moisture at the time of germination. In 1948 a dry period followed planting and placing the fertilizer with the seed probably intensified the drought effect which was not present in 1947.
>
> There was an apparent but not significant average increase in stand on the fertilized plots over the non-fertilized plots in 1947 and 1948 which might have been due to the greater vigor of the fertilized plants.

Mellor in his conclusions stated that there was an evident differential effect of season or location of experiment on the comparative result from the different treatments. This is a fact which bothers all researchers working in the field.

Reports of many researchers indicate that the effect of fertilizer placement on emergence is not fully known. For example, Whitney et al (32) in 1948 reported a significantly lower stand of sugar beets on plots receiving no fertilizer when fertilizer was drilled in with the seed using a drill with fertilizer attachment. The results of their work are given in Table II.

TABLE II (32)

EFFECT OF FERTILIZER APPLIED WITH THE SEED ON EMERGENCE

Treatment*	Percent Stand
Manure	98.2
P	95.6
N and P	97.6
N, P, and K	97.8
No Treatment	77.8

*The analyses of the three commercial fertilizers used were 32.5-0-0, 0-43-0, and 0-0-50.

Frakes (10) in more recent work stated that when using Arasan in fertilizer for black-root control it was observed that some fertilizer in direct contact with the seed gave better stands. Frakes and Draher (12) wrote:

> It has been shown that by placing a small quantity of fertilizer in direct contact with the seed an increased emergence and subsequent rate of growth will result. Since 200 pounds is the limit which can safely be placed in direct contact with the seed, and since this is not enough to bring a crop through to maximum yield, methods other than the above for placing fertilizer must be used.

Fertilizer placement studies conducted by Cook (5) show that when fertilizer was placed with the seed or directly under the seed the plants emerged faster than when fertilizer was placed some distance from the seed.

Frakes and Draher (12) developed a drill which placed fertilizer three inches below the seed. The results of extensive field tests show an average increase from 31.1 beet containing inches using a regular drill to 50.1 beet containing inches per 100 inches using the new drill.

Crusting

Formation of a crust on the soil surface following a rain is a serious problem affecting sugar beet seedling emergence. Nearly every report in the literature concerned with sugar beet emergence studies mentions the inhibiting effect of crusting. Liljedahl (22) used Krilium as a soil conditioner in an attempt to reduce the surface crust. At the present time this problem has not been solved and is one of the remaining blocks to the solution of the emergence problem.

Depth of Planting

McBirney (23) reported that depth of planting is one of the most influential factors affecting the percentage of seedling emergence. He found that in the early part of the season plantings made at a depth of one inch produced significantly higher percentages of seedling emergence than deeper plantings of one and one half or two inches. Later in the season the reverse was found to be true.

McBirney explained that on the early planting moisture from precipitation had been sufficient so that moisture was not a limiting factor. Since the weather and soil were cooler, germination was slow and the deeper seedlings lacked enough vigor to reach the surface. However, towards the latter part of the planting season the soil had warmed up considerably and moisture was very likely the limiting factor for seedling emergence. Since the soil moisture was usually higher at the one and one-half inch depth than at the one-inch depth, higher emergence resulted from the deeper planting late in the season.

The increases obtained by McBirney in his four year study not only represented larger numbers of seedlings to select in thinning, but also resulted in more uniform stands which were better adapted to mechanical thinning.

Other Factors

There are many other known but seemingly less important factors affecting germination that have not been discussed here. Such factors as soil organisms, soil structure, climatic factors, and light affect the germination of many seeds. For example, Crocker (7) reported that some seeds did not germinate in the absence of light while others are inhibited by light. Another group apparently germinates equally well with or without light. Sugar beets are thought to belong in the latter group (15).

It is obvious that there is still a great deal of uncertainty about the factors and interrelations between various factors affecting germination of seeds. As researchers accumulate more knowledge on the effect of various factors on germination the problem of obtaining uniform and high percentages of germination and emergence will gradually be solved.

The review of literature suggests many points worthy of further study. The author chose the following points because of their great influence on emergence as pointed out in the review of literature.

1. The effect of soil moisture content on the rate and percentage of emergence.

2. The effect of various compaction pressures and the interrelation between soil moisture and soil compaction on emergence.

INVESTIGATION

Effect of Soil Moisture on Emergence

Objectives

An experiment was designed to study the effect of soil moisture on sugar beet emergence. The objectives of this laboratory experiment were as follows:

1. To determine the range of soil moisture that will produce satisfactory percentages and rates of emergence.

2. To determine the effect of adding a small amount of water to those seeds which had failed to emerge due to lack of soil moisture.

This experiment was designed so that the results could be compared with those obtained by previous researchers working on this problem.

Method of Procedure

All plantings in the laboratory were made in Brookston sandy clay loam at moistures ranging from six to twenty-seven percent of the oven dry weight of the soil. In order to insure homogeneity enough soil was obtained at one location for use in all laboratory work reported in this thesis.

The soil was first put through a one-fourth inch mesh screen to remove all clods, stones, roots, and other foreign material. It was then stored and allowed to dry.

When preparing for planting the air dry soil was again screened through a U. S. number sixteen screen having fourteen meshes to the inch. This provided a fairly homogeneous soil which insured uniform soil moistures.

The soil moisture content was adjusted to the desired level by placing approximately 1200 grams of air dry soil in a gallon jar. It was found that the moisture content of the air dry soil varied from one and one half to two percent. Enough water was added to bring the soil in the jar to the desired moisture content. It was recognized that in the lower range moisture movement through the soil was very slow. The jars were tightly sealed and allowed to sit approximately 24 hours. In this time the gravitational water had filled a portion of the soil to field capacity. The jars were then thoroughly shaken and allowed to sit another 24 hours. Shaking the jars caused that portion of the soil that was at field capacity to be dispersed throughout the sample. Thus a small amount of capillary action would provide a uniform moisture sample. The shaking process was carried out twice making a total of three days to prepare the soil. This procedure proved to be quite effective in obtaining uniform moistures, although it was rather time-consuming. Figure 1 shows several jars of soil being prepared in this manner.

After the soil and water had been mixed three days approximately three-fourths pound (three hundred forty grams) of wet soil was placed in a plastic box. Clear plastic sandwich boxes measuring 4 3/4 x 4 3/4 x 1 1/4 inches with tight fitting lids were used.

Fig. 1. Soil being prepared at various moisture contents.

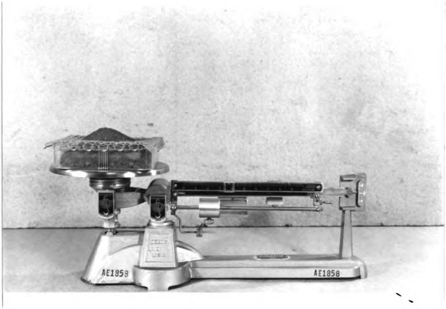

Fig. 2. Plastic box being filled with soil.

At moistures less than twenty percent a one-fourth inch screen was placed over the box to take out any large clods that had formed in the jar. Figure 2 shows a plastic box with screen being filled with soil.

At higher moistures the screen was not used because of the difficulty in getting the soil to pass through it. Also, it was not considered necessary since the clods were soft and easily broken.

Each jar contained enough soil to fill three boxes. After the boxes were filled a soil sample was taken and its moisture content determined on an oven dry weight basis.

After the soil was placed in the box it was leveled off and compacted with a five pound weight and a piece of plywood as shown in Figure 3.

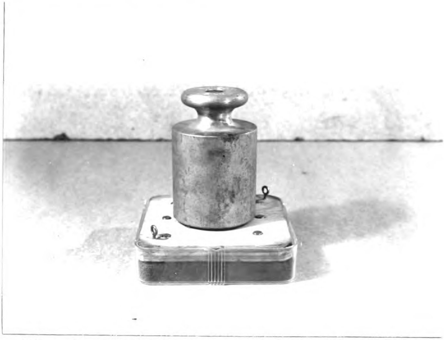

Fig. 3. Soil being compacted with a five-pound weight.

Nails had been driven through the plywood and sawed off to form the pattern for planting seeds shown in Figure 4.

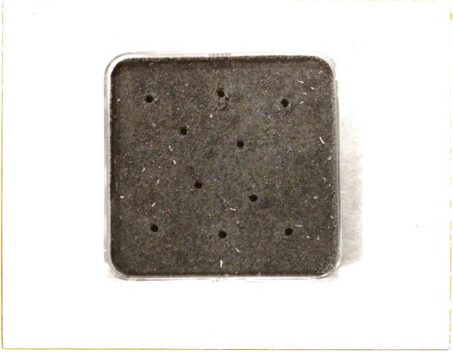

Fig. 4. Pattern in which seeds were planted in soil moisture experiment.

Figure 5 shows the U.S. 400 whole seeds placed in the holes ready to be pressed down and covered with soil.

The nails made holes one-fourth inch deep. The device shown in Figure 6 was used to push the seed three-eighths inch into the soil. This placed each seed so that it had at least a three-fourths inch cube of soil from which to draw moisture.

Each seed was covered by pushing soil over it from the surrounding area. The soil was compacted slightly in this

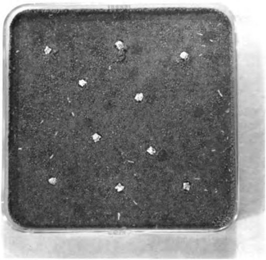

Fig. 5. U. S. 400 sugar beet seeds ready to be pressed into the soil.

Fig. 6. Device used for pushing seeds into the soil.

process, but an attempt was made to apply the same amount to each seed.

A weight record was kept on each box in order to determine how much moisture was lost. Although the boxes had tight fitting lids there was some evaporation. This could have been prevented by taping the lids on the boxes but it was felt that some air transfer was desirable in order that the germination and emergence process would not be seriously affected by lack of oxygen.

Figure 7 shows the rate of evaporation from the boxes. Seven days after planting the moisture content in the boxes had dropped approximately one percent. It may be seen that the rate was very nearly the same for all boxes.

Because of the change in moisture content of the boxes during the experiment it was necessary to arbitrarily select the moisture content at a certain time as being representative of that under which the seedlings developed. The moisture at planting time was selected for use in all cases.

Experimental Work

This experiment involved a total of 69 boxes with ten U. S. 400 whole sugar beet seeds planted in each box. The temperature ranged from 60 to 70 degrees Fahrenheit during the experiment. A daily record was kept of the number of seeds from which one or more seedlings emerged. (Table VII in the Appendix.) A seedling was considered to be emerged

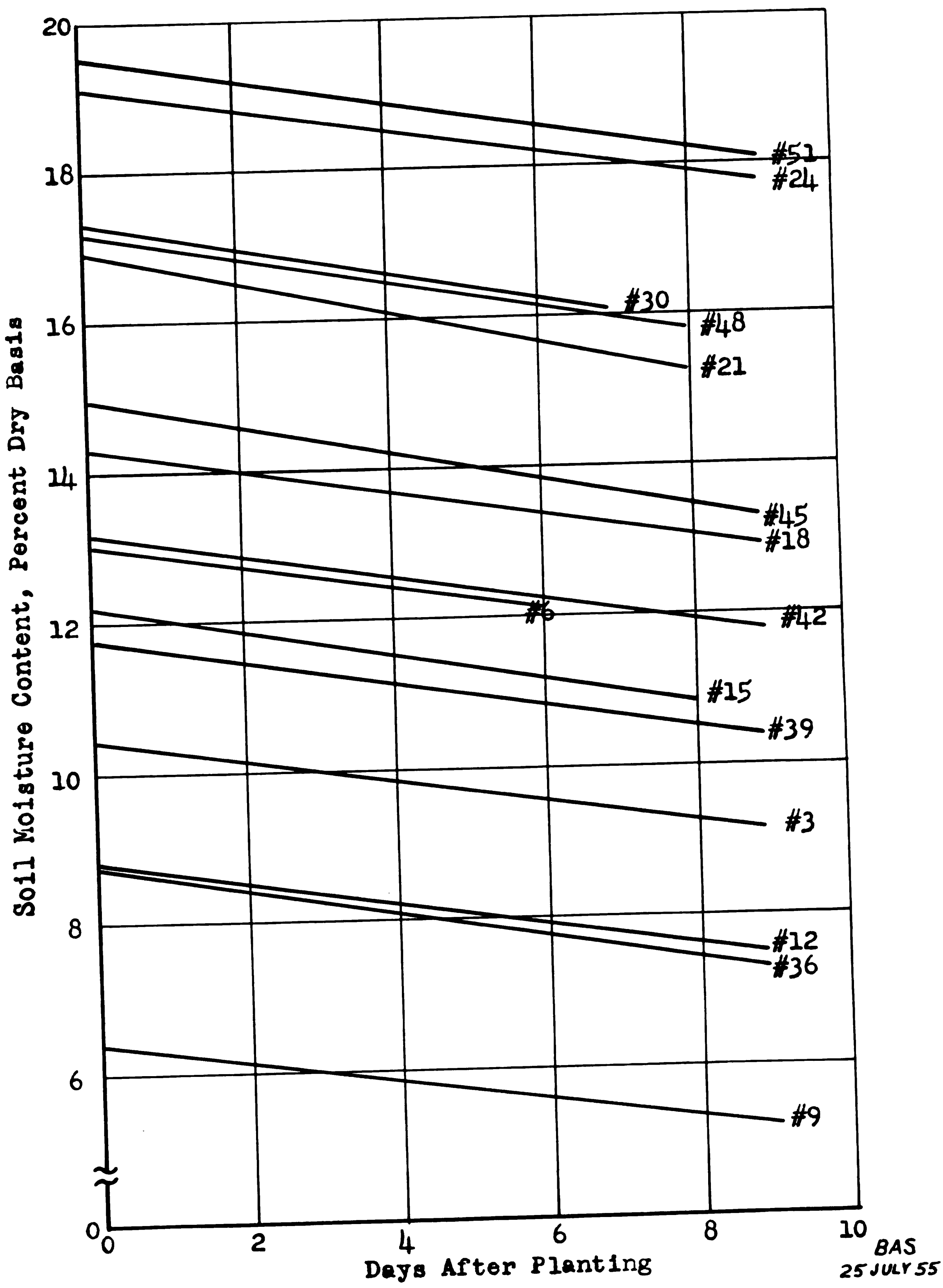

Fig. 7. Rate of evaporation from boxes of soil.

when the hypocotyl first could be observed breaking through the soil. It was not possible to keep this record much longer than ten days after planting because the first plants that emerged had withered and died in this time. This was probably due to the lack of oxygen in the boxes.

Figure 8 shows how the soil moisture content affected the percentage emergence. This curve represents the emergence seven days after planting time and is based on the moisture content at planting time. It shows the optimum range of soil moisture to produce emergence to be from 12 to 21 percent. In this range slightly over 90 percent emergence was obtained. However, at moistures less than 12 percent or more than 21 percent the emergence dropped off sharply. Only a relatively small number of tests were made using moistures above 21 percent since it would not be practical to plant in soil that wet.

It is important to note the sharp dividing line between soil that was too dry and soil that produced satisfactory emergence. The transition occurred between 11 and 12 percent soil moisture.

The analysis of variance of these data is shown in Table VIII in the Appendix. As would be expected the "F" test shows a highly significant difference between the various moisture levels. The "t" test was made to determine the mean difference required for significance. The results of the "t" test are shown in Table III.

TABLE III

EFFECT OF SOIL MOISTURE ON SUGAR BEET EMERGENCE

LABORATORY EXPERIMENT, 1955

Soil Moisture Content at Planting Time, Percent	Average Emergence, Percent	
6.4	0.0	Highly significantly
8.7	3.3	lower emergence than
8.8	0.0	in optimum range
10.4	6.7	
11.9	73.3	Sign. lower than opt.
12.2	76.7	
12.9	93.3	
13.0	93.3	
13.2	70.0*	Range of soil
14.8	90.0	moisture for
16.0	93.3	optimum emergence*
16.8	96.7	
16.9	80.0	
18.4	83.3	
19.4	80.0	
19.9	93.3	
20.2	70.0*	
20.8	93.3	
21.2	96.7	
21.6	83.3	
23.8	53.3	Highly significantly
24.4	53.3	lower emergence than
26.4	6.7	in optimum range

*Because one replication ran very low these two moistures produced significantly lower emergence at the five percent level; there was no significant difference in emergence in the range of optimum soil moisture at the one percent level.

With two exceptions which appear to be sampling freaks there was no significant difference in emergence in the moisture range from 12.2 to 21.6 percent.

The rate of emergence may be equally as important as percentage. It is desirable to get the plant up and started growing as soon as possible after planting. The very serious problem of crusting is reduced by fast emergence. Also, yields are increased by getting an early start. Figure 9 shows emergence rates at various soil moistures. Again it is to be noted that the middle range of moistures studied produced the best results. Slower rates of emergence were noted both in very dry and very wet soil.

The effect of various soil moistures on rate of emergence is perhaps shown better in Figure 10, which shows the number of days required to reach 50 percent emergence. The curve shows definitely that soil moistures ranging from 15 to 22 percent produced faster emergence. An advantage of as much as four days was gained by raising the moisture content of the soil from 10 percent to 15 percent.

Since a definite minimum soil moisture for satisfactory emergence had been established it seemed practical to apply water to the soil in order to raise its moisture content above the critical point. It was observed that many seeds had germinated but failed to emerge because of lack of moisture.

Six boxes of seed planted in the previous experiment failed to show any emergence after nine days. On the ninth

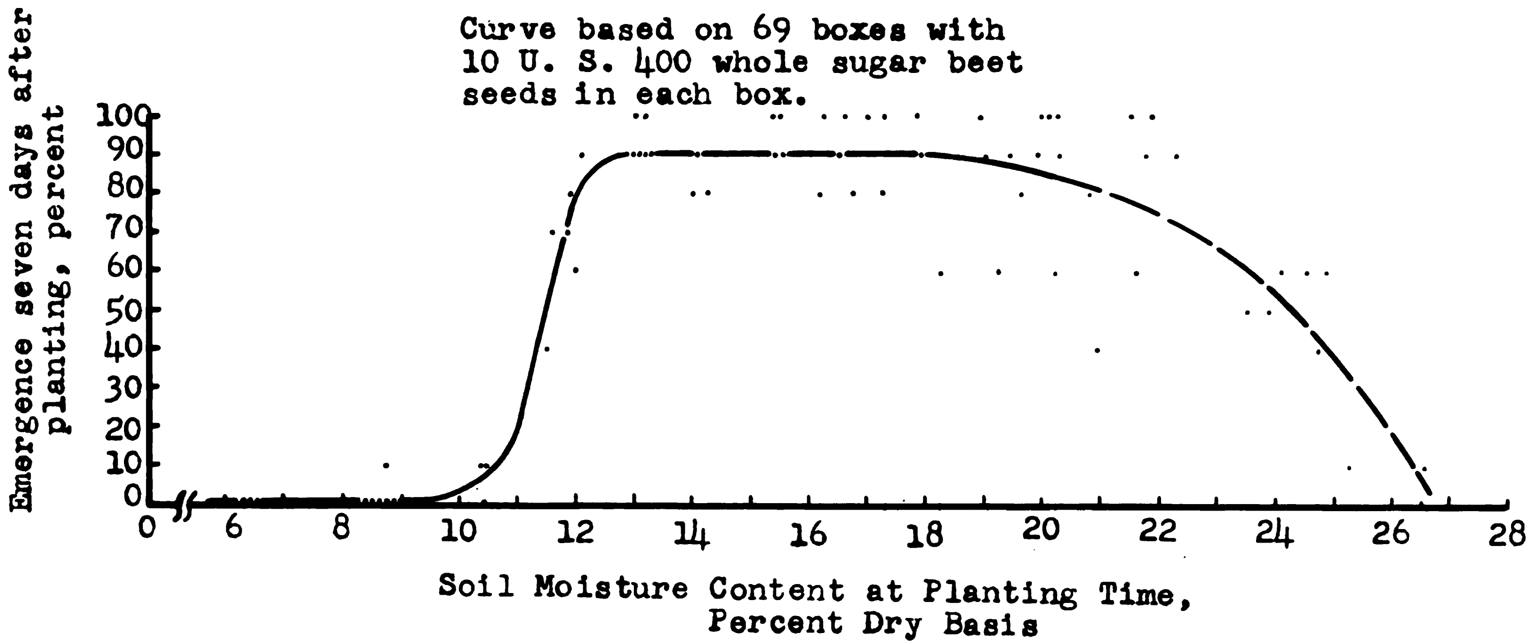

Fig. 8. Effect of soil moisture on sugar beet emergence in the laboratory.

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U. S. 400 Whole Seed

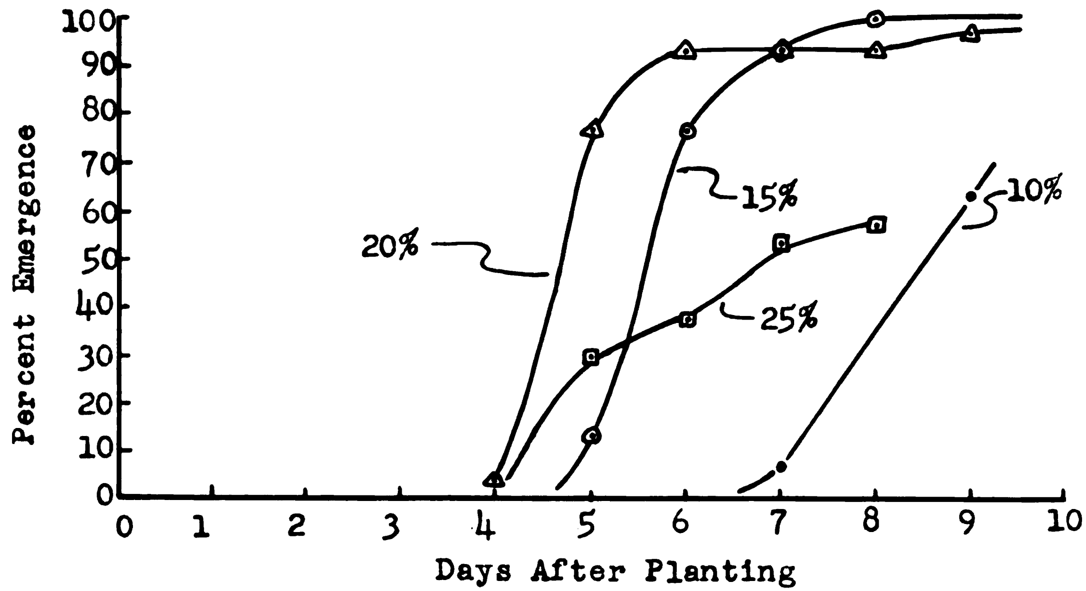

Fig. 9. Rate of emergence of sugar beets in soils of various moisture contents.

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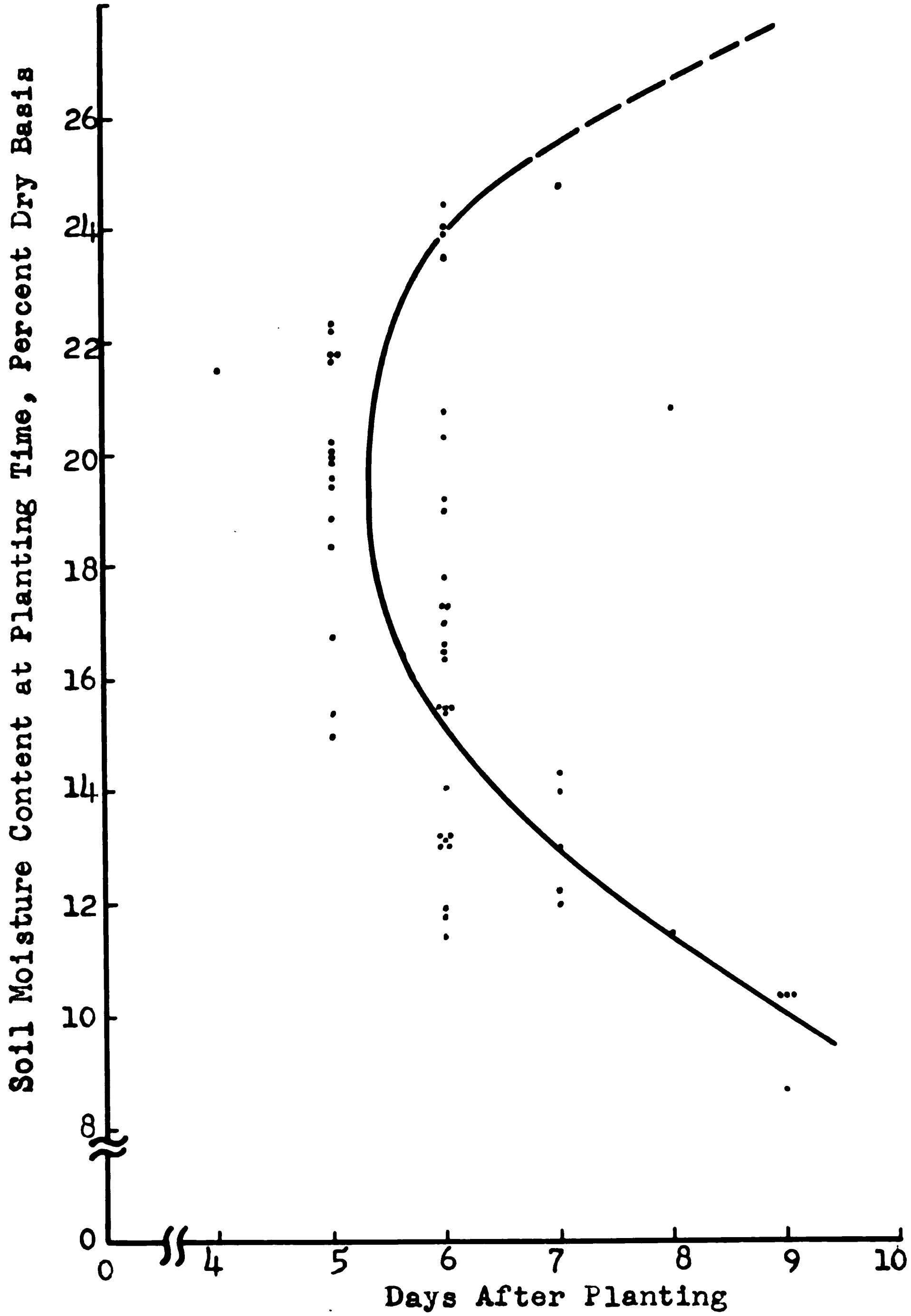

Fig. 10. Time required for sugar beets to reach fifty percent emergence.

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day two cubic centimeters of water were added to each of the four corner seeds in three boxes of soil at 6.4 percent moisture at planting time. The other three boxes containing soil which was at 8.8 percent moisture at planting time had one cubic centimeter of water added to each corner seed. The effect of this added moisture is shown in Table IV.

Table IV shows that 66.7 percent of the seeds to which water was added had emerged within six days after the water was applied. The remaining 33.3 percent had germinated but were unable to penetrate the heavy crust which formed over the seeds. None of the seeds which had no added water had emerged in fifteen days after planting.

This limited scale experiment indicated that it was possible to increase emergence considerably by applying a small quantity of water to the seed. Because of the beneficial effect of adding water to the seed in the laboratory it seems logical to devise a method whereby under dry soil conditions water could be added to the seed in the field to improve emergence.

Discussion of Results

The effect of soil moisture was found to be a very important factor influencing sugar beet emergence. Soil moistures ranging from 12 to 21 percent produced high percentages and rates of emergence.[1] Above and below this range there

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[1]The range of soil moisture which produced satisfactory emergence agrees closely with that found by Hunter and Dexter (17) who reported that U.S. 215 X 216 sugar beet seeds germinated only in soil moistures ranging from 12 to 20 percent.

TABLE IV

EFFECT OF WATER ADDED TO SEEDS THAT FAILED TO

GERMINATE DUE TO LACK OF SOIL MOISTURE

Soil Moisture at Planting Time, Percent	Water Added, cc/seed	Days After Planting									
		11		12		13		14		15	
		Emerged	Pushing up Soil	Emerged	Pushing up Soil	Emerged	Pushing up Soil	Emerged	Pushing up Soil	Emerged	Pushing up Soil
6.4	2	0	0	0	0	0	1	1	0	1	1
6.4	2	0	0	0	0	1	0	2	1	3	1
6.4	2	0	0	0	0	0	0	0	1	2	1
8.8	1	0	0	2	2	2	2	3	1	3	1
8.8	1	0	0	0	2	2	2	3	1	3	1
8.8	1	0	0	3	0	3	1	4	0	4	0

was a sharp drop-off. The drop-off is shown clearly in the series of photographs in Figure 11. The photographs in the top row, taken four days after planting, show no emergence although one seed in the soil at 12 percent moisture was beginning to push up the soil. In the second row, taken five days after planting, there was no emergence in the soils at 8 and 23 percent moisture, but the soils at 12 and 18 percent moisture showed high percentages of emergence. In the third row, taken six days after planting, there was still no emergence in the soil at 8 percent moisture and only one seedling in the soil at 23 percent moisture. All seeds in the area photographed had produced seedlings in the soils at 12 and 18 percent. In the bottom row, taken seven days after planting, there was little change from the sixth day. These results were typical of the results obtained throughout the soil moisture experiment.

The results obtained in this laboratory experiment were not expected to be exactly comparable to field conditions. The laboratory work was carried out using closed containers where evaporation rates were held to a minimum. The depth of planting was less than would normally be used in the field. The purpose of the experiment was to obtain basic data on the effect of moisture on emergence. To do this it was necessary to work under controlled conditions which would not be possible in the field. Further investigation is necessary to adapt this study to field conditions.

Fig. 11. Effect of soil moisture on sugar beet emergence four, five, six, and seven days after planting.

Effect of Soil Compaction on Emergence

Objective

The object of the laboratory compaction experiment was to determine the effect of soil compaction on sugar beet seedling emergence over the range of soil moistures commonly encountered at planting time.

Method of Procedure

Soil for the laboratory compaction experiment came from the same location and was prepared in the same manner as in the moisture experiment. The procedure used for adjusting the soil moisture to the desired level was also the same.

A compressed air operated compaction device was used to apply the desired pressures to the soil. This device was designed and built by George W. French of the U.S.D.A. Sugar Beet Machinery Project in Michigan. Figure 12 shows this device along with a scale which was used to measure the total force applied to the soil. An aluminum foot was used throughout the experiment to apply pressures to the soil over an area four inches square. Thus, a force of sixteen pounds on the scale represented a pressure on the soil of one psi. This means of measuring pressure was more accurate than a pressure gage would have been. Also, the friction in the cylinder could be neglected since the force measured was the actual force delivered to the soil surface.

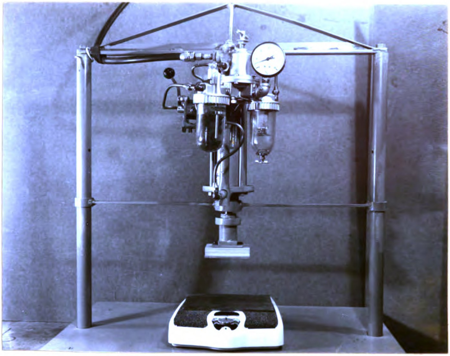

Fig. 12. Soil compacter operated by compressed air.

Approximately 150 grams of wet soil were placed loosely into a plastic box. Using an aluminum template sixteen seeds were placed in a three-inch square area in the box which made the seeds one inch apart.

An additional 150 grams of soil were placed over the seeds. The sample was then placed in the compaction device and the desired pressure applied. Pressures ranging from zero to thirty psi were applied to the soil in this experiment.

After planting the samples were placed in a darkened room where the temperature varied from 65 to 75 degrees Fahrenheit.

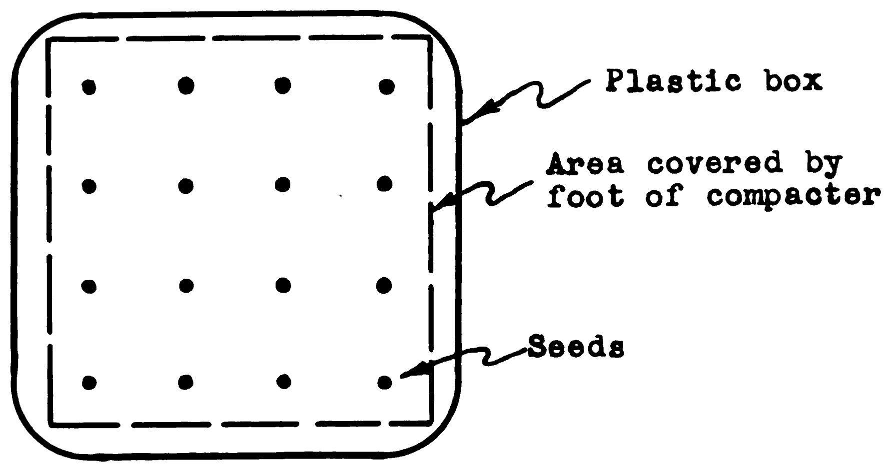

Fig. 13. Sketch showing pattern in which seeds were planted and area covered by the aluminum foot on the soil compacter.

Emergence counts were made each day to determine the percentage and rate of emergence. (Table IX in the Appendix)

Data were recorded for twelve days after planting at which time the samples were discarded and soil samples taken from each box. The moisture content was determined by oven drying and was used as a check on the moisture content determined at planting time. For all graphs the moisture content at planting time was arbitrarily chosen to represent the soil moisture content at which the seedlings developed.

Experimental Work - Part I

U. S. 400 decorticated seed was used for the first part of the investigation. An experiment using a two-way classification of variates with three replications was set up in the following manner.

Soil Moisture, Percent	Rep.	Soil Compaction, psi					
		0	2	5	7	10	15
11	1	--*	--	--	--	--	
	2	--	--	--	--	--	
	3	--	--	--	--	--	
15	1	--	--	--	--	--	--
	2	--	--	--	--	--	--
	3	--	--	--	--	--	--
20	1	--	--	--	--	--	
	2	--	--	--	--	--	
	3	--	--	--	--	--	

*Dashes indicate data taken

Fig. 14. Design of experiment to determine the effect of various soil compaction pressures at three moisture levels in the laboratory.

The results of this experiment are shown graphically in Figure 15. From this graph it is apparent that the higher moistures produced faster emergence. However, the effect of soil compaction is not clear.

The analysis of variance of the data obtained is shown in Table X in the Appendix. In order to simplify the analysis the data for 15 psi were omitted.

The effect of soil moisture on emergence was highly significant, but the effect of the various pressures was not significant. The results were the same for the data taken four, five, and ten days after planting.

It was rather surprising to find the effect of soil compaction not significant. A possible explanation for this

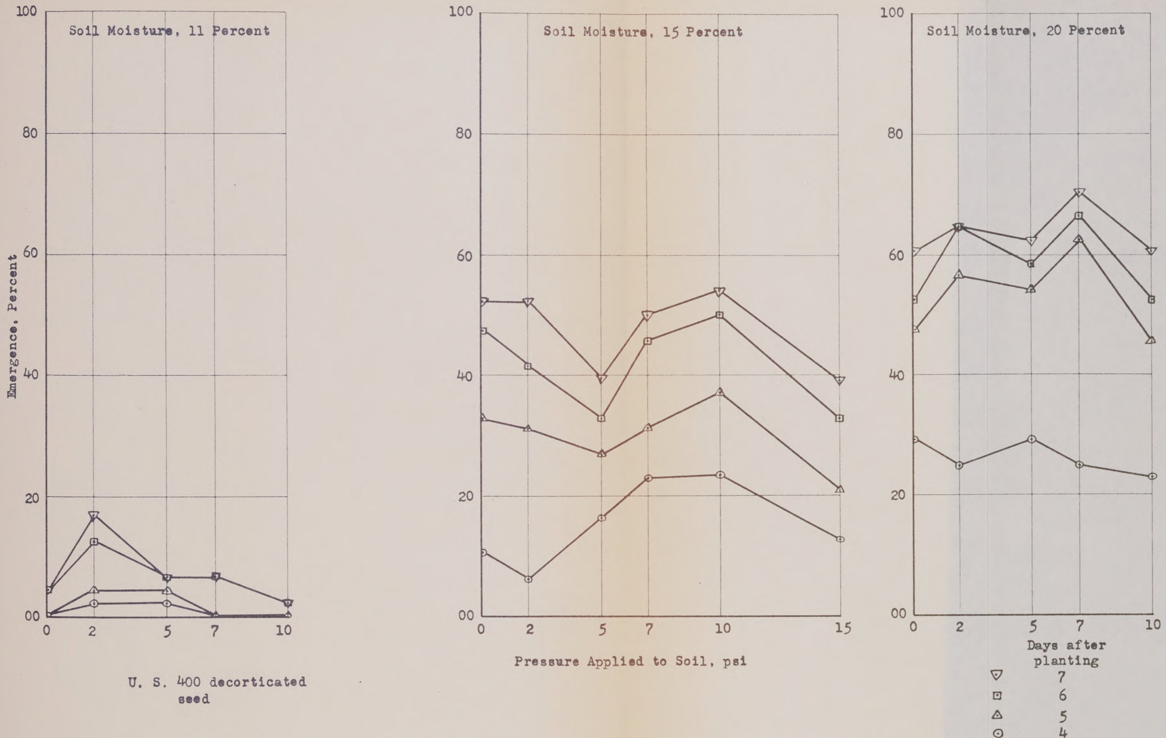

Fig. 15. Effect of soil compaction on sugar beet emergence, laboratory soil compaction experiment-part I.

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was that use of decorticated seed had introduced a variable that was not accounted for in the analysis. It was recognized that some seed germs were damaged in the decortication process and it was felt that this might possibly have affected the results obtained.

A germination test was run using five samples of twenty U.S. 400 decorticated seeds in each sample. The seeds were planted on blotters that were moistened daily. The temperature during the germination tests was the same as during the compaction tests. It varied from 65 to 75 degrees Fahrenheit. The results of this test are shown in Table V.

TABLE V

GERMINATION TESTS FOR U.S.400 DECORTICATED SUGAR BEET SEED USED IN THE COMPACTION EXPERIMENT-PART I

Replication	Days After Placing Seeds on Moist Blotter				
	2	3	4	6	7
A	7/20	11/20	11/20	13/20	13/20
B	9/20	16/20	17/20	17/20	17/20
C	9/20	12/20	15/20	15/20	16/20
D	12/20	16/20	16/20	16/20	17/20
E	7/20	12/20	13/20	13/20	13/20
Total	44/100	67/100	72/100	74/100	76/100

The above table shows a considerable variation between the five samples used in the germination test which further strengthens the theory that there may have been a variable present in the first part of the compaction experiment that was not accounted for.

Experimental Work - Part II

Due to the inconclusive results obtained it was decided to repeat the experiment using whole seed of an improved variety. First, a germination test identical to the one just described was run using U. S. 401 whole seed. The results are shown in Table VI.

TABLE VI

GERMINATION TESTS FOR U.S. 401 WHOLE SUGAR BEET SEED USED IN THE COMPACTION EXPERIMENT-PARTS II AND III

Replication	Days After Placing Seeds on Moist Blotter			
	4	5	6	7
A	6/20	12/20	20/20	20/20
B	10/20	18/20	19/20	19/20
C	12/20	17/20	17/20	17/20
D	9/20	16/20	19/20	20/20
E	6/20	15/20	18/20	19/20
Total	43/100	78/100	93/100	95/100

The above table shows a fairly uniform and high percentage of germination after the fifth day. It was felt that the more reliable seed would lessen the possibility of error in the experiment.

The data from part II of the compaction experiment in which U. S. 401 whole seed was used are given in Table XI in the Appendix.

The results are shown graphically in Figure 16. This graph indicates somewhat faster emergence caused by compaction pressures of two and five psi in the first few days after planting.

The analysis of variance of the data is shown in Table XII in the Appendix. As in part I of this experiment the effect of different soil moistures was highly significant for the entire experiment.

Soil compaction pressures of two and five psi produced significantly higher emergence on the fourth day after planting. The effect of compaction was similar on the fifth day although it was not statistically significant. On the sixth day a compaction pressure of two psi produced significantly higher emergence than pressures of seven, ten, and fifteen psi. This trend continued, but was not quite significant after ten days.

These results were not as expected. It seemed logical that in dry soils higher compaction pressures would give better seed-soil contact thereby permitting better transfer

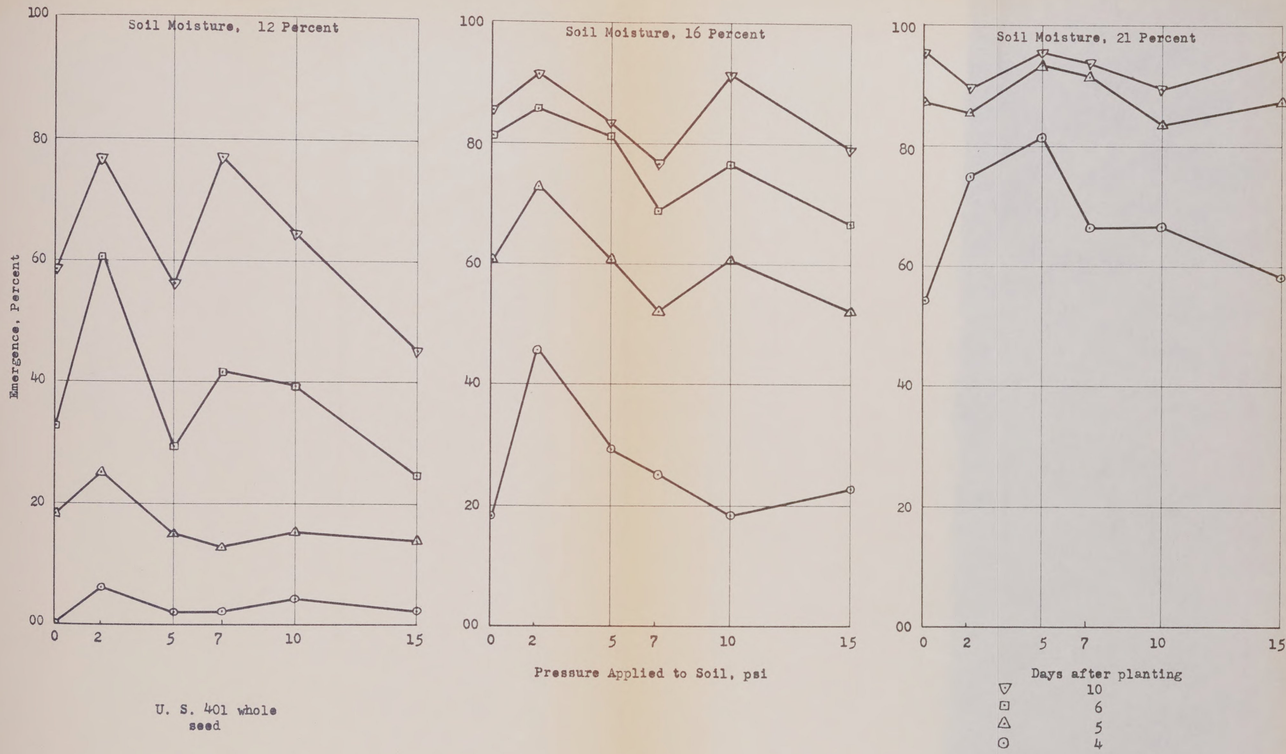

Fig. 16 Effect of soil compaction on sugar beet emergence, laboratory soil compaction experiment-part II

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of moisture to the seed which would produce better emergence. Also, in wet soils where moisture was no problem it was expected that high compaction pressures would cause decreased emergence due to poor aeration.

Referring to Figure 16 the general effect of soil compaction seems to be as follows. Pressures of two to five psi produced fastest emergence. No compaction caused a considerable drop-off in emergence, especially in the low and medium soil moistures. Pressures above ten psi produced definitely slower emergence in the medium and low moistures but slightly faster emergence in the soil at high moisture.

Experimental Work -- Part III

To verify this drop-off trend at higher compaction pressures and to determine why the drop-off did not occur in wet soils an experiment was designed using compaction pressures of two, fifteen, and thirty psi at three moisture levels.

The procedure used was the same as that used in parts I and II with one small change. The spring scale used to measure the compaction force had a range of zero to two hundred fifty pounds. In order to apply a pressure of thirty psi over a sixteen square inch area it was necessary to apply four hundred eighty pounds of force. A suitable scale having this range was not available so the system shown in Figure 17 was used. This in effect doubled the range of the scale making it possible to measure the four hundred eighty pound force.

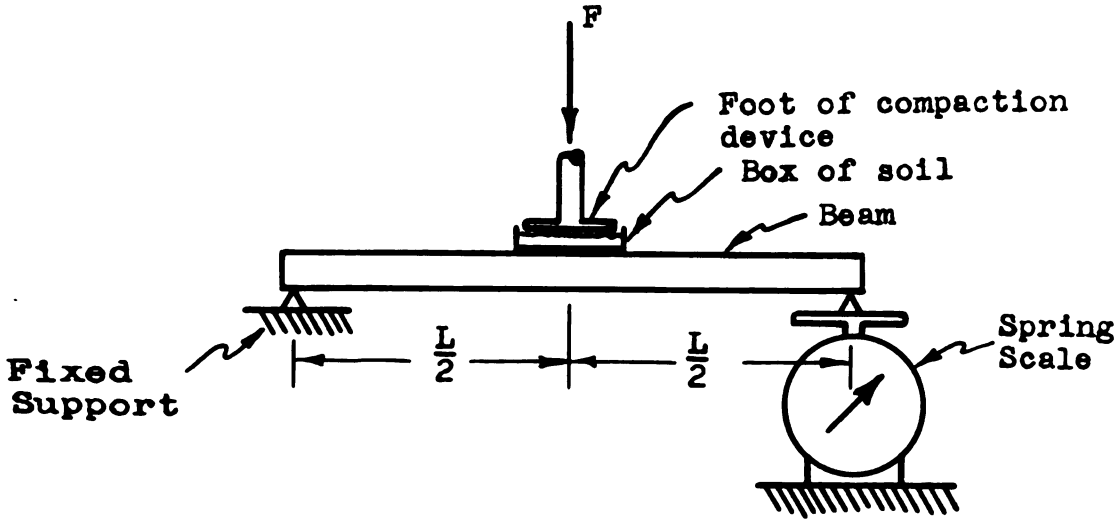

Fig. 17. Sketch of system used to measure force on soil in laboratory compaction experiment -- part III.

U. S. 401 whole seed was planted in 27 boxes with 16 seeds in each box. The data obtained in part III of the compaction experiment are given in Table XIII in the Appendix.

The results of this experiment are shown graphically in Figure 18. The effect of soil compaction in soils of low and medium moisture content was very definite. In both cases the higher pressures caused markedly decreased emergence. However, this effect was not apparent in soils at high moisture content.

An analysis of variance of the data obtained in part III of the compaction experiment is given in Table XIV in the Appendix. Because of the small number of samples the effect of compaction was not statistically significant until the sixth day after planting. The "t" test shows that a compaction pressure of two psi produced significantly higher

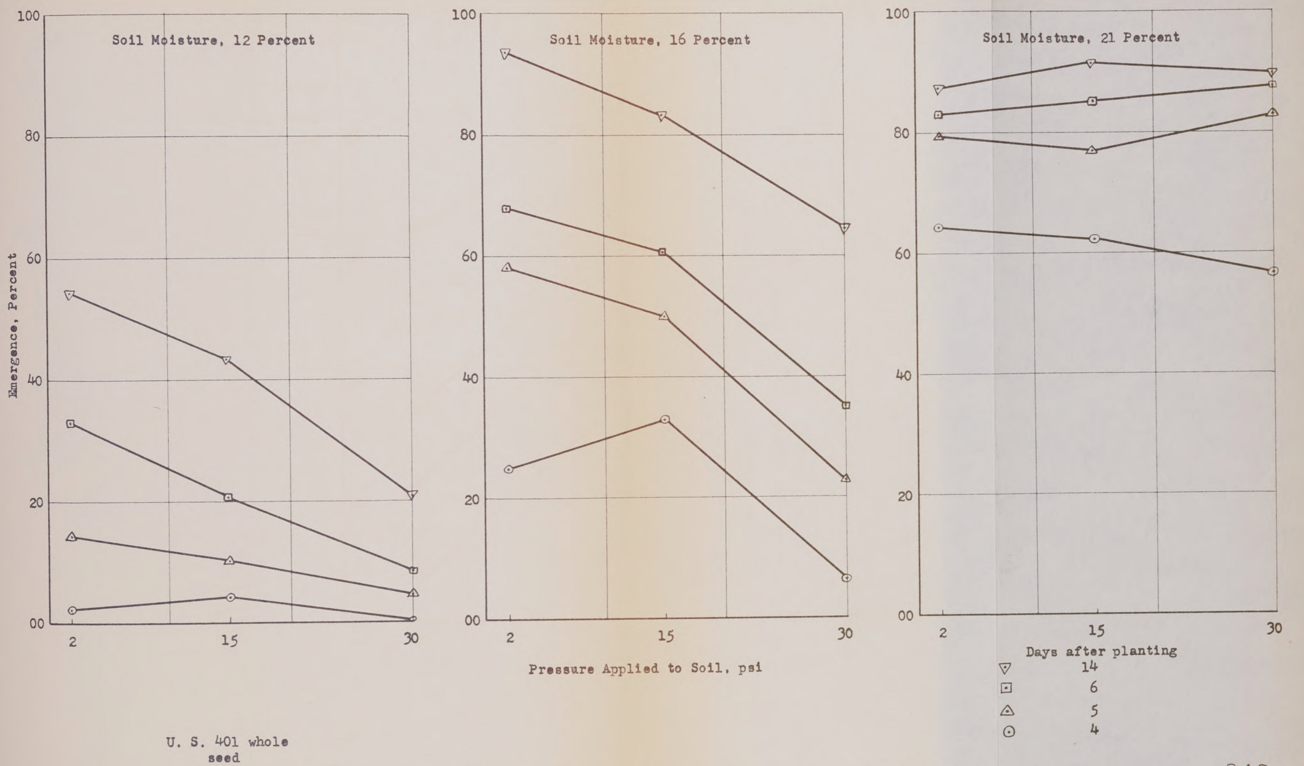

Fig. 18. Effect of soil compaction on sugar beet emergence, laboratory soil compaction experiment—part III.

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ence than thirty psi on the sixth day. By the four-
h day both two and fifteen psi produced significantly
r emergence than thirty psi.

ssion of Results

The results obtained in part I do not appear to yield information as to the effect of soil compaction on the beet seedling emergence. The statistical analysis d no significant difference in emergence using pressures zero to ten psi. Some of the variability between repli-ns was attributed to seed damage in the decortication ss.

Some definite trends were established in part II of this iment. The U. S. 401 whole seed used gave better agree-between replications. The statistical analysis showed ficantly higher emergence produced by compaction pres-of two psi on the fourth and sixth day after planting. e fifth day after planting this effect was not signifi- although the graphs of these data indicate the trend till the same. Ten days after planting the effect of ction had become not significant. It was felt that by time other factors such as lack of oxygen and growth ld and fungi were probably affecting emergence more the initial soil compaction.

The results of part III show essentially the same s indicated in part II of this experiment. Very definite decreases in emergence were noted for pressures of fifteen and thirty psi at the lower soil moistures. The harmful effect of higher pressures was statistically significant after the fifth day. However, in soil at 21 percent moisture, compaction pressures had very little adverse effect on emergence (Figure 18). The percentage emergence remained essentially constant over the entire range of two to thirty psi. These results cannot be fully explained at the present time.

Field Plantings

Objectives

A series of field experiments was designed to test the factors affecting sugar beet seedling emergence that were studied previously in the laboratory. Also, data on effect of various amounts of fertilizer applied with the seed at planting time and the interrelation of fertilizer and moisture were desired.

The object of this field investigation was to determine if the data obtained in the laboratory would hold true under field conditions where environmental factors could not be controlled. More specifically, the objectives were to test:

1. The effect of added moisture on sugar beet emergence in soils at several moisture contents.

2. The effect of various compaction pressures applied by the planter press wheels.

3. The effect of rates of fertilizer application with the seed, especially the interrelation between fertilizer rates and soil moisture required to produce satisfactory emergence.

Method of Procedure

An experiment was designed using a three-way classification of variates having three rates of added moisture, three rates of fertilizer, and three compaction pressures on the press wheels making a total of twenty-seven treatments. Each treatment was applied to one row one hundred feet in length and a check row was planted to correspond with each experimental row. Replications were obtained by making the desired number of one hundred inch stand counts along the one hundred feet of row. The number of beet containing inches were recorded since this is a good means of measuring uniformity of emergence and is the accepted method used for determining the proper cutting head for use in mechanical thinning (11). For each count made on an experimental row a count was made on the adjacent check row. The difference between these counts was attributed to the treatment. An analysis of variance was made to determine the significance of the results.

The planter used in these tests was that which has become known as the Michigan State College Experimental Sugar Beet Planter. This planter was designed and constructed by the Agricultural Engineering Department of Michigan State College in 1946 for use in testing various components of sugar beet planters. French (13) gave a more detailed description of the planter in his 1949 annual report. This planter is shown in Figure 19 as it was used in 1955.

Liljedahl (22) added a device for mechanically sterilizing a strip of soil for weed control in the row. This device was used in 1955, not for weed control, but to pulverize a layer of soil to act as a dust mulch to reduce moisture losses due to evaporation.

Fig. 19. Field planter with remote hydraulic cylinder removed.

A tank mounted on the planter was used to apply a small amount of water just ahead of the tube which deposited the seed. The laboratory investigation had indicated that a very small quantity of water applied to the seed had a great influence on emergence in soils at the critically dry level. Figure 20 shows the planter with the seed tube and attached water line removed from the planting unit. This method of applying the water did not interfere with the placement of the seed.

A cable and lever system similar to that used by French (13) was used to apply the desired forces to the press wheels. The cable with 2 five-pound weights on it can be seen in

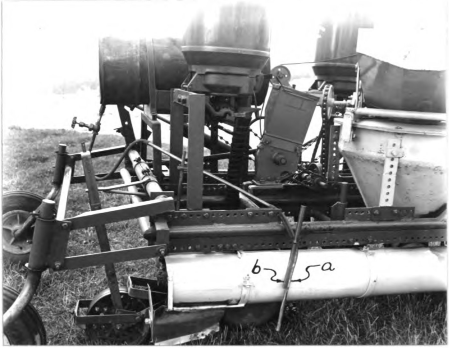

Fig. 20. Field planter showing (a) tube for placing a stream of water along the row with the seed, and (b) seed tube.

Figure 19. The cable was attached to a lever which rotated about the pipe across the rear of the planter, and produced a downward force on the press wheels (Figure 21). This system was designed so that a one-pound weight on the cable produced a six pound force on the press wheels in addition to the static load. It was felt that the effect of friction would be negligible when the machine was in operation due to the vibrations caused by the power take off driven centrifugal device used to pulverize the soil.

Plantings were made on May 9, May 23, and June 1. The May 9 planting served mainly the purpose of getting acquainted with the field planter and for working out a suitable technique for preparing the seed bed. The seed bed was prepared by

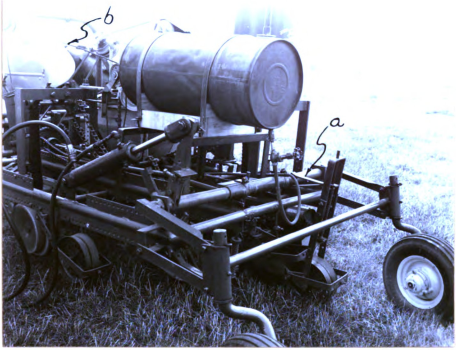

Fig. 21. Field planter showing (a) lever for applying force on press wheels, and (b) cable upon which weights were hung.

plowing and cultipacking in a once over operation using the machinery and methods worked out by Shustary.[1] This left the surface cloddy and uneven and did not produce a satisfactory seed bed for the purposes of this investigation.

Due to the many mechanical problems encountered only twelve treatments were applied on the first planting. No check row was planted so the data were not analyzed statistically.

In order to obtain a more even surface with fewer clods a different procedure was used for preparing the seed bed for the May 23 and June 1 plantings. First, the land was

[1]J. Shustary. Research in progress for M. S. degree.

plowed approximately six inches deep. It was then gone over with a Rotovator approximately three inches deep. This left too many clods on the surface so the Rotovator was used again at depth of one inch. This method produced a better seed bed for the purposes of this investigation than the once over operation used for the May 9 planting.

The mechanical soil sterilizer was used as means of pulverizing a strip of soil on the experimental row. This pulverized soil was replaced after the seed had been planted. It was hoped that the dust mulch would reduce moisture losses due to evaporation so that a beneficial effect might be obtained by adding a small amount of water to the seed during the planting process.

A continuous stream of water was applied to the row at rates of fifty and one hundred gallons per acre. The calibration was based on a constant travel speed of two miles per hour.

10-10-10 pulverized fertilizer was applied at rates of zero, one hundred, and two hundred pounds per acre. The fertilizer was applied in direct contact with the seed. Since the effect of fertilizer on emergence was being studied it was felt that this method would affect emergence most. To obtain zero rate of fertilizer application the fertilizer box was removed from the planter.

To obtain zero compaction the press wheels were removed from the planter. For the May 23 planting weights of five and ten pounds were hung on the cable producing forces of approximately one hundred fifty and one hundred eighty pounds respectively on the press wheels. Conventional concave press wheels set together were used on both the experimental and check rows. For the June 1 planting the press wheels were used with zero and five pound weights on the cable producing forces of one hundred twenty and one hundred fifty pounds respectively. The area of the press wheel in contact with the soil at any instant was estimated to be approximately ten square inches. Thus, compaction pressures of zero, twelve, fifteen, and eighteen psi were used.

The check row was the same as the experimental row except that no water or fertilizer was applied. The force on the press wheels was constant at approximately eighty pounds.

Experimental Work -- May 23 Planting

A complete experiment was planted on May 23 using U.S. 400 decorticated seed. The planter had been adjusted and some of the components revised to improve its performance. The field layout for this planting is shown in Figure 22.

The soil was very dry due to an unusually dry spring. There had been only 0.18 inch[1] of rain in the two-week period preceding planting. The average of three soil samples taken at planting time showed the soil moisture content to be 12.48 percent on an oven dry weight basis. The laboratory work

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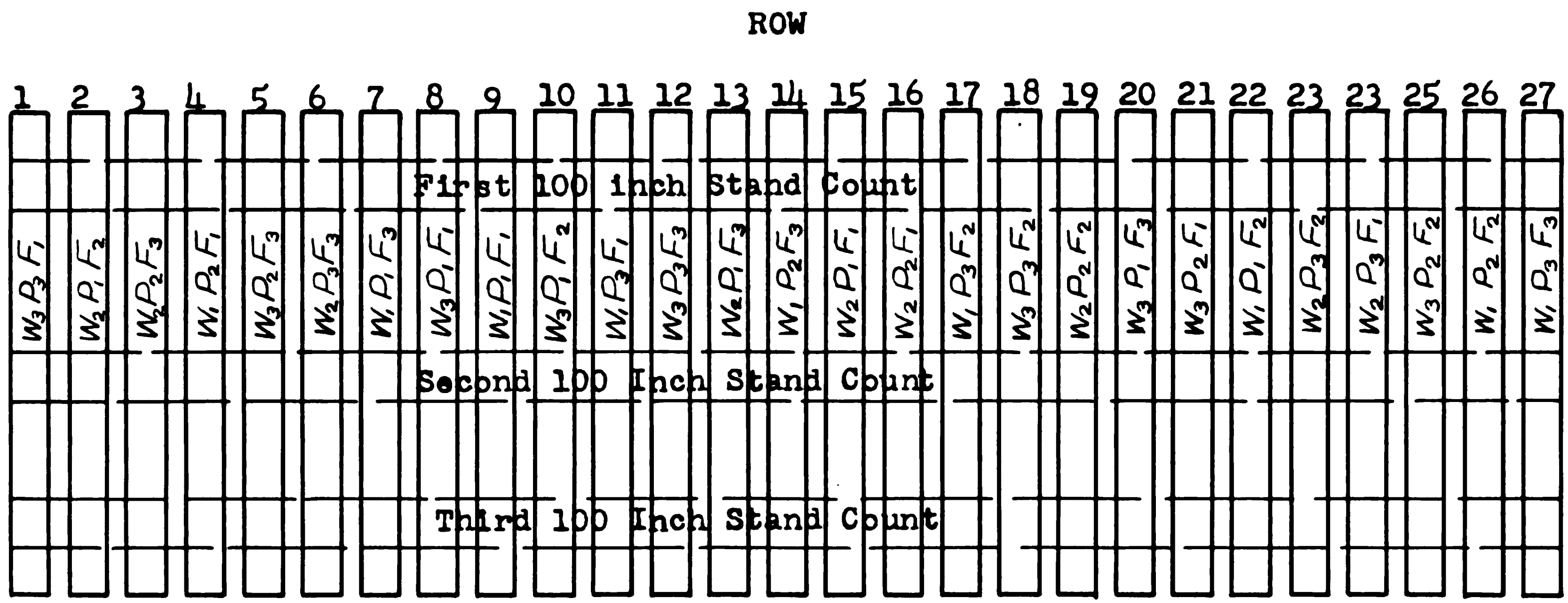
[1]Rainfall data from Michigan Hydrologic Research Station, A Cooperative Research Project of the Michigan Agricultural Experiment Station and Soil and Water Conservation Research Branch, Agricultural Research Service U.S.D.A.



Added Water		Force on Press Wheels		Fertilizer	
W_1	No water	P_1	No press wheels	F_1	No fertilizer
W_2	50 gal. per acre	P_2	150 pounds	F_2	100 lb. per acre
W_3	100 gal. per acre	P_3	180 pounds	F_3	200 lb. per acre

Fig. 22. Layout for May 23 field planting and stand counts.

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showed that this was near the lower limit of moisture required for satisfactory emergence. It was felt that this was an ideal time to test the effect of moisture added along with the seed. However, on May 24 there was 0.42 inch of rain which was probably sufficient to overcome any benefit gained by adding water. Following this there were rains of 0.46, 0.30, 2.71, 0.54, 0.72, 0.44 on May 28, June 6, 7, 9, 11 and 12 respectively. These heavy rains caused severe surface crusting with resulting low percentages of emergence.

Stand counts were made on June 16. Three one hundred inch counts were made on each experimental row and each check row. The average percentage of beet containing inches was 10.54 for the experimental rows and 9.68 for the check rows. The extremely unfavorable weather conditions account mainly for the unsatisfactory stands.

The data obtained are given in Table XV in the Appendix. An analysis of variance of the data was made to determine if the treatments had any effect on the emergence. (Table XVI in the Appendix).

Neither added moisture nor compactions produced any significant effect on the emergence. However, the 200 pounds per acre application of fertilizer produced highly significantly better emergence than no fertilizer. The increase was only 3.89 percent over the check row which does not seem to be of much consequence.

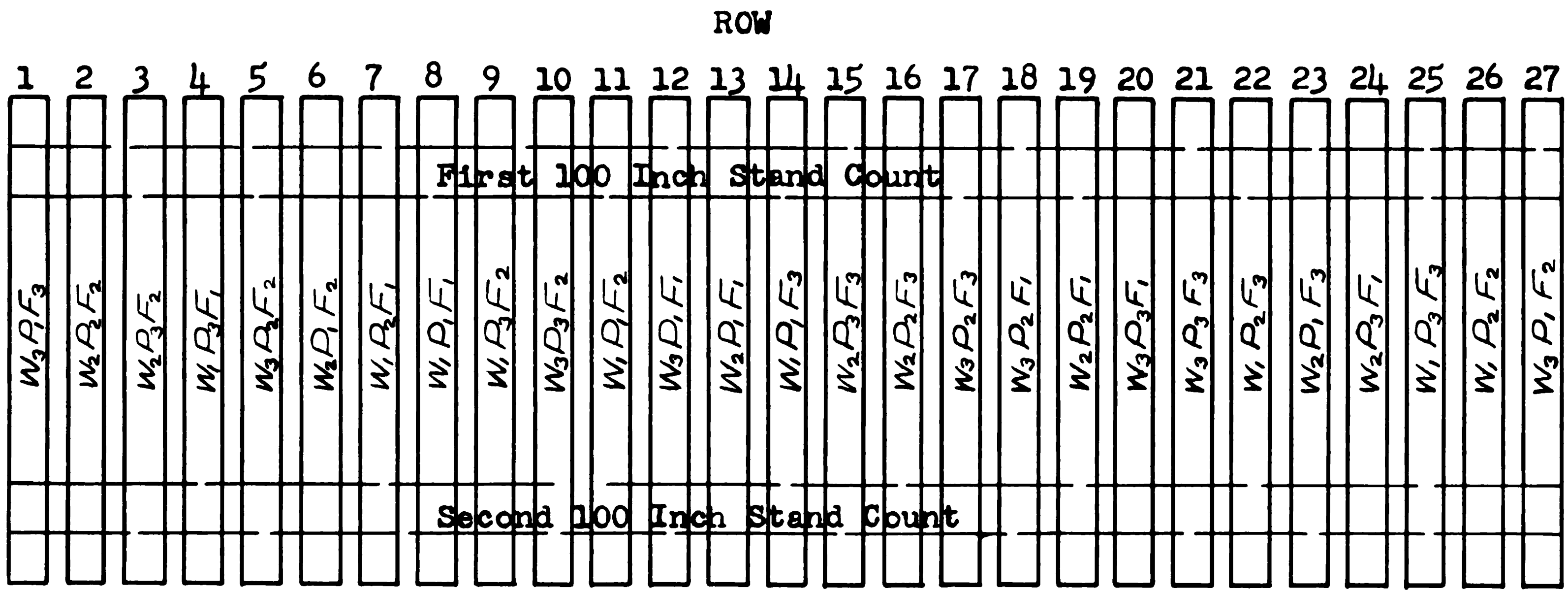
Experimental Work - June 1 Planting

The last planting was made on June 1. The soil moisture content was considerably higher than for the previous planting due to rains totaling almost one inch. The average of three soil samples showed that the soil moisture content was 19.89 percent. The seed bed for this planting was prepared in exactly the same manner as for the May 23 planting. The treatments used were essentially the same but were re-randomized. The field layout for the June 1 planting is shown in Figure 23.

No rain fell for five days after the June 1 planting. This was the desired condition for it was felt that if the effect of added moisture was to be evaluated it would be necessary to have no rainfall for several days after planting.

The weather conditions had been more favorable for this planting. The beets had had a chance to get started in the five days of no rain. The week or so of wet weather had kept a crust from forming. The soil had dried enough that stand counts were made on June 16. Two one hundred inch counts were made on each experimental row and each check row. (Table XVII in the Appendix) The experimental rows averaged 27.04 and the check rows 22.18 percent of beet containing inches.

An analysis of variance of these data is given in Table XVIII in the Appendix. The "t" test showed that added water at a rate of 100 gallons per acre produced significantly higher emergence than no added water. Also a force on the press wheels of 150 pounds produced significantly higher emergence than that obtained using no press wheels.



Added Water		Force on Press Wheels		Fertilizer	
W_1	No water	P_1	No press wheels	F_1	No fertilizer
W_2	50 gal. per acre	P_2	120 pounds	F_2	100 lb. per acre
W_3	100 gal. per acre	P_3	150 pounds	F_3	200 lb. per acre

Fig. 23. Layout for June 1 field planting and stand counts.

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Discussion of Results

Weather conditions after the May 23 planting virtually destroyed any effect that might have been caused by the treatments applied. Although the highest rate of fertilizer application produced statistically significantly better emergence than no fertilizer it is felt that the increase over the check row is insignificant from a practical standpoint.[1]

Weather conditions following the June 1 planting were more favorable for determining the effect of the various factors in this study on sugar beet emergence. Added moisture at rates of one hundred gallons per acre and a force of one hundred fifty pounds on the press wheels produced significantly higher percentages of emergence.

It is theorized that those seeds which had added moisture were able to germinate and start growing faster than those without added moisture. Even though a large amount of rain fell starting five days after planting the effect of added moisture was not lost.

The significantly higher emergence produced by a one hundred fifty pound force on the press wheels agrees closely with the results obtained by French (13) who found forces in this range produced best results with many different types of press wheels. The one hundred fifty pound force was equivalent

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[1]These results agree with the work of Frakes and Draher (12), Whitney et al (32), and Cook (5) who reported increased emergence when small amounts of fertilizer were placed in direct contact with the seed.

to a compaction pressure of approximately fifteen psi. It is important to note that this pressure did not produce the best emergence in the laboratory.

The laboratory investigation, conducted under conditions somewhat different than encountered in the field, showed the best emergence at compaction pressures from two to five psi. Since this was apparently the compaction pressure which caused the seed to react best, it follows that more pressure was required in the field to produce the desired environmental conditions. The higher pressure requirement may be due to the presence of clods, organic material, and other foreign material.

CONCLUSIONS

Laboratory Work

1. U.S. 400 whole sugar beet seed showed good emergence, under the conditions investigated, only in the range of soil moisture from twelve to twenty-one percent.

2. The addition of one or two cubic centimeters of water to individual seeds produced a marked increase in emergence in soils near the lower limit of moisture required for germination.

3. Compaction pressures above two psi had very little beneficial effect and in many cases had a harmful effect on emergence in soils at twelve and sixteen percent moisture.

4. Compaction pressures from two to thirty psi produced no significant differences in emergence in soil at twenty-one percent moisture.

5. The effect of soil moisture was highly significant throughout the soil compaction experiment.

Field Work

1. An increase in emergence of approximately seven percent over the check row was obtained by adding water to the seed at planting time at a rate of one hundred gallons per acre.

2. A force of approximately 150 pounds on the planter press wheels produced significantly better emergence than when no press wheels were used and pulverized soil was placed loosely over the seed.

3. In a field planting which was followed by heavy rains, the effects of added moisture and compaction were not significant, while 200 pounds per acre of 10-10-10 fertilizer placed with the seed produced significantly higher emergence. Weather conditions following planting apparently had a great deal of influence on the results obtained.

APPENDIX

TABLE VII

EMERGENCE DATA FOR SOIL MOISTURE EXPERIMENT

IN LABORATORY, 1955

Box Number	Soil Moisture Content at Planting Time, Percent (Corrected)*	Percent Emergence Days After Planting					
		4	5	6	7	8	9
1	10.4			00	00	-	60
2	10.4			00	10	-	60
3	10.4			00	10	-	70
4	13.0			40	90	-	100
5	13.0			60	90	-	100
6	13.0			50	100	-	100
7	6.4			00	00	00	00
8	6.4			00	00	00	00
9	6.4			00	00	00	00
10	8.8			00	00	00	00
11	8.8			00	00	00	00
12	8.8			00	00	00	00
13	12.0			10	60	60	80
14	14.0			00	80	90	90
15	12.2			60	90	100	100
16	14.1			50	90	100	100
17	11.5			00	40	60	80
18	14.3			40	80	80	80
19	16.5			50	90	90	90
20	16.6			90	100	100	100
21	17.0			70	100	100	100
22	20.8		30	80	80	80	80
23	20.3		40	80	90	90	90
24	20.9		10	30	40	60	60
25	19.0		30	80	90	90	90
26	18.9		60	100	100	100	100
27	19.2		30	50	60	60	80
28	17.8		40	90	100	100	100
29	17.3		20	60	80	80	80
30	17.3		00	80	100	100	100
31	15.5		10	80	90	100	100
32	15.5		10	70	100	100	100
33	15.5		20	80	90	100	100
34	8.7		00	00	00	10	20
35	8.7		00	00	00	00	10
36	8.7		00	00	10	40	50
37	11.9		10	60	80	90	90
38	11.6		00	60	70	80	90

TABLE VII (Cont.)

Box Number	Soil Moisture Content at Planting Time, Percent (Corrected)*	Percent Emergence					
		Days After Planting					
		4	5	6	7	8	9
39	11.8		00	60	70	80	80
40	13.2		10	90	100	100	100
41	13.1		00	70	90	90	90
42	13.2		20	80	90	100	100
43	15.4		60	80	90	90	90
44	15.4		40	90	100	100	100
45	15.0		50	80	80	80	80
46	16.7	00	50	70	80	80	80
47	18.3	00	50	60	60	60	60
48	16.3	00	10	70	100	100	100
49	20.1	00	90	100	100	100	100
50	20.0	10	80	100	100	100	100
51	19.6	00	60	80	80	80	90
52	21.5	50	80	100	100	100	100
53	21.8	00	50	50	60	80	80
54	21.7	00	90	90	90	90	90
55	24.1	00	40	50	60	60	60
56	23.9	10	30	50	50	50	60
57	23.5	00	30	50	50	50	60
58	20.2		50	60	60	60	
59	19.9		90	90	90	90	
60	19.4		80	80	90	100	
61	22.2		90	90	100	100	
62	22.3		70	70	90	90	
63	21.8		70	80	100	100	
64	24.8		30	30	60	70	
65	24.7		20	30	40	40	
66	24.5		40	50	60	60	
67	26.6		00	00	10	10	
68	27.0		00	00	00	00	
69	25.3		00	00	10	10	

*The soil moisture content at planting time was determined by oven drying a sample from each jar; the moisture content determined by a sample from each of the three boxes of soil taken from one jar after completion of the experiment was used to correct the moisture content at planting time.

TABLE VIII

STATISTICAL ANALYSIS OF SUGAR BEET EMERGENCE,

SOIL MOISTURE EXPERIMENT

1955

Analysis of Variance,
Seven Days After Planting

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	"F"
Total	68	901.3		
Between	22	820.6	37.30	21.3**
Within	46	80.7	1.75	

$$\sigma(M_i - M_j) = \sqrt{1.75 \quad (1/3 + 1/3)} = 1.08$$

$$\text{LSD} = (t)(\sigma) = 2.90 \text{ @ } 1\% \text{ level}$$

$$= 2.18 \text{ @ } 5\% \text{ level}$$

** Indicates significant difference in emergence due to moistures at one percent level

TABLE IX

EFFECT OF SOIL COMPACTION ON EMERGENCE, DATA FROM LABORATORY EXPERIMENT-PART I, APRIL 22, 1955

Soil Moisture, Percent	Compaction Pressure, psi	Percent Emergence Days After Planting 3	4	5	6	10
11	0		0.0	0.0	0.0	0.0
	0		0.0	0.0	12.5	18.8
	0		0.0	0.0	0.0	0.0
	2		0.0	0.0	6.2	12.5
	2		6.2	6.2	18.8	25.0
	2		0.0	6.2	12.5	12.5
	5		0.0	0.0	0.0	0.0
	5		0.0	6.2	6.2	6.2
	5		6.2	6.2	12.5	12.5
	7		0.0	0.0	0.0	0.0
	7		0.0	0.0	12.5	12.5
	7		0.0	0.0	6.2	6.2
	10		0.0	0.0	6.2	6.2
	10		0.0	0.0	0.0	0.0
	10		0.0	0.0	0.0	0.0
15	0	0.0	6.2	37.5	56.2	75.0
	0	0.0	6.2	31.2	43.8	43.8
	0	0.0	18.8	31.2	43.8	56.2
	2	0.0	0.0	25.0	37.5	50.0
	2	0.0	0.0	18.8	25.0	50.0
	2	0.0	18.8	50.0	62.5	68.8
	5	0.0	0.0	12.5	25.0	31.2
	5	0.0	18.8	18.8	18.8	31.2
	5	6.2	31.2	50.0	56.2	75.0
	7	0.0	12.5	18.8	31.2	37.5
	7	0.0	31.2	31.2	43.8	50.0
	7	18.8	25.0	43.8	62.5	62.5
	10	0.0	6.2	18.8	31.2	43.8
	10	6.2	37.5	50.0	56.2	68.8
	10	12.5	25.0	43.8	62.5	62.5
	15	0.0	6.2	12.5	25.0	31.2
	15	0.0	12.5	25.0	43.8	56.2
	15	6.2	18.8	25.0	31.2	37.5
20	0	0.0	18.8	37.5	37.5	43.8
	0	0.0	37.5	68.8	68.8	81.2
	0	0.0	31.2	37.5	50.0	56.2
	2	6.2	18.8	50.0	50.0	50.0
	2	6.2	18.8	43.8	62.5	62.5
	2	25.0	37.5	75.0	81.2	81.2
	5	6.2	18.8	50.0	50.0	62.5
	5	6.2	31.2	50.0	62.5	68.8
	5	12.5	37.5	62.5	62.5	62.5
	7	0.0	6.2	56.2	56.2	75.0
	7	6.2	31.2	56.2	68.8	75.0
	7	12.5	37.5	75.0	75.0	75.0
	10	0.0	12.5	43.8	43.8	62.5
	10	0.0	31.2	56.2	56.2	56.2
	10	6.2	25.0	37.5	56.2	62.5

TABLE X

STATISTICAL ANALYSIS OF EFFECT OF SOIL COMPACTION ON EMERGENCE

LABORATORY EXPERIMENT-PART I 1955

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	"F"
	Analysis of Variance, Four Days After Planting			
Total	44	219.24		
Moisture	2	125.37	62.68	25.38**
Compaction	4	4.13	1.03	0.42
M x C	8	15.74	1.97	0.80
Error	30	74.00	2.47	
	Analysis of Variance, Five Days After Planting			
Total	44	640.31		
Moisture	2	517.91	258.95	75.72**
Compaction	4	2.98	0.74	0.22
M x C	8	16.75	2.09	0.61
Error	30	102.67	3.42	
	Analysis of Variance, Ten Days After Planting			
Total	44	856.80		
Moisture	2	713.20	356.60	93.84**
Compaction	4	7.02	1.76	0.46
M x C	8	22.58	2.82	0.74
Error	30	114.00	3.80	

** Indicates highly significant difference between treatments

TABLE XI

EFFECT OF SOIL COMPACTION ON EMERGENCE,
DATA FROM LABORATORY EXPERIMENT-PART II
May 16, 1955

Soil Moisture, Percent	Compaction Pressure, psi	Percent Emergence, Days After Planting				
		3	4	5	6	10
12	0		0.0	12.5	25.0	43.8
	0		0.0	25.0	37.5	68.8
	0		0.0	18.8	37.5	62.5
	2		6.2	31.2	37.5	56.2
	2		0.0	18.8	81.2	93.8
	2		12.5	25.0	62.5	81.2
	5		6.2	25.0	37.5	62.5
	5		0.0	25.0	31.2	56.2
	5		0.0	0.0	18.8	50.0
	7		6.2	25.0	43.8	75.0
	7		0.0	12.5	43.8	81.2
	7		0.0	6.2	37.5	75.0
	10		12.5	18.8	37.5	62.5
	10		0.0	6.2	37.5	68.8
	10		0.0	25.0	43.8	62.5
	15		0.0	18.8	18.8	31.2
	15		0.0	12.5	43.8	62.5
	15		6.2	12.5	12.5	43.8
16	0	6.2	37.5	87.5	93.8	93.8
	0	0.0	18.8	62.5	81.2	81.2
	0	0.0	0.0	31.2	68.8	81.2
	2	0.0	56.2	75.0	81.2	93.8
	2	0.0	56.2	87.5	87.5	93.8
	2	0.0	25.0	56.2	87.5	87.5
	5	0.0	37.5	75.0	81.2	81.2
	5	0.0	31.2	50.0	75.0	75.0
	5	0.0	18.8	56.2	87.5	93.8
	7	6.2	37.5	43.8	75.0	81.2
	7	0.0	25.0	62.5	75.0	81.2
	7	0.0	12.5	50.0	56.2	68.8
	10	0.0	25.0	50.0	68.8	87.5
	10	0.0	25.0	75.0	87.5	93.8
	10	0.0	6.2	56.2	75.0	93.8
	15	6.2	31.2	62.5	68.8	81.2
	15	0.0	18.8	50.0	62.5	75.0
	15	0.0	18.8	43.8	68.8	81.2

TABLE XI (Cont.)

Soil Moisture, Percent	Compaction Pressure, psi	Percent Emergence				
		Days After Planting				
		3	4	5	6	10
21	0	0.0	68.8	93.8	100.0	100.0
	0	0.0	37.5	75.0	87.5	93.8
	0	0.0	56.2	93.8	93.8	93.8
	2	6.2	75.0	81.2	87.5	93.8
	2	6.2	62.5	81.2	81.2	81.2
	2	0.0	87.5	93.8	93.8	93.8
	5	0.0	75.0	87.5	87.5	87.5
	5	6.2	93.8	100.0	100.0	100.0
	5	0.0	75.0	93.8	100.0	100.0
	7	6.2	81.2	93.8	93.8	93.8
	7	0.0	68.8	93.8	93.8	93.8
	7	0.0	50.0	87.5	93.8	93.8
	10	6.2	68.8	81.2	81.2	87.5
	10	0.0	62.5	68.8	81.2	81.2
	10	6.2	68.8	100.0	100.0	100.0
	15	12.5	62.5	93.8	93.8	93.8
	15	0.0	62.5	87.5	100.0	100.0
	15	0.0	50.0	81.2	87.5	93.8

TABLE XII

STATISTICAL ANALYSIS OF EFFECT OF SOIL COMPACTION ON EMERGENCE, LABORATORY EXPERIMENT--PART II 1955

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	"F"
	Analysis of Variance, Four Days After Planting			
Total	53	1156.82		
Moisture	2	971.15	485.57	165.72**
Compaction	5	50.60	10.12	3.45*
M x C	10	29.74	2.97	1.01
Error	36	105.33	2.93	

$$\sigma_{(P_i - P_j)} = \sqrt{2.93 \quad (1/9 + 1/9)} = 0.81$$

$$\text{LSD} = (2.03)(0.81) = 1.64$$

Conclusions from "t" test:

1. No significant difference between compaction pressures of 0, 7, 10, and 15 psi.

2. 5 psi produced significantly higher emergence than 0 psi.

3. 2 psi produced significantly higher emergence than 0, 7, 10, and 15 psi.

TABLE XII (Cont.)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	"F"
Analysis of Variance, Five Days After Planting				
Total	53	1323.50		
Moisture	2	1158.78	579.39	159.61**
Compaction	5	14.16	2.83	0.78
M x C	10	19.89	1.99	0.55
Error	36	130.67	3.63	
Analysis of Variance, Six Days After Planting				
Total	53	879.93		
Moisture	2	708.93	354.46	152.12**
Compaction	5	30.15	6.03	2.59*
M x C	10	56.85	5.68	2.44*
Error	36	84.00	2.33	

$$\sigma (P_i - P_j) = \sqrt{2.33 \quad (1/9 + 1/9)} = 0.72$$

$$LSD = (2.03)(0.72) = 1.46$$

Conclusions from "t" test:

1. No significant difference between compaction pressures of 5, 7, 10, and 15 psi.
2. 2 psi produced significantly higher emergence than 7, 10, and 15 psi.

TABLE XII (Cont.)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	"F"
Analysis of Variance, Ten Days After Planting				
Total	53	366.09		
Moisture	2	222.92	111.46	60.25**
Compaction	5	20.76	4.15	2.24
M x C	10	55.74	5.57	3.01*
Error	36	66.67	1.85	

* Indicates significant difference between treatments.
** Indicates highly significant difference between treatments.

TABLE XIII

EFFECT OF SOIL COMPACTION ON EMERGENCE,
DATA FROM LABORATORY EXPERIMENT-PART III
June 21, 1955

Soil Moisture, Percent	Compaction Pressure, psi	Percent Emergence Days After Planting 4	5	6	14
12	2	0.0	6.2	18.8	62.5
	2	6.2	18.8	50.0	62.5
	2	0.0	18.8	31.2	37.5
	15	0.0	0.0	0.0	31.2
	15	6.2	12.5	25.0	50.0
	15	6.2	18.8	37.5	50.0
	30	0.0	6.2	6.2	18.8
	30	0.0	0.0	0.0	18.8
	30	0.0	6.2	18.8	25.0
16	2	37.5	75.0	87.5	100.0
	2	31.2	56.2	62.5	87.5
	2	6.2	43.8	56.2	93.8
	15	37.5	62.5	68.8	81.2
	15	37.5	50.0	50.0	87.5
	15	25.0	37.5	62.5	81.2
	30	6.2	12.5	31.2	56.2
	30	6.2	43.8	56.2	81.2
	30	6.2	12.5	18.8	56.2
21	2	56.2	81.2	81.2	87.5
	2	75.0	81.2	87.5	87.5
	2	62.5	75.0	81.2	87.5
	15	50.0	68.8	81.2	93.8
	15	56.2	68.8	81.2	81.2
	15	81.2	93.8	93.8	100.0
	30	37.5	68.8	68.8	75.0
	30	56.2	87.5	93.8	93.8
	30	75.0	93.8	100.0	100.0

TABLE XIV

STATISTICAL ANALYSIS OF EFFECT OF SOIL COMPACTION ON EMERGENCE, LABORATORY EXPERIMENT-PART III 1955

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	"F"
Analysis of Variance, Four Days After Planting				
Total	26	504.75		
Moisture	2	416.97	208.48	68.58**
Compaction	2	19.86	9.93	3.27
M x C	4	13.25	3.31	1.09
Error	18	54.67	3.04	
Analysis of Variance, Five Days After Planting				
Total	26	690.67		
Moisture	2	566.89	283.44	78.08**
Compaction	2	22.89	11.44	3.15
M x C	4	35.56	8.89	2.45
Error	18	65.33	3.63	

TABLE XIV (Cont.)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	"F"
Analysis of Variance, Six Days After Planting				
Total	26	642.52		
Moisture	2	480.96	240.48	47.71**
Compaction	2	38.74	19.37	3.84*
M x C	4	32.15	8.04	1.60
Error	18	90.67	5.04	

"t" TEST

$$\sigma_{(P_i - P_j)} = \sqrt{5.04 \quad (1/9 + 1/9)} = 1.06$$

$$\text{LSD} = (2.10)(1.06) = 2.23$$

Conclusions from "t" test:

1. No significant difference between compaction pressures of 15 and 30 psi.
2. 2 psi produced significantly higher emergence than 30 psi.

TABLE XIV (Cont.)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	"F"
Analysis of Variance, Fourteen Days After Planting				
Total	26	450.08		
Moisture	2	327.19	163.59	67.04**
Compaction	2	49.86	24.93	10.22**
M x C	4	29.03	7.26	2.98*
Error	18	44.00	2.44	

"t" TEST

$$\sigma(P_i - P_j) = \sqrt{2.44 \quad (1/9 + 1/9)} = 0.74$$

$$\text{LSD} = (2.10)(0.74) = 1.55$$

Conclusions from "t" test:

1. No significant difference between compaction pressures of 2 and 15 psi.

2. 2 and 15 psi produced significantly higher emergence than 30 psi.

* Indicates significant difference between treatments.
** Indicates highly significant difference between treatments.

TABLE XV

STAND COUNTS FOR MAY 23 FIELD PLANTING

JUNE 16, 1955

Row* Number	Percent Beet Containing Inches					
	Rep. 1		Rep. 2		Rep. 3	
	Treated Row	Check Row	Treated Row	Check Row	Treated Row	Check Row
1	1	5	5	6	10	8
2	9	9	8	12	14	16
3	17	4	12	6	11	10
4	10	7	4	7	8	9
5	10	2	7	10	1	8
6	7	4	8	9	20	12
7	6	11	9	10	22	8
8	6	9	6	11	8	12
9	4	8	8	10	18	14
10	3	10	10	7	20	6
11	10	4	10	7	29	10
12	11	9	10	8	9	12
13	14	9	12	14	20	7
14	9	2	13	9	21	9
15	9	7	6	8	16	9
16	9	8	8	7	10	9
17	5	8	8	7	7	15
18	7	10	7	16	10	12
19	8	9	12	12	10	16
20	10	5	19	7	17	10
21	10	9	12	19	16	21
22	11	6	18	11	24	17
23	16	8	13	8	12	22
24	6	9	12	17	4	14
25	8	8	8	9	8	13
26	7	12	4	11	3	6
27	12	8	14	12	8	9

*See Figure 22 for explanation of treatments.

TABLE XVI

STATISTICAL ANALYSIS OF SUGAR BEET EMERGENCE DATA

FIELD PLANTING, May 23, 1955

Analysis of Variance

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	"F"
Total	80	2927.51		
Replications	2	52.03	26.01	0.94
Added Moisture	2	86.84	43.42	1.58
Compaction	2	91.95	45.97	1.67
Fertilizer	2	375.88	187.94	6.82**
AM x F	4	92.57	23.16	0.84
AM x C	4	80.05	20.01	0.73
F x C	4	157.68	39.42	1.43*
AM x F x C	8	558.54	69.82	2.54
Error	52	1431.97	27.54	

Conclusions:

1. Effect of fertilizer was highly significant.
2. AM x F x C interaction was significant.
3. All other factors were not significant.

"t" TEST FOR FERTILIZER AVERAGES

$$\sigma(F_i - F_j) = \sqrt{27.54 \quad (1/27 + 1/27)} = 1.43$$

$$\text{LSD} = (2.01)(1.43) = 2.87$$

Conclusions from "t" test:

1. No significant difference between rates of fertilizer of 0 and 100 pounds per acre.
2. 200 pounds per acre produced significantly better emergence than 0 and 100 pounds.

TABLE XVII

STAND COUNTS FOR JUNE 1 FIELD PLANTING

JUNE 16, 1955

Row* Number	Percent Beet Containing Inches			
	Rep. 1		Rep. 2	
	Treated Row	Check Row	Treated Row	Check Row
1	24	23	29	17
2	26	23	22	22
3	33	23	27	25
4	26	26	32	23
5	37	27	32	20
6	29	28	22	19
7	32	25	14	17
8	28	26	22	18
9	26	19	23	20
10	39	22	25	25
11	27	25	18	15
12	31	29	21	21
13	31	23	20	17
14	24	27	15	19
15	30	28	31	20
16	31	18	29	13
17	28	20	22	23
18	30	26	22	18
19	29	27	28	17
20	26	20	24	21
21	34	22	29	16
22	22	33	22	26
23	20	17	21	24
24	33	22	30	26
25	22	19	27	23
26	31	13	34	31
27	35	22	35	29

*See Figure 23 for explanation of treatments.

TABLE XVIII

STATISTICAL ANALYSIS OF SUGAR BEET EMERGENCE DATA, FIELD PLANTING, JUNE 1, 1955

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	"F"
		Analysis of Variance		
Total	53	1864.82		
Replications	1	29.63	29.63	1.15
Added Moisture	2	200.15	100.07	3.90*
Compaction	2	115.60	107.80	4.20*
Fertilizer	2	55.60	27.80	1.08
AM x F	4	352.74	88.18	3.44*
AM x C	4	41.07	10.27	0.40
F x C	4	57.29	14.32	0.55
AM x F x C	8	327.37	40.92	1.58
Error	26	667.37	25.67	

Conclusions:

1. Effect of added moisture was significant.
2. Effect of compaction was significant.
3. AM x F interaction was significant.

"t" TEST FOR ADDED MOISTURE AVERAGES

$$\sigma(AM_i - AM_j) = \sqrt{25.67 \quad (1/18 + 1/18)} = 1.69$$

$$LSD = (2.05)(1.69) = 3.47$$

Conclusions from "t" test for added moisture:

1. No significant difference between rates of 0 and 50 gallons of added moisture per acre.
2. 100 gallons per acre produced significantly better emergence than no added moisture.

TABLE XVIII (Cont.)

"t" TEST FOR COMPACTION AVERAGES

$$\sigma_{(C_i - C_j)} = \sqrt{25.67 \quad (1/18 + 1/18)} = 1.69$$

$$LSD = (2.05)(1.69) = 3.47$$

Conclusions from "t" test for compaction:

1. No significant difference between 0 and 120 pounds of compaction force.

2. 150 pounds compaction produced significantly better emergence than no compaction.

LITERATURE CITED

1. Barmington, R. D. A press wheel study to improve beet seedling emergence. Proc. Amer. Soc. Sugar Beet Tech. 225-228, 1948.

2. Brown, H. W. Applying fertilizers to sugar beets in Ontario. Proc. Amer. Soc. Sugar Beet Tech. 68-74, 1940.

3. Carleton, W. M. Principles affecting the performance of mechanical sugar beet planters. Unpublished Ph. D. Thesis. Michigan State College, 1948.

4. Cook, R. L. Tillage practices and sugar beet yields. Proc. Amer. Soc. Sugar Beet Tech. 286-293, 1950.

5. Cook, R. L. Effect of fertilizer on sugar beet stands. Proc. Amer. Soc. Sugar Beet Tech. Eastern United States and Canada. 124-127, 1951.

6. Crabb, G. A. and J. L. Smith. Soil-temperature comparisons under varying covers. Bulletin 71, Highway Research Board, Washington, D. C., 1953.

7. Crocker, W. Role of seed coats in delayed germination. Bot. Gaz. 42: 265-291, 1906.

8. Doneen, L. D. and J. H. MacGillivray. Germination of vegetable seeds as affected by different soil moisture conditions. Plant Physiology. 18(3): 524-529, 1943.

9. Farnsworth, R. B. Soil aeration and sugar beet growth. Proc. Amer. Soc. Sugar Beet Tech. 6-9, 1941.

10. Frakes, M. G. Palsgrove "Place-Rite" row crop planter with Milton seeding units. Unpublished paper, Undated.

11. Frakes, M. G. Spring work is mechanized. Sugar Beet J. 20(8): 1-2, 1955.

12. Frakes, M. G. and H. L. Draher. An improved method of applying fertilizer to sugar beets. Proc. Amer. Soc. Sugar Beet Tech. 285-290, 1954.

13. French, G. W. Sugar beet emergence studies, Michigan, 1949. U.S.D.A. Sugar Beet Machinery Annual Report, 104-127, 1949.

14. Harrington, G. T. Use of alternating temperatures in germination of seeds. J. Agr. Res. 23: 295-333, 1923.

15. Hunter, J. R. Some factors affecting germination in sugar beet seeds (Beta Vulgaris L.). Unpublished Ph. D. Thesis. Michigan State College, 1951.

16. Hunter, J. R. and A. E. Erickson. Relation of seed germination to soil moisture tension. Agron. J. 44: 107-109, 1952.

17. Hunter, J. R. and S. T. Dexter. Some seed-soil moisture studies with sugar beets. Proc. Amer. Soc. Sugar Beet Tech. 270-274, 1952.

18. Jenneke, L. E. Scientific advancement in sugar beet production. Paper prepared for presentation at the Colorado Academy of Science meeting at Fort Collins, Colorado. U.S.D.A. Sugar Beet Machinery Annual Report. 130-137, 1950.

19. Jensen, J. E. Fertilizers--manner of application. Proc. Am. Soc. Beet Tech. 119-120, 1942.

20. Jones, R. A. Methods and equipment for fertilizing row crops. Proc. Amer. Soc. Sugar Beet Tech. 283-286, 1942.

21. Leach, L. D., R. Bainer, and L. D. Doneen. Emergence and rate of emergence of sugar beet seed as influenced by seed preparation, soil moisture, and temperature. Proc. Amer. Soc. Sugar Beet Tech. 107-116, 1946.

22. Liljedahl, J. B. Weed control by mechanical energy as a pre-emergence soil treatment. Unpublished Ph. D. Thesis. Michigan State College, 1954.

23. McBirney, S. W. Improvement of sugar beet seedling emergence by planter development. Proc. Amer. Soc. Sugar Beet Tech. 229-239, 1948.

24. Mellor, J. L., H. P. H. Johnson, and R. Gardner. Fertilizer placement for sugar beet production. Proc. Amer. Soc. Sugar Beet Tech. 428-435, 1950.

25. Morinaga, T. Effect of alternating temperatures upon the germination of seeds. Amer. J. Bot. 13: 141-158, 1926.

26. Shull, C. A. The oxygen minimum and germination of Xanthium seeds. Bot. Gaz. 52: 453-477, 1911.

27. Shull, C. A. Temperature and rate of moisture intake of seeds. Bot. Gaz. 69: 361-390, 1920.

28. Shull, C. A. The role of oxygen in germination. Bot. Gaz. 57: 64-69, 1914.

29. Snyder, F. W. Germination and emergence in sugar beet-preliminary note. Proc. Am. Soc. Sugar Beet Tech. Eastern United States and Canada. 59-63, 1955.

30. Stout, M. and B. Tolman. Factors affecting the germination of sugar beet and other seeds, with special reference to the toxic effects of ammonia. J. Agr. Res. 63: 687-713, 1941.

31. Tolman, B. and M. Stout. Toxic effects on germinating sugar beet seed of water soluble substances in the seed ball. J. Agr. Res. 61: 817-830, 1940.

32. Whitney, R. S., D. W. Robertson, and R. Gardner. Sugar beet fertilizer experiments on recently levelled land. Proc. Amer. Soc. Sugar Beet Tech. 353-357, 1948.

33. Wood, R. R. Selection for cold tolerance and low temperature germination in sugar beets. Proc. Amer. Soc. Sugar Beet Tech. 407-410, 1952.

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