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PRINCIPLES AFFECTING THE PERFORMANCE OF MECHANICAL
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By

Walter Monroe Carleton

A THESIS

Submitted to the School of Graduate Studies of Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

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The production of sugar beets requires two principal labor peaks; one for spring blocking and thinning and the other for harvest in the fall. Much progress has been made in the mechanical harvesting of sugar beets and commercial machines are now available which will successfully eliminate hand labor. Progress has also been made in seeding machines and planting techniques but much hand labor is still the rule for spring work. This investigation was made to determine some of the factors which influence emergence of sugar beets and to device ways and means of improving the emergence. The long-time objective is the elimination of hand work from the production of sugar beets.

Research on planting equipment has been carried on along two main lines:

1. Precision planting. As late as 1930 sugar beet drills were made to scatter along the row approximately 15 to 20 pounds of whole seed per acre. Machines now available are capable of metering and distributing about 4 pounds of segmented seed per acre.

2. The determination and improvement of those elements which may improve the effectiveness of planters or planting methods on field germination. Some progress has been made in this work but new devices or techniques must be proved in the field over a period of years.

A new type of rolling wheel furrow opener was designed and used in the experimental work. The results of field tests indicate that certain planting treatments which include this opener are better than conventional planting methods but final judgment must be reserved until the opener has been tried for more seasons.

A pneumatic compaction wheel which imparted a uniform and consistent pressure upon the soil was found to be better than a cast-iron compaction wheel. Greater unit pressures by the compaction wheel resulting in heavier soil compactions around the seed were found to give better emergence than the lighter compactions, especially under drier seed-bed conditions.

Greenhouse tests were used to determine the comparative performance of the experimental openers with the performance of plantings made under conditions of known compaction. Compactions resulting from the application of a static pressure of a maximum of 4 pounds per square inch on the soil were found to be statistically better as measured by plant emergence, than compactions obtained by the application of lower pressures down to 1 pound per square inch.

It was found that the air permeability test of soil was a satisfactory method in the laboratory of comparing the compaction effects of furrow openers with the effects of known static pressures on the soil. The checking of planting procedures by laboratory and greenhouse experiments permitted planter research to be carried out more rapidly than by usual summer field experiments only.

A new machine for more accurately and scientifically measuring the compaction of soil was designed and built. This machine was successfully used to evaluate compaction treatments used in the planting experiments and provides a valuable tool for use in soils, planting, and tillage research.

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INTRODUCTION

Sugar beets provide approximately 25% of all the sugar consumed in the United States (5). According to the United States Department of Agriculture (21) the average annual acreage of sugar beets in the United States varies from about 750,000 to 1,000,000 acres. Production in the Eastern area (principally Michigan and Ohio) for the last 20 years has varied from a low of about 12 percent to a high of about 25 percent of the national total (4).

A great deal of effort has been put forth to mechanize the production of sugar beets in an attempt to lower the high production costs which are primarily due to the large amounts of hand labor required during two distinct labor peaks. Mervine and McBirney (16) quote California figures showing that 75 man hours labor were required (year 1936) to grow a crop. The spring work of hoeing and thinning accounted for 36 percent of the total while 33 percent were required for topping and loading at harvest time. Common practice was and is yet to accomplish these labor peaks by the use of transient or contract labor. Thus there was a danger of local shortage of labor even during periods of unemployment.

Much progress has been made toward mechanization of the harvest work. According to McBirney (14) the acreage of beets mechanically harvested previous to 1943 was negligible. He states that in 1944, seven percent and in 1945, twelve percent of the U.S. acreage was harvested mechanically. California growers harvested approximately 30 percent of their 1945 crop by mechanical means. (22) Gardner (6) indicates that in Michigan in 1946 probably less than 5 percent of the sugar beet acreage was harvested mechanically; in 1947 the percentage would probably be nearer 20. Walker (22) suggests that the immediate problem before the sugar beet industry is no longer one of feasibility of mechanization (of harvest) but one of programs of development which will bring to greater perfection the mechanization now established.

In order to completely mechanize sugar beet production the evidence above indicates that the emphasis must now be laid on mechanization of the spring work. The Michigan State College project on sugar beet planting mechanisms and techniques was initiated in the spring of 1946. Hentschel (8) states that the problem was to determine the effects of various methods of mechanical seed bed preparation, including tillage, seed placement, seed coverage, and soil compactness over the seed.

REVIEW OF LITERATURE

Problems of Sugar Beet Seeding Machines

Historical

The problems involved in planting sugar beet seed have long been a source of study. Grant (7), previous to the year 1880, made a trip to France to investigate the culture of sugar beets and the manufacture of sugar with the intent of establishing the industry in Illinois. In his work describing his findings he wrote:

> The irregularity in size and shape of beet seed renders it necessary to subject it to certain treatments in order to facilitate the operation of sowing, and to prevent the clogging of the machine, the result of which would be to leave long spaces in the lines (rows) without any seed. This preliminary treatment also facilitates its germination, and in a measure guards it against destruction by insects.
>
> The seed should be passed through a screen with meshes sufficiently fine to retain all that would not pass easily through the gauge that regulates the passage in the machine.
>
> The seed which do not pass must be rubbed between two boards and partially crushed, in order to reduce those which are large and irregularly formed to a size that permits their easy transmission through the screen.
>
> As soon as the seed are sown the ground should be rolled. This hastens germination. The beet roller is a cast-iron one, in joints or sections. The roller should follow the lines made by the seed-sower as

exactly as is possible.

In addition to discussing the actual seeding work Grant discusses a method used at that time for mechanically blocking the beets to reduce the hand labor requirement. He adds:

> In many parts of Europe the farmer not only runs his cultivator between the rows, but also across them, leaving his plants at the corners of squares eighteen inches apart each way, thus doing almost all his work with a horse cultivator. . . .
>
> The use of the horse cultivator is not recommended as it leaves the plants too far apart in the lines. In some cases the hand hoe ("rasette a main") is used for both operations, and oftener still for cultivating across the lines. The "rasette a main" is mounted on low wheels, and is a species of thrust hoe and cultivator combined. . . .
>
> In case the field is not cultivated across the lines either by the horse or hand rasette, it is necessary, as soon as cultivation between the lines has taken place, to thin out the beets, leaving single plants standing, from twelve to fourteen inches apart in the rows.

The general use of segmented seed has come into existence since 1941 when Bainer (2) succeeded in successfully reducing the number of germs per seed unit. Attempts to reduce field thinning of excess plants had been previously tried with little success. Palmer (18) writing in 1918 mentions attempts to plant beet-balls in paper tubes in a seed-bed. The beets were thinned while in trays, conveyed to the field in trays and planted in the tubes. This was found to be too expensive. Palmer further continued:

> At the same time a German seed grower tried to obviate the necessity of thinning, by passing the seed-balls through a grater and cracking them into several parts. Some of this cracked seed was placed on the American market, but did not give satisfactory results. The drawbacks to this method were both numerous and serious. Some of the seed germs were destroyed in the cracking machine. Others were exposed and the function of the beet-ball to regulate the germination was destroyed. The oxalates in the beet-ball did not perform their function of protecting the young plant from its micro-enemies. And finally, unless a large portion of the germs were ruined, it was impossible so to crack the balls but that many of the pieces contained more than one germ and the field had to be thinned as usual.
>
> With these experiments in mind, the writer (Palmer) cracked open and examined thousands of beet-seed balls and finally concluded that the only manner in which the desired result might be attained would be to breed a single beet-ball.

Present problems

The problems which Grant discussed about sixty years ago have not been entirely solved at this date but progress has been made. Walker (23) in discussing the trends in sugar beet machinery in 1942 said that fluted feed drills had been generally used up to about 10 years previously. The drilled beet seedlings came up more or less in clumps of seedlings. The need for a single seed-ball planter was evident. Mervine and McBirney (17) in 1939 reported on the development of single-seed planting. These two men developed a chain-feed single drop planter which gave significantly more uniform spacing of the seed but they concluded that the extra cost of manufacture was not justified provided the conventional planters were equipped with proper plates for single seeding.

The research on and development of planting equipment is an indirect approach to the problem of the mechanization of production. McBirney (12) states that the production of sugar beets requires approximately 100 man hours per acre where mechanization of thinning and harvesting is not practiced. Approximately one-third of the 100 is required for hand thinning and hoeing the crop. McBirney further states that most of the planter development so far has been concerned with investigating planter characteristics affecting seed distribution. The result has been successful single-seed planters and practically all commercial planters are now of the single-seed type. The success of single-seed planters together with segmented seed has reduced seeding rates from about twenty pounds of whole seed per acre in 1930 to about four pounds of segmented seed per acre at the present time (8).

It has been stated above that one objective of planter development has been to affect good seed distribution. This objective has been at least partially attained in present day planters. Therefore greater emphasis may be laid on attempting to determine those factors which may improve the effectiveness of planters or planting methods on seed germination.

In order to mechanize the thinning operation it is necessary that the proper stand of beets be secured. Reeve and Nichol (19) give data from a five-year study of per-acre plant populations on 50,000 acres located around St. Louis, Michigan. They define a 100 percent stand as one beet every 12 inches in 22-inch rows or a total of 23760 beets per acre. If 28-inch rows are used then the beets need be closer together to obtain a 100 percent stand. The data show that the average yield of beets decreases as the number of beets per acre decreases. It is shown that the average weight per beet does not increase significantly as the number of beets per acre decreases. These data show the importance of proper seeding technique.

Factors Which Influence Emergence of Sugar Beets

Yoder (24) lists the following soil factors as directly influencing the growth of root plants:

1. Soil-water supply	4. Plant nutrient supply
2. Soil-air supply	5. Depth of rootbed, and
3. Soil-heat relations	6. Presence or absence of injurious substances.

According to Hoffer (9) surface crust sometimes smothers the roots of young plants. Bainer (1) states that weather hazards will continue to be one of the controlling factors in obtaining satisfactory stands even though the best available planting equipment and seed is used. McBirney (11) concludes that:

> The wide variation in field emergence on hundred inch counts with even the best types of openers on what are apparently good seed beds seems to indicate that our seed beds are too variable and not as good as they should be. We know from grease-board tests that the variation in seed drop in hundred inch runs is not great and that the extreme variance in emergence must result from some other cause. Further work to obtain improved and more uniform emergence should include studies of seed beds and bed preparation in addition to that on planting equipment.

Tolman and Stout (20) made a comparison of the germination of sheared sugar beet seed, whole seed balls, and naked seed using blotters, soil in special glass germinators and also on the greenhouse bench. They found that very few seedlings from naked seeds and imperfect sheared seeds emerged from the soil when planted more than one-half inch deep. They state that the optimum depth of planting for both whole seed and sheared seed is that they should be planted just as shallow as moisture will permit. Depth of planting should therefore be governed by soil moisture and not by kind of seed planted.

Baver (3) discusses the significance of soil structure:

> It is known that plants require nutrients, water, and air for growth. The amount of nutrients in the soil is usually taken as an index of fertility. The air and water relationships are dependent upon structure. . . . The growth of plant roots and the germination of seeds require favorable conditions for respiration. If there is a limited supply of oxygen within the soil as a result of poor structural conditions, respiration processes are hindered; germination and growth are retarded. Moreover, a small root system restricts the volume in which nutrients are available to the plant. Consequently a low air capacity may affect plant development in more than one way.
>
> These facts indicate that abundant nutrients in the soil do not insure good crop production. The investigations of numerous workers emphasize that insufficient attention has been given to providing a favorable environment for the germination of seeds and growth of crops.

Seed Planter Development

The precision planting of sugar beet seed has come about in the last fifteen or twenty years in an attempt to reduce the spring labor requirements due to blocking and thinning. Mervine and McBirney (17), in 1939, reported that an investigation of commercial planters disclosed that none seemed to have a uniformity of seed drop. They developed a rather accurate but elaborate chain-feed planter but its manufacture was not pushed due to improvements in conventional plate planters.

Success in producing segmented sugar beet seed in 1941 (2) led to the development of precision planters for segmented seed. Bainer (1) states (in 1947) that several planting units are capable of precision metering of properly graded seed. He also states that:

> . . . the principal problem yet to be solved deals with proper placement of the seed in the ground to insure maximum germination. The relatively poor field germination for machine-planted segmented seed indicates a necessity for improvement of furrow opening and covering devices. Precision planting requires precision seed and precision farming practices if the greatest gains are to be realized.

McBirney (13), reporting on 1945 planter investigations in Colorado, gave recommendations for planter design to improve seedling distribution characteristics and for improving the percentage of field emergence. The suggestions for improving field emergence were:

1. Use more pressure on press wheels, particularly on firm seed beds. . . .

2. Loosen up the surface of firm seed beds by surface harrowing prior to planting. . . .

3. Use deep concavity press wheels with considerable pressure for loose seed beds.

4. Level, scrape; or smooth out the bottom of the seed furrow before dropping seed. Considerable experimental work should be done to develop suitable equipment to do this.

5. Use shallower depths for early plantings when germination is slow and moisture may be excessive.

6. Use deeper plantings for later plantings when soil is likely to be dry and germination is rapid.

7. Use furrow planting only when necessary to get the seed into moisture. . . .

8. Our plantings have not shown the ridged planting to be of any benefit. . . .

Evaluation of Planting Tests

In order to evaluate the field performance of sugar beet planters some method must be agreed upon for measuring the regularity of spacing of seeds or seedlings. Mervine (15) defines the "stand" as being simply the percentage of inches in the row in which beets are found, either singles or multiples. This percentage is found by placing a hundred inch scale along the row and recording the number of inches opposite which there are one or more seedlings. For the sake of simplicity these may simply be called "beet-containing inches".

INVESTIGATION

Objectives

The objectives of this investigation were classified as immediate and long-time objectives. The immediate objective was to determine those factors, of sugar beet planters or of planting technique, which affect the germination and emergence of sugar beets. The long-time objective was to contribute to the elimination of the spring labor peak now required in the thinning and blocking operations.

Methods of Procedure

The methods of procedure were:

1. A bibliographic study of past research on planting equipment. This research gave a good picture of work which had been accomplished to date and suggested certain lines of attack for the laboratory and field work in this investigation.

2. A study of existing planting equipment with the aim of determining its effectiveness in comparison with experimental planters and to determine what factors were responsible for varying performance.

3. Field trials of planting equipment.

4. Hand planting trials as a check on seeding equipment.

5. Laboratory checks on planting techniques.

6. Statistical analysis of all trials with the aim of determining the significance of any differences in treatments.

7. Alterations and improvements of planting equipment based on the results of laboratory and field trials.

Experimental Work

Experimental plantings were made in the field in the summer of 1947, in the greenhouse during the winter of 1947-48 and again in the field during the summer of 1948. The experimental work will be presented in chronological order since certain modifications in equipment and techniques came about as the research progressed.

Summer 1947

Equipment. Fig. 1 shows the Michigan State College planter as it was used during the 1947 field trials. This two-row planter was designed to simplify the interchange of experimental units. The left furrow opening and packing unit was taken from a commercial John Deere sugar-beet drill

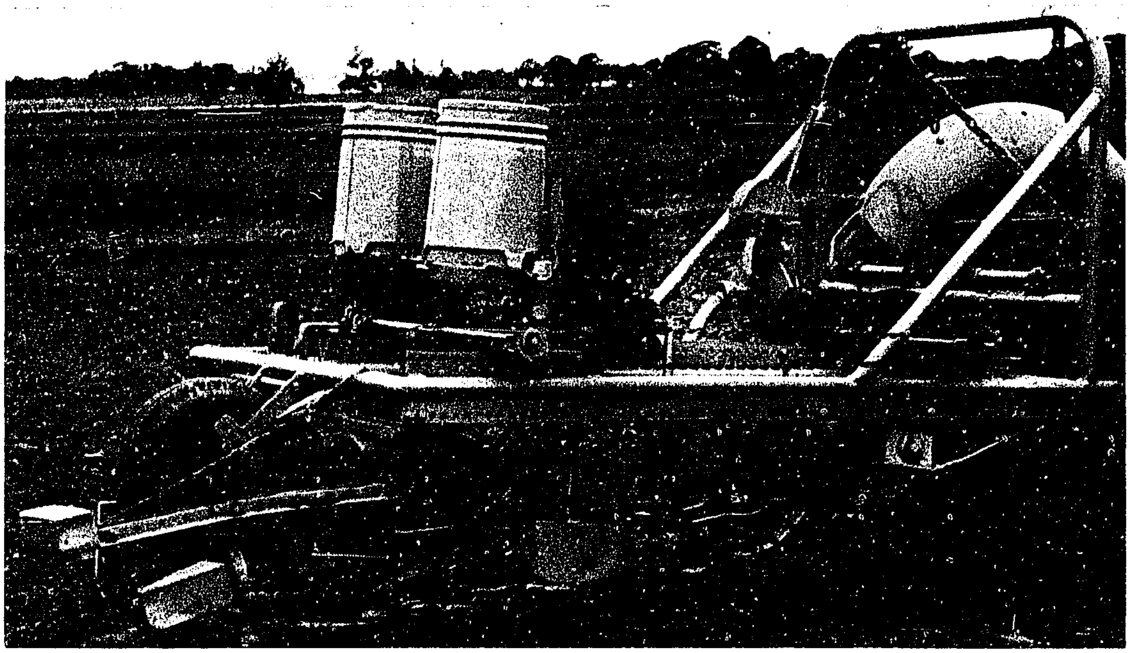


Fig. 1 Michigan State College Experimental Two-Row Sugar-Beet Planter.

and served as the conventional or check row unit. The right hand unit was built for the quick exchange of various experimental furrow openers. In addition a heavy cast iron packing wheel shown at "a" in Fig. 1 could be used ahead of the opener if desired. In like manner the small packing wheel "b" could be used for after-seeding compaction. Commercial Cobbley seeding units were used for both rows. Seeding units for both segmented and pelleted-segmented seed were available. The seeding units were calibrated in the laboratory at a speed equivalent to about two miles per hour and found to be dropping segmented seed at the rate of 3.8

pounds per acre. Since the pelleted seed units had the same number of seed holes and were turned at the same rate of speed it was assumed in the tests that the same number of seed balls were deposited in the furrow for either type of seed.

The fertilizer units were driven by a ground-wheel separate from that which drove the seeding units. The fertilizer units were calibrated in the laboratory to apply 175 pounds per acre with the seed. This procedure was in conformity with recommendations which permitted up to 200 pounds of fertilizer per acre to be placed directly in the row with the seed. The plan of the experiment called only for making stand counts of seedlings. Since it was not planned to grow the beets to maturity the application of the usual additional 200 to 300 pounds of fertilizer per acre beside the beet row was not deemed necessary.

Three types of furrow openers were used experimentally during the 1947 season:

1. Conventional shoe type
2. M.S.C. boat-type
3. M.S.C. Rolling-disk type

Fig. 2 shows the shoe opener as used in the experimental combinations.

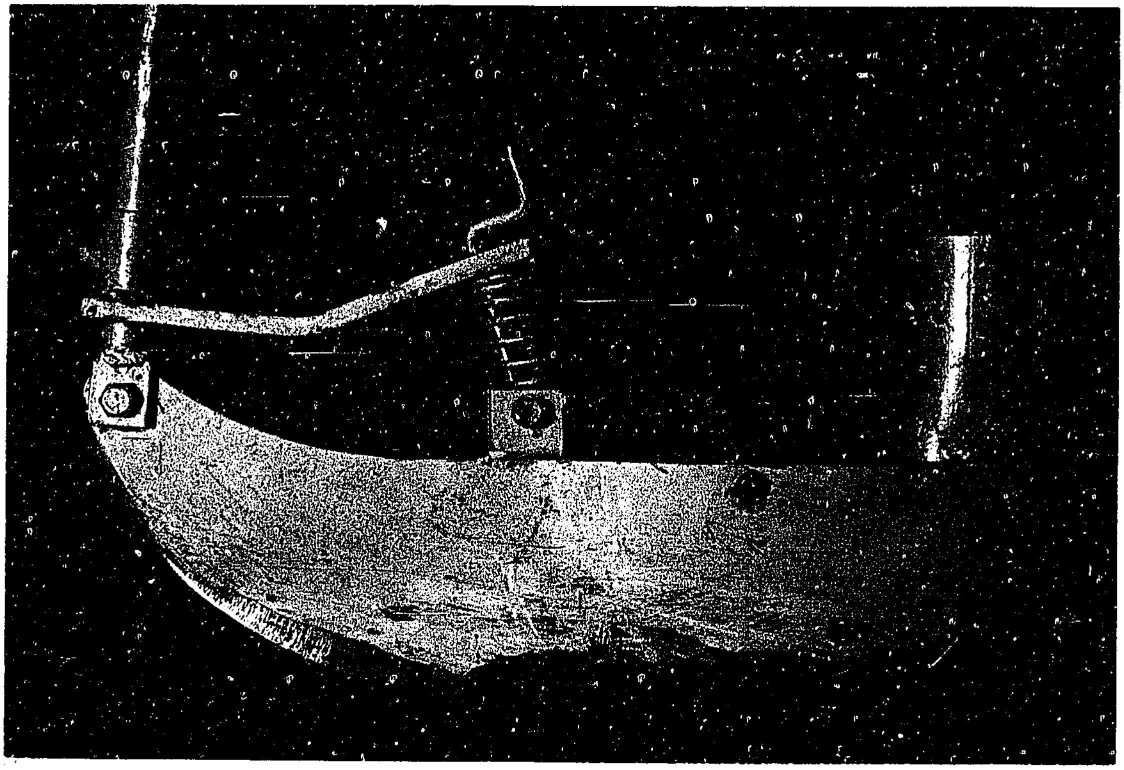


Fig. 2 Shoe-Type Opener with Fertilizer Tube for Direct Application with the Seed.

An experimental furrow opener designed by the Michigan State College Agricultural Engineering Department seemed to show some promise during preliminary trials in the summer of 1946. A slightly modified design of the opener, to permit the addition of fertilizer with the seed is shown in Fig. 3.

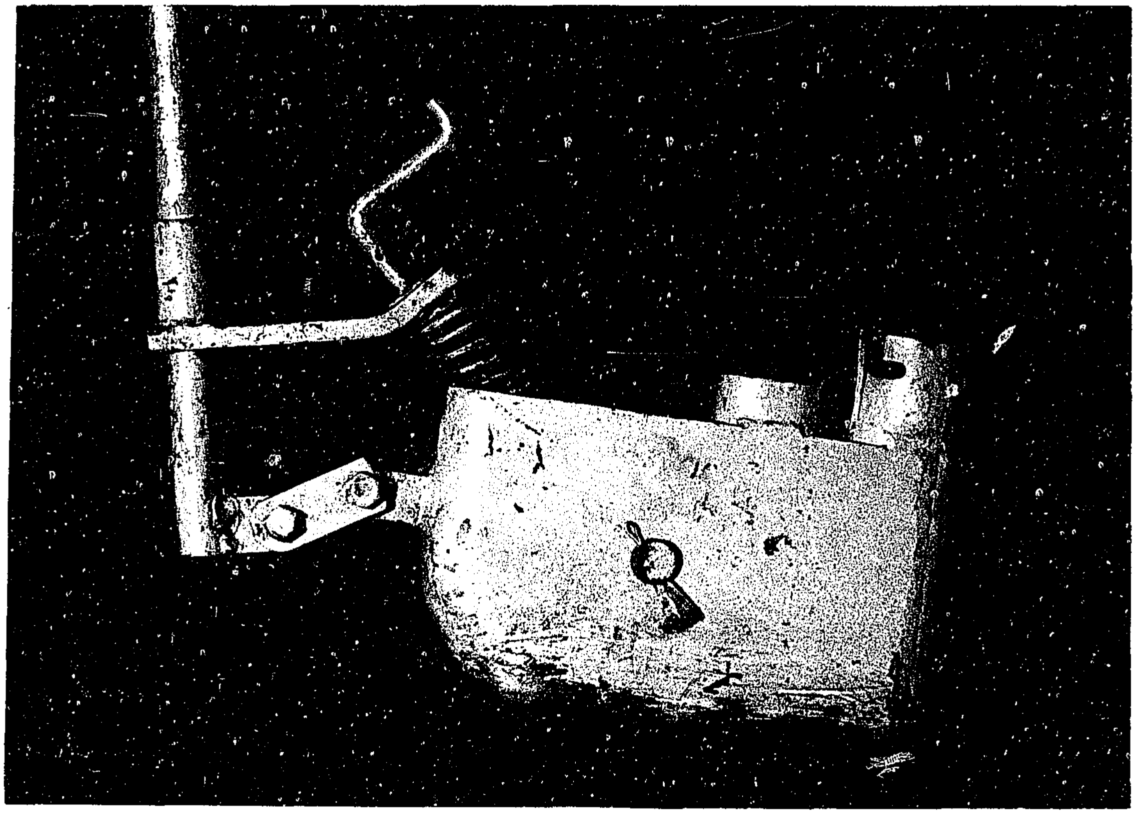


Fig. 3 Experimental Boat-Type Furrow Opener

In discussion of pre-emergence weed control it was suggested that the soil which has been treated prior to planting should be disturbed as little as possible. This was suggested as being necessary to prevent bringing nearer the surface those weed seeds that had not been damaged by the pre-planting treatment. The opener shown in Fig. 4 utilized as a furrow-opening device a three-fourths inch thick plate which was machined to three-eighths thickness along the outer edge. Runners were provided for depth control. This unit worked reasonably well but was improved for use in the 1948 season as shown in Fig. 9.

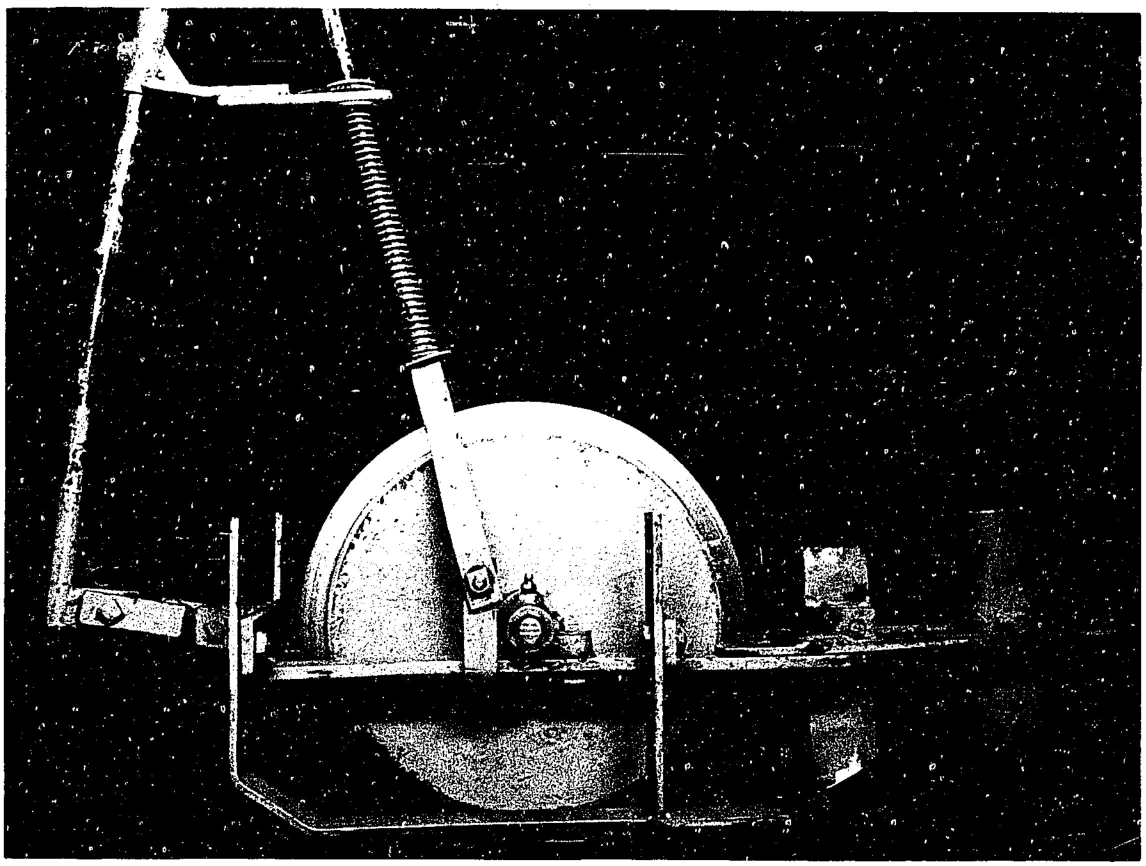


Fig. 4 Experimental Rolling Wheel Furrow Opener

Seed. The seed was supplied by the Farmers and Manufacturers Beet Sugar Association of Saginaw, Michigan. Three types were used in the experimental work. They were:

1. Segmented
2. Segmented, soaked in salt solution, and dried

3. Pelleted

The segmented seed was U.S. 215 x 216 graded through a 9/64 inch and over a 7/64 inch screen.

The treated segmented seed was a part of the same U.S. 215 x 216 previously mentioned. It was soaked for two hours in water, transferred to a 2% Na Cl salt brine for two hours and then dried. The washing treatment was first suggested to the author by Dr. N. S. Hall, formerly of the Michigan State College Soils Department, as a means of attempting to overcome toxic effects as the sugar beet seed decomposes in the soil.

The pelleted seed was No. 801½. According to information supplied by the Farmers and Manufacturers Beet Sugar Association the pellet material, based on the weight of the seed before pelleting, was as follows:

Cupricide 7.5 per cent

Treble Superphosphate 10.0 per cent

Inert---remainder

Samples of the dry segmented and pelleted seeds were sent to the Michigan State seed testing laboratory in

Lansing for germination tests. The tests which showed only the total percent of germinating seed balls were:

Segmented 86 percent

Pelleted 47 percent

<u>Soil</u>. Similar experiments were conducted at the Michigan State College Farm Crops field laboratory and on a farm near Breckenridge, Michigan. The soil at the Farm Crops laboratory was a heavy dense clay loam which tended to crack upon drying. The soil at Breckenridge was a light sandy loam, and although not the type of soil generally considered best for sugar beets, the operator was very successfully growing commercial beets in the same field.

<u>Soil compaction</u>. The design of the planter permitted packing of the soil both before and after the seeding unit. This permitted the use of four packing combinations in the experimental plantings as follows:

Packing Combination	Packing ahead of opener	Packer after seeder
1	No	No
2	No	Yes
3	Yes	Yes
4	Yes	No

Combinations of the three seeds, three openers and four packings resulted in thirty-six experimental combinations.

The actual process of planting was simplified a great deal by the proper choice of planting sequence. The experimental plots were laid out before planting and numbered stakes used to indicate the position of each. Since the combinations had been previously assigned randomized positions within the blocks it was possible to plant the combinations in any order desired. The most difficult change was that of installing the rolling wheel opener; therefore all combinations involving it were planted first. The seeding units were the next most difficult to change while the packing units were the easiest.

Determination of results. The results of the planting trials were evaluated on the basis of the percent of "beet-containing" inches. Fig. 5 shows the type of stand-count sheet which was used for recording the information in the field. Two or more hundred inch counts were made on each row.

Design of the experiments--machine planting. The machine planted plots were laid out according to a Greco-Latin arrangement. The variables of seed and time were first randomized and the combinations within blocks were then separately randomized. The experimental layout for the

MICHIGAN STATE COLLEGE

										10										20										30										40										50	
COUNT NO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
1																																																			
2																																																			
3																																																			
4																																																			
5																																																			

									60										70										80										90										100	
COUNT NO.	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	TOTAL
1																																																		
2																																																		
3																																																		
4																																																		
5																																																		

COUNT NO.	INCHES WITH BEETS	INCHES CONTAINING			TOTAL PLANTS IN 100"	NUMBER OF GAPS					MAX. GAP IN INCHES	PERCENT PLANTER EFFICIENCY
		SINGLE PLANTS	DOUBLE PLANTS	THREE or MORE		6"-11"	12"-23"	24"-35"	36"-47"	48" & OVER		PERCENT EMERGENCE
1												
2												PERCENT SINGLE BEET-CONTAINING INCHES
3												
4												PERCENT DOUBLE BEET-CONTAINING INCHES
5												
TOTAL												PERCENT MULTIPLE BEET-CONTAINING INCHES
AVER.												

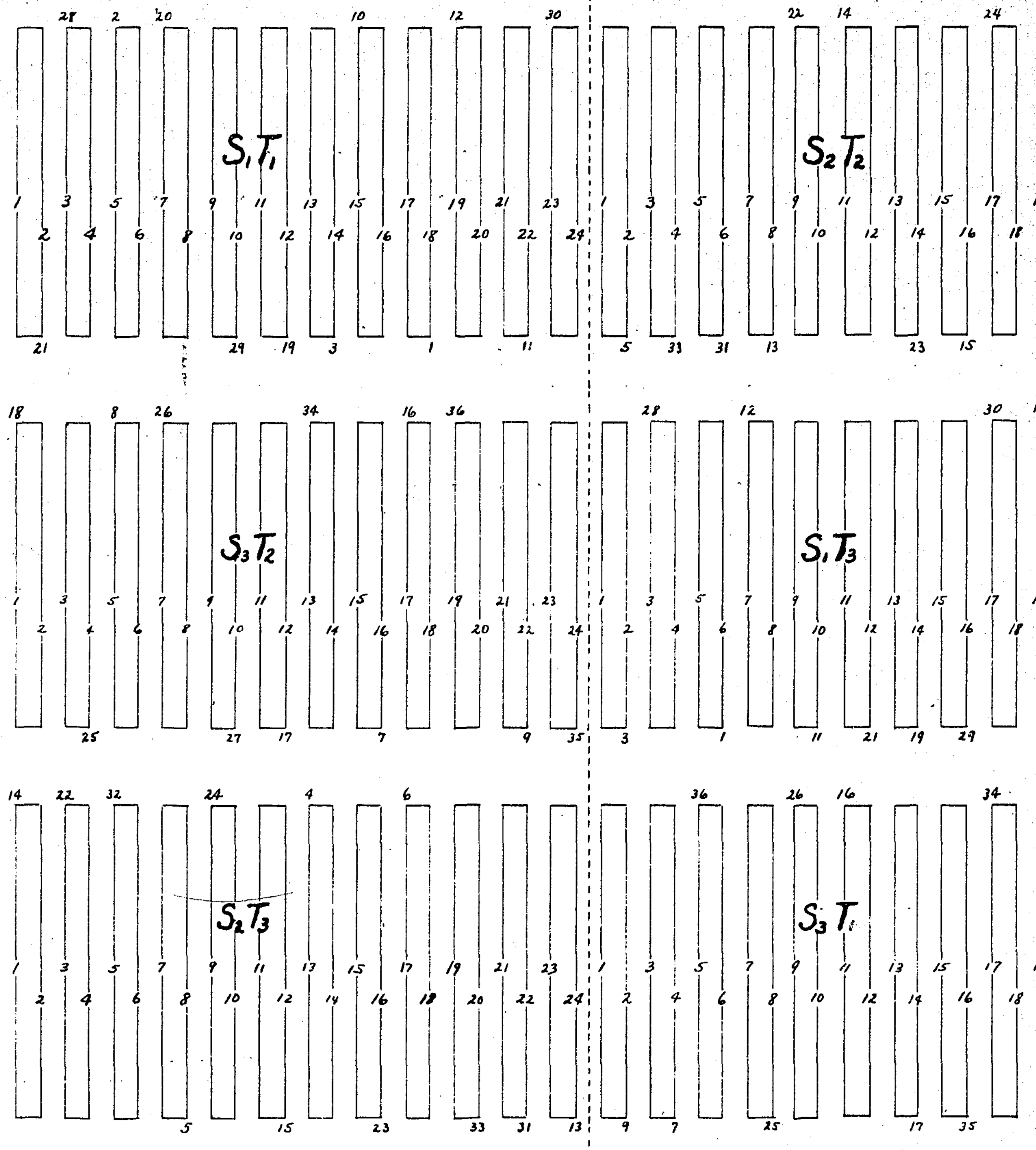
FIG. 5. Pre-Thinning Stand Count Sheet.

Breckenridge planting is shown in Fig. 6.

Design of the experiment-hand planting. In order to serve as a check on machine planting equipment a hand planting experiment was made at the Farm Crops laboratory. The plots were laid out as 4 x 4 Latin squares for both segmented and pelleted seed. The only variable introduced into this experiment was the method of packing. Packing before and/or after the seed was placed in the hand-made furrow was accomplished by packing the soil with the side of a small round stick held parallel to the ground. Each plot was fifty inches long with one seed planted per inch.

Criticism of designs. The design of the machine layout made it possible to determine the effects of a large number of variables and from that standpoint was desirable. Although the procedures which were set up made the task of field planting rather simple it was felt, at the completion of the experiments, that too large a number of variables were being tested and that a better design would be one in which there were fewer variables with more replications of each combination.

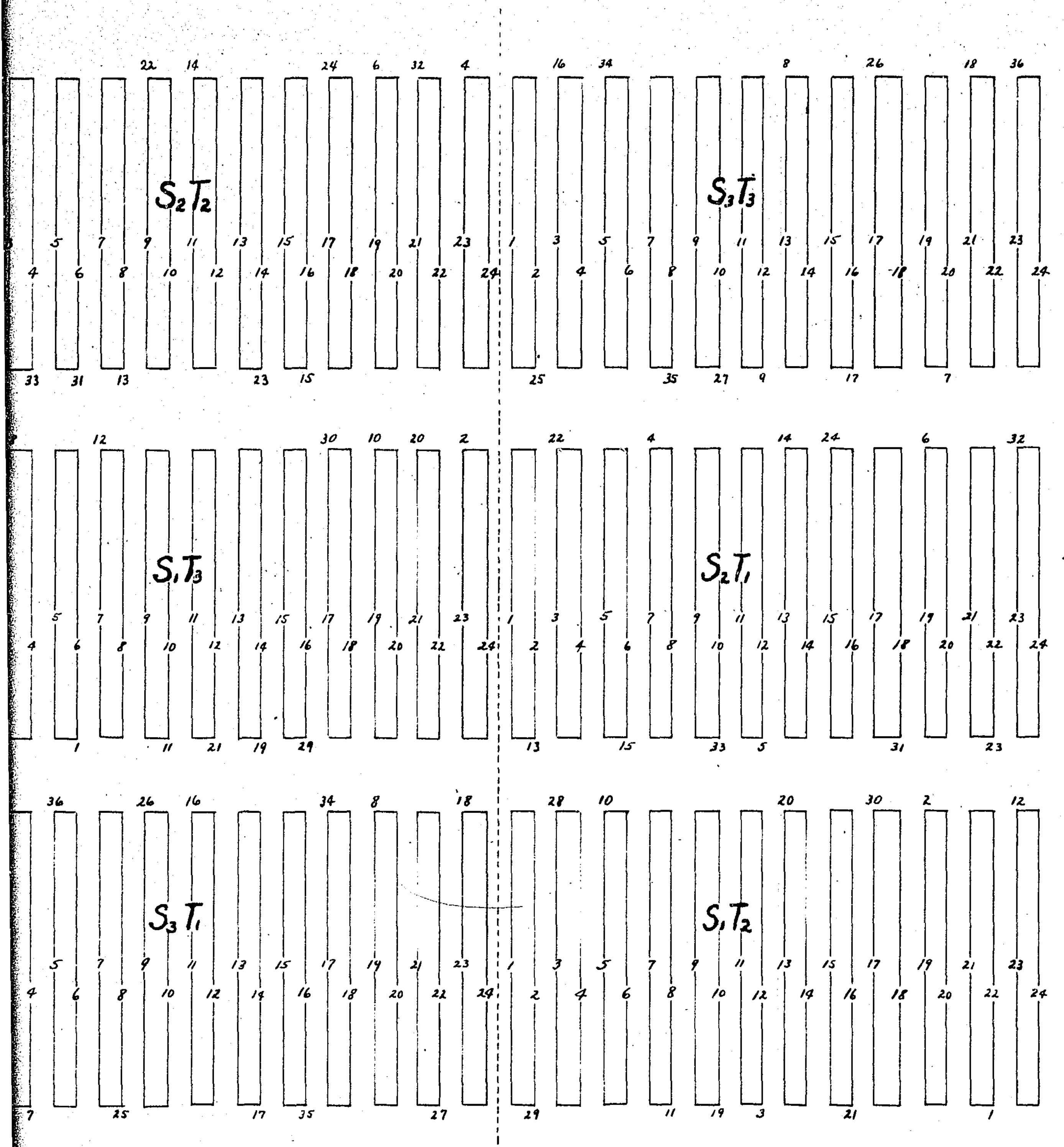
Notes on experiments. The soil at the Farm Crops laboratory was a clay loam soil which tended to form cracks upon drying. Fig. 7 shows one section of a row in the block



SEED
1 Segmented
2 Segmented-Soaked
3 Pelleted

OPENERS
1 Shoe Type
2 Boat Type
3 Wheel Type

Fig. 6. Experimental Sugar-Beet Planting Layout at Br



TREAT	OPEN.
1	1
2	2
3	3
4	1
5	2
6	3
7	1
8	2
9	3
10	1
11	2
12	3
13	1
14	2
15	3
16	1
17	2
18	3
19	1
20	2
21	3
22	1
23	2
24	3
25	1
26	2
27	3
28	1
29	2
30	3
31	1
32	2
33	3
34	1
35	2
36	3

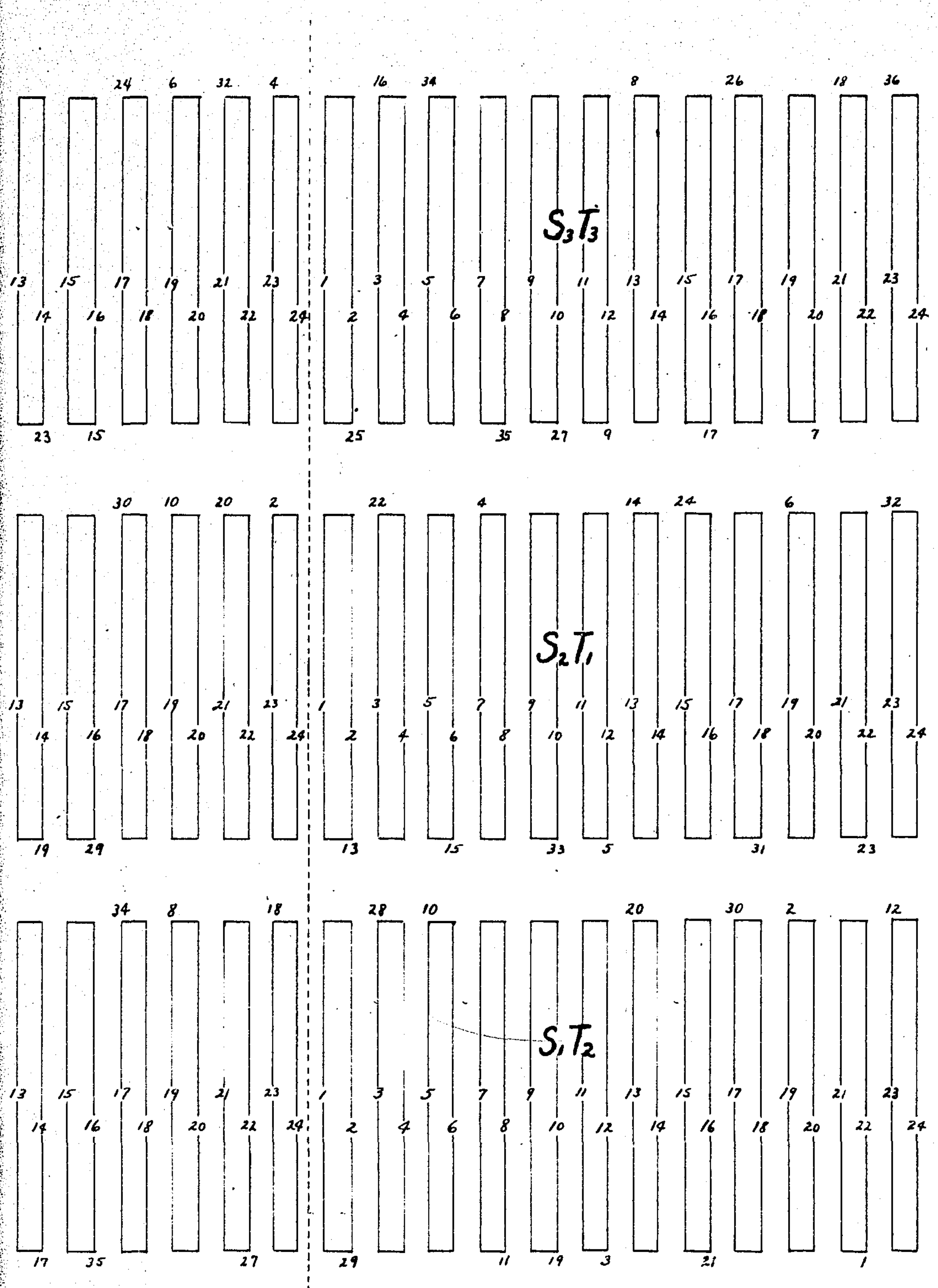
TREATM
CODE

ced

OPENERS
1 Shoe Type
2 Boat Type
3 Wheel Type

PACKING		
NO.	BEFORE	AFTER
1	NO	NO
2	NO	YES
3	YES	YES
4	YES	NO

ugar-Beet Planting Layout at Breckenridge Michigan 1947



TREAT.	OPEN.	SEED	PACK.
1	1	1	1
2	2	1	1
3	3	1	1
4	1	2	1
5	2	2	1
6	3	2	1
7	1	3	1
8	2	3	1
9	3	3	1
10	1	1	2
11	2	1	2
12	3	1	2
13	1	2	2
14	2	2	2
15	3	2	2
16	1	3	2
17	2	3	2
18	3	3	2
19	1	1	3
20	2	1	3
21	3	1	3
22	1	2	3
23	2	2	3
24	3	2	3
25	1	3	3
26	2	3	3
27	3	3	3
28	1	1	4
29	2	1	4
30	3	1	4
31	1	2	4
32	2	2	4
33	3	2	4
34	1	3	4
35	2	3	4
36	3	3	4

TREATMENT CODE

NERS
e Type
Type
/ Type

PACKING		
NO.	BEFORE	AFTER
1	NO	NO
2	NO	YES
3	YES	YES
4	YES	NO

Layout at Breckenridge Michigan 1947

S_1T_1. This row was a part of combination nineteen of which the shoe-type furrow opener was a part. The crack shown was approximately 1/4 inch wide and 2 inches deep.

Fig. 7 A Clay-Loam Soil Which Formed Cracks Along the Path of the Planter When the Soil Dried.

<u>Results of 1947 summer planting.</u> Stand counts were made and all data submitted to statistical analysis. A summary of the results showed:

1. Hand planting at M.S.C. Field Crops laboratory. There were no significant differences between any of the packing treatments for either the pelleted or the segmented

seeds. Unusually favorable moisture conditions were encountered during this test.

2. Machine planting at the M.S.C. Field Crops laboratory.

(a) A comparison of experimental treatments with paired check counts showed no significant differences in favor of the experimental treatments.

(b) Segmented and pelleted seeds were both better than the segmented seed which had been soaked in brine. There was no significant difference between pelleted and untreated segmented seed.

(c) A comparison of only experimental treatments, showed the wheel opener to be significantly better than the boat or shoe openers. There was no significant difference between the boat and shoe openers.

(d) There was no significant difference between the experimental packing treatments although field observations of plants favored compaction of the soil around the seed.

3. Machine planting at Breckenridge, Michigan.

(a) A comparison of experimental treatments with paired check rows showed the combination of the shoe opener with packing both before and after seeding to be significantly better than the paired check rows on the basis of stand counts. However, field observations of plant conditions did not substantiate this difference.

(b) Segmented and pelleted seeds were both significantly better than the segmented seed which had been soaked in brine.

(c) A comparison of only experimental treatments, showed both the wheel and shoe openers to be better than the boat-type opener. Packing after seeding was significantly better than no packing or packing before seeding.

Winter-Spring 1947-48

Plan of procedure. The determination and measurement of the effect of planting mechanisms upon the soil is a difficult problem. In order that research on the problem might be continued through the winter months, it was decided to place a large box of suitable soil in the greenhouse. A machine was built to support the planting mechanism on the box and a suitable arrangement was provided for moving the machine along the length of the box.

The relative compaction effects of furrow openers and known static pressures were compared by means of an air permeability unit (10). In addition, the pre-seeding packing wheel used in the 1947 summer tests was compared with static pressure packing.

The effect of various packing procedures on hand and machine plantings were compared.

Soil. The soil used in the tests was a Brookston clay-loam. This soil was placed to a depth of approximately 9 inches in the greenhouse in a box 3.5 feet wide and 18 feet long.

Equipment. The boat-type opener as used in the summer tests did not posses sufficient flexibility to satisfactorily care for unevenness in the seed bed. Figs. 8, 9, and 10 show the mechanism used for planting in the greenhouse. Fig. 11 shows the 53.5 pound cast-iron wheel which was used for pre-seeding packing during the 1947 summer experiments.

Fig. 12 shows the method used for applying a known static pressure upon the soil. The effects of these known pressures were then compared to the effects of the experimental equipment. Static pressures of 1, 2, 3, and 4 pounds per square inch were used. In practice, four containers were filled with sand so that the weight of the container plus the block on which it rested would exert a pressure of 1, 2, 3, or 4 pounds per square inch on the soil.

Fig. 13 shows the unit designed for testing the air permeability of the soil in place. In operation the sampling device "A" was inserted a given depth into the soil being tested. Air was pumped into the tanks "B" (connected

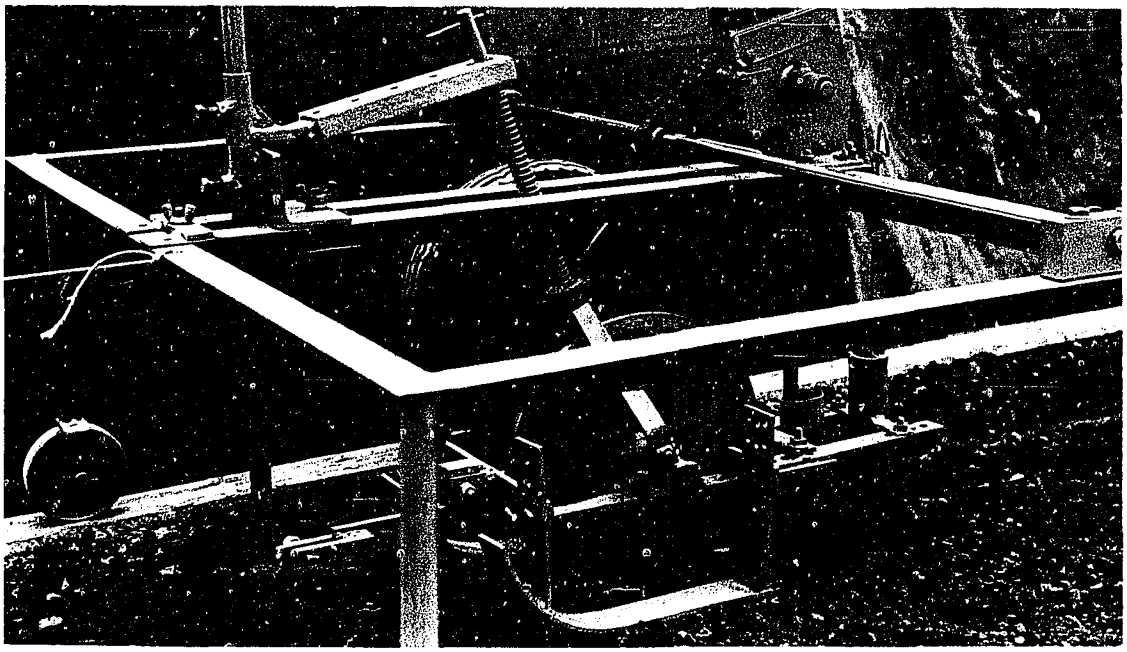


Fig. 8. The Machine for Planting in the Greenhouse. Wheel Opener Equipped with Revised Depth Control Skids.

together) until the high side of the water manometer "C" indicated a height of about 40 centimeters above the equilibrium point. The clamp on the hose leading to the sampling device was then released. As the manometer reading dropped to 27, the watch was started and was stopped when the water reached a point 2 centimeters above equilibrium. This gave the time for a definite volume of air to pass through the soil sampler. The wheel "D" was the same as in Fig. 11.

<u>Test procedure-soil compaction</u>. The comparison of the

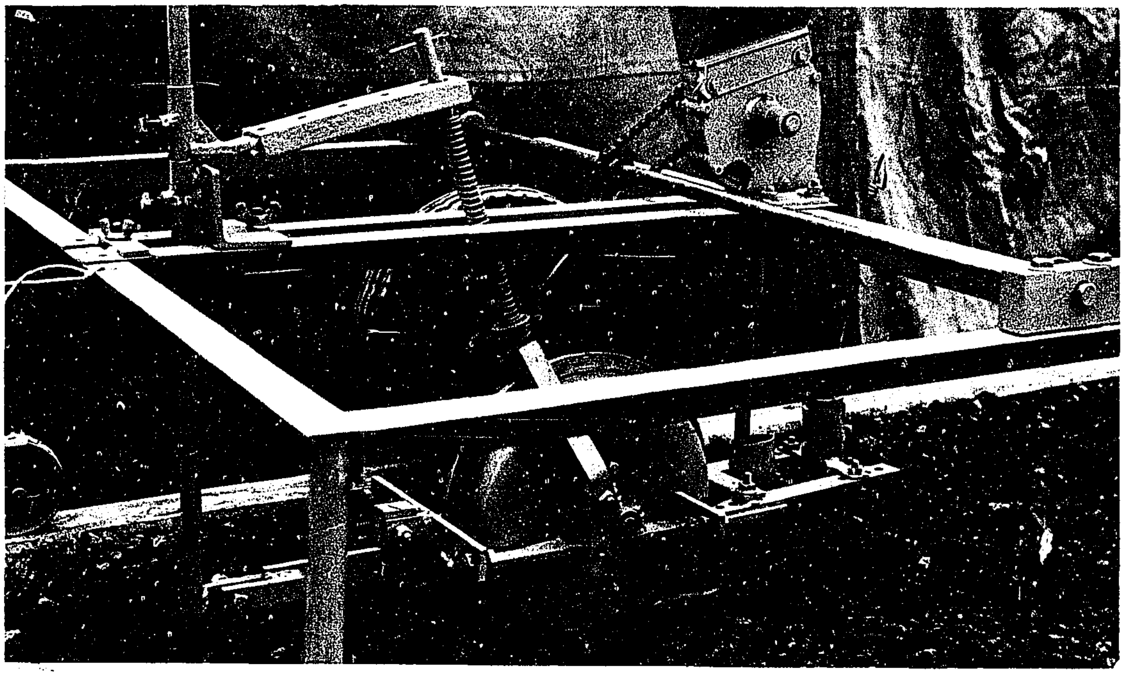


Fig. 9 The Machine for Planting in the Greenhouse. Wheel Opener Equipped with Depth Bands.

compaction effect of various treatments was carried out as follows: The soil was thoroughly wetted by sprinkling before starting a series of tests. It was allowed to drain for about two days or until the soil would not puddle when cultivated. The soil was then worked, the wheel opener and the packing wheel were run the length of the box and the various static pressures were applied. Permeability tests were then made, as described in connection with Fig. 13, for each of the soil treatments.

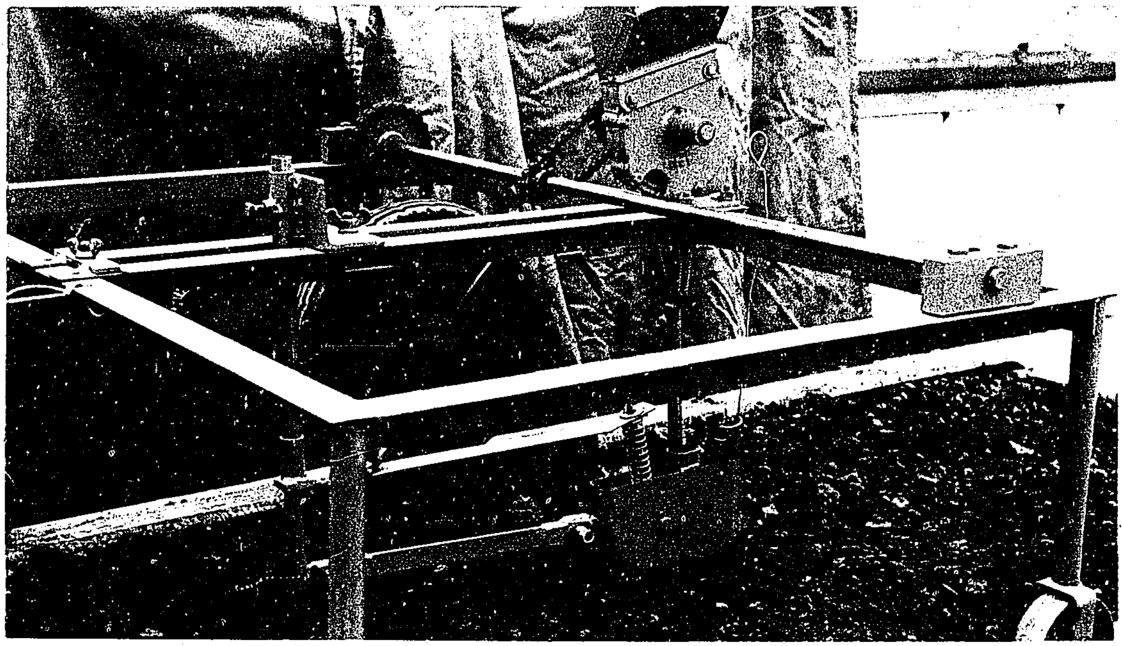


Fig. 10 The Machine for Planting in the Greenhouse. The Revised Boat Opener is Installed.

The soil was smoothed after the tests, permitted to dry for two days, and the procedure repeated. These determinations were continued until the soil became sufficiently dry that dust tended to blow out around the sampling unit.

Test procedure-compaction on emergence. In order to determine if there would be any significant effects on germination due to the various packing and planting procedures which had been tested in the air permeability work, two experimental plantings were made. The layout for the

Fig. 11 The 53.6 Pound Cast-Iron Compaction Wheel Used for Pre-Seeding Compaction During the 1947 Summer Experiments.

Fig. 12 The Application of a Known Static Pressure Upon the Soil.

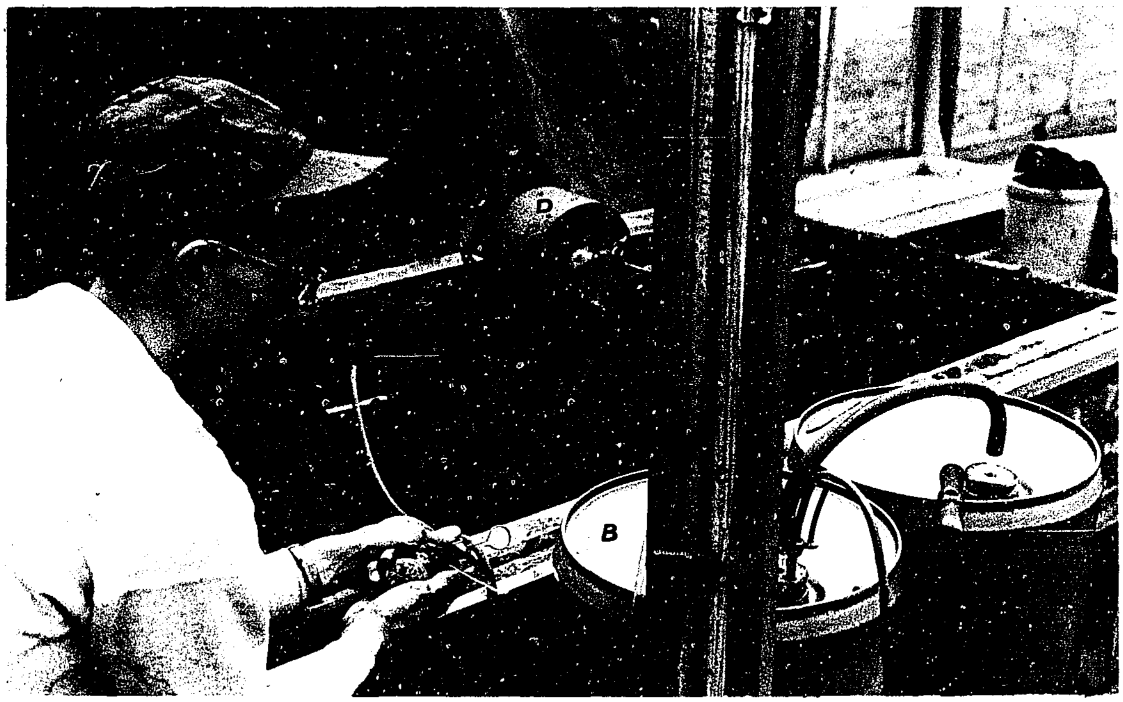
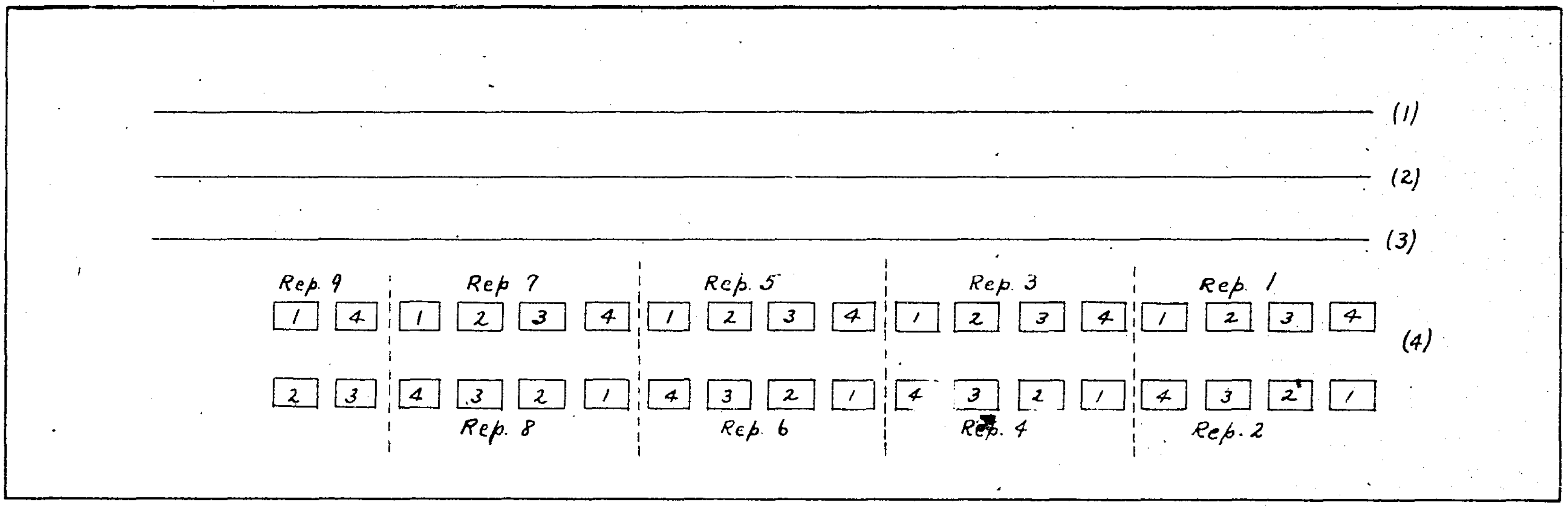


Fig. 13 Air Permeability Unit for Testing the Soil in Place.

second planting made on April 7, 1948 is shown in Fig. 14.

<u>Seed</u>. The segmented seed was furnished by the Farmers and Manufacturers Beet Sugar Association of Saginaw, Michigan. It was graded through a 9/64 inch screen and over a 7/64 inch screen. The averaged results of a detailed germination test on three samples was as follows:

Purity	99.7%
Seeds per gram	135
Seeds per pound	61236



(1) Boat Opener (10.7 seeds per foot)

(2) Wheel Opener (10.7 seeds per foot)

(3) Hand Plant. (One seed per inch)

(4) Ten seeds planted per rectangular print. Pressures in p.s.i. as shown.

Planted 4-7-48

Counted 4-21-48

Fig. 14. Layout of Experimental Plantings in Greenhouse.

Germination ----------------------------	89.6%
Sprouts --------------------------------	120
Singles --------------------------------	61.33
Doubles --------------------------------	26.33
Triples --------------------------------	2
Hypocotyls -----------------------------	5

Sprouts per pound, minus hypocotyls 70421

Test results-soil compaction. The data shown in Table 1 were taken by utilizing the air permeability unit shown in Fig. 13. A study of the data shows that the compaction of the wheel opener appeared to be approximately the same as that caused by static pressures of two to three pounds per square inch.

The 53.5 pound cast iron wheel used during the compaction tests was shown in Fig. 11. It was found that this wheel had an adverse effect on the soil since small cracks of about 1/2 inch in depth were formed across the wheel track at right angles to the direction of travel as shown at "a" in Fig. 15. This resulted in rapid drying of the soil to a depth of about 1 inch.

Test results-compaction on emergence. Emergence counts

Table 1 Time in Seconds for Manometer Reading to Drop from 27 to 2 Centimeters.

% Moisture	53.5 lb. Wheel	Wheel	Static P.S.I.				Check
dry basis	Wheel	Opener	4	3	2	1	Plot
27.7	7.8		20.9	13.4	12.1	6.7	5.6
24.2	8.4		12.5	8.9	7.5	6.2	4.9
22.5	4.6	9.5	7.9	8.1	6.0	3.7	3.3
21.6	5.6	8.8	11.5	10.2	7.4	7.0	4.6
19.0	10.1	9.6	17.6	12.8	10.6		8.5
17.5	10.6	9.6	14.6	13.4	10.3		7.9
15.6	14.6	13.6	16.1	14.7	12.1	10.8	10.8
12.5	15.9	16.3	14.0	14.6	11.2		

were used to evaluate the results of the various planting combinations.

According to the laboratory germination results, page 35, 89.6 percent of the seeds would be expected to germinate and, due to some seeds being doubles or triples, one might expect to obtain 115 plants per 100 seeds planted. On that assumption, the following definitions will apply:

1. Percent seed attainment

$$= \frac{\text{seeds actually germinating}}{\text{seeds planted} \times .897} \times 100$$

Fig. 15 Cracks in the Soil Caused by the 53.5 Pound Cast-Iron Packing Wheel.

In other words if the number of seeds actually producing seedlings was .897 times the number of seeds planted the seed attainment would be equal to 100 percent.

2. Percent plant attainment

$$= \frac{\text{number plants actually emerging (per 100 seeds planted)}}{115} \times 100$$

If 100 seeds actually produced 115 plants (singles counted as 1 plant, doubles as 2 plants etc.) the plant attainment would be 100 percent.

The static pressure method of planting was as follows: The soil was scraped aside from the planting area and ten seeds were placed on this area. Soil, to a depth of about one inch, was carefully spread over the seeds to avoid disturbing their placement and a block of wood was placed on top of this soil. A pressure of 1, 2, 3, or 4 pounds per square inch was then applied. A calibration of the mechanical seeding unit showed that an average of 10.9 seeds were being planted per foot of travel.

No water was added to the soil from the time of planting to the time of stand-counts. The moisture content of the soil at seed depth for the two trials was

Planting	% moisture at seed depth-dry basis	
date	Start of test	End of test
3-4-48	22	13
4-7-48	20	10

The results of the final stand counts on the two experiments are shown in Table 2.

Table 2 Seed and Plant Attainment by Various Planting Methods

Planting date	Method	% seed attainment	% seed attainment
3-4-48	4 p.s.i.	71.4	83.5
	3 p.s.i.	62.4	62.8
	2 p.s.i.	53.5	55.7
	1 p.s.i.	24.5	19.1
	Boat Opener	58.8	56.2
	Wheel Opener	45.3	50.5
	Wheel Opener plus 53.5 lb. Wheel	36.8	41.8
	Hand plant in row	21.2	17.5
4-7-48	4 p.s.i.	53.3	56.0
	3 p.s.i.	53.3	58.9
	2 p.s.i.	36.0	36.7
	1 p.s.i.	37.3	41.5
	Boat Opener	40.5	36.3
	Wheel Opener	38.0	42.1
	Hand plant in row	8.8	7.8

Analyses of variance for the static pressure plantings for the two dates were made. The comparisons for seed and plant attainment are shown in Tables 3 and 4.

Table 3 Comparison of Germinated Seeds

Planting Date 3-4-48

P.S.I.	Count for 5 Replications	Comparisons
4	32	Significantly better than 1
		No difference between 4, 3, and 2
3	29	Significantly better than 1
		No difference between 3 and 2
2	24	Significantly better than 1
1	11	

There were no significant differences in either germinated seeds or total plants for the seeding made on April 7, 1948. However the trend was in favor of heavier compaction.

No analysis was made including the mechanical seeding units since there was insufficient room to permit replications. Table 2 shows the boat opener was slightly better

Table 4 Comparison of Total Plants

Planting Date 3-4-48

P.S.I.	Count for 5 Replications	Comparisons
4	48	Highly significant over 1
		Significantly better than 2
		No difference between 4 and 3
3	39	Highly significant over 1
		No difference between 3 and 2
2	32	Highly significant over 1
1	11	

than the wheel opener and both were much better than the hand planting. It was noted, in the case of hand planting, that the soil dried out quickly down to the seed depth. There was no compaction of the soil in the case of hand planting.

Summer - 1948.

Equipment. The 53.5 pound cast-iron wheel was found to be unsatisfactory for packing the soil. (Fig. 15) In order to arrive at compaction of the soil over the planted seed, such as was attained by means of the static pressure method (i.e. without cracking of the surface) a bicycle tire compaction unit was devised as shown in Fig. 16. In operation the tire was run slightly deflated (inflation pressure approximately 14 pounds per square inch) which resulted in a fairly large flat surface in contact with the soil at any given time. This arrangement permitted a compaction of the soil without the undesirable cracking condition as caused by the 53.5 pound wheel.

In the field experiments the force of the bicycle tire on the soil was varied by adding weights to the box at "a" in Fig. 16. The weights in the box were regulated so that the tire exerted forces of 58 and 100 pounds on the soil. As a laboratory check on the tire area in contact with the soil, the tire was placed on a sheet of paper, weights were added to the box "a", and a record made of the area of the tire in contact with the paper. The results are shown in Table 4.

Fig. 17 shows an underneath view of the planter as used for the 1948 summer experimental plantings. The only change was the addition of the rotary tillage unit shown at "a" in Fig. 17. The rotary tillage unit was introduced as a

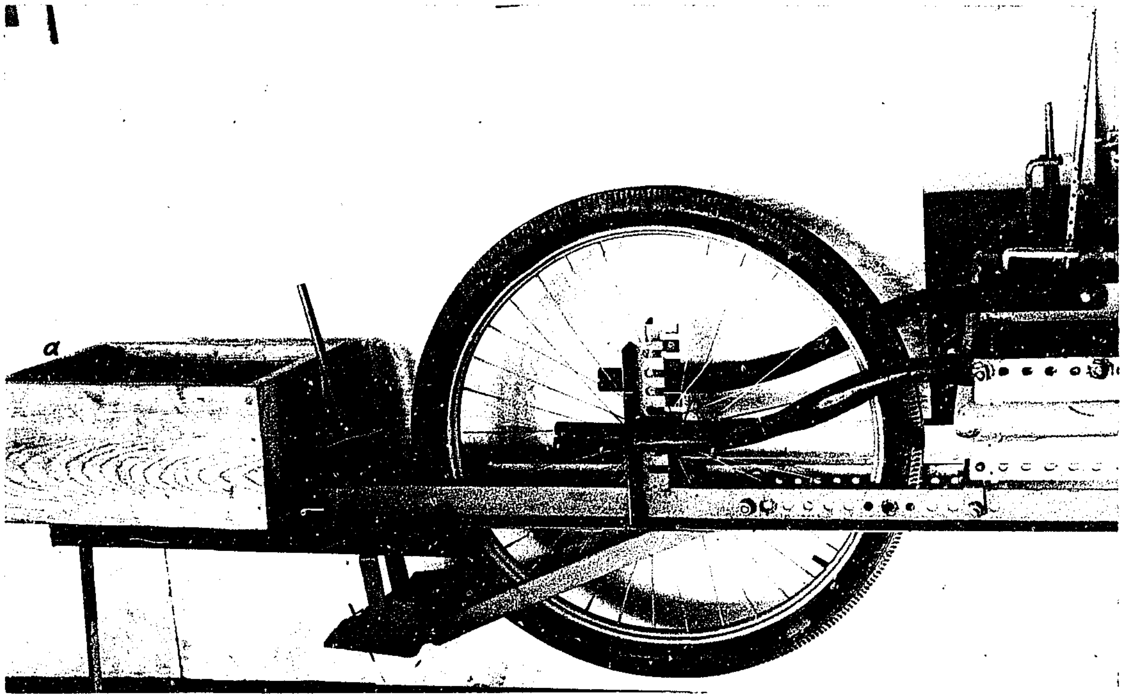


Fig. 16 Bicycle Wheel Arrangement for Compacting Soil Around the Seed. Shown in Position on Planter.

Table 4 Force on Tire vs. Tire Area in Contact with Paper. Tire Inflated to 14 P.S.I. at Start of Test.

Weight at "a", lbs.	26	45	55	70
Force on Bicycle Tire, lbs.	58	100	122	155
Tire Area in Contact, Sq. In.	5.8	7.5	8.1	9.8

variable with the aim of determining what effect a finely pulverized seedbed might have on emergence.

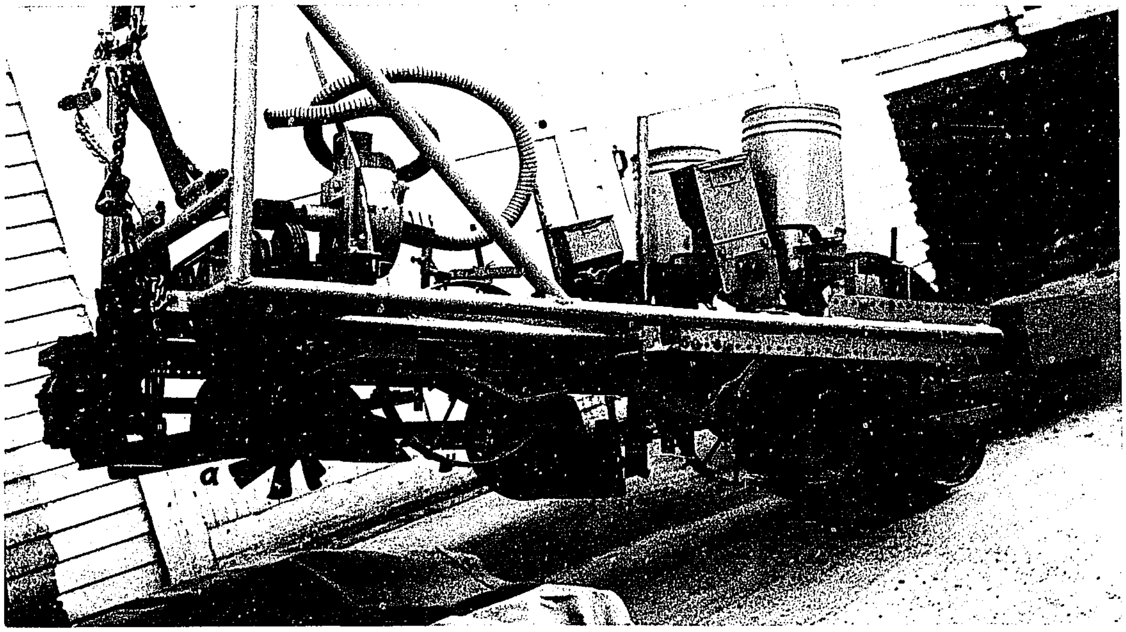


Fig. 17 Underneath View of Michigan State College Experimental Sugar Beet Planter.

Design of field experiments. Fig. 18 shows the design of an experiment which was performed at four different times. Two furrow openers, three packing procedures, and two variations in pre-seeding rotary tillage gave a total of twelve experimental combinations. The experimental planter was a two-row machine and planted one conventional or check row for each experimental row. The experimental combinations are shown on Fig. 18.

Observations and stand counts on early-season plantings

O_1 P_1 T_1	1
O_1 P_1 T_2	2
O_1 P_2 T_2	3
O_1 P_2 T_1	4
O_1 P_3 T_1	5
O_1 P_3 T_2	6
O_2 P_3 T_2	7
O_2 P_3 T_1	8
O_2 P_2 T_1	9
O_2 P_2 T_2	10
O_2 P_1 T_2	11
O_2 P_1 T_1	12

O_1	Wheel Opener
O_2	Boat Opener
P_1	Bicycle Wheel, 58 lbs wheel force on soil.
P_2	Bicycle Wheel, 100 lbs wheel force on soil
P_3	Drag-in Only
T_1	Rotary Tillage in front of Opener
T_2	No Rotary Tillage

Planter Combinations

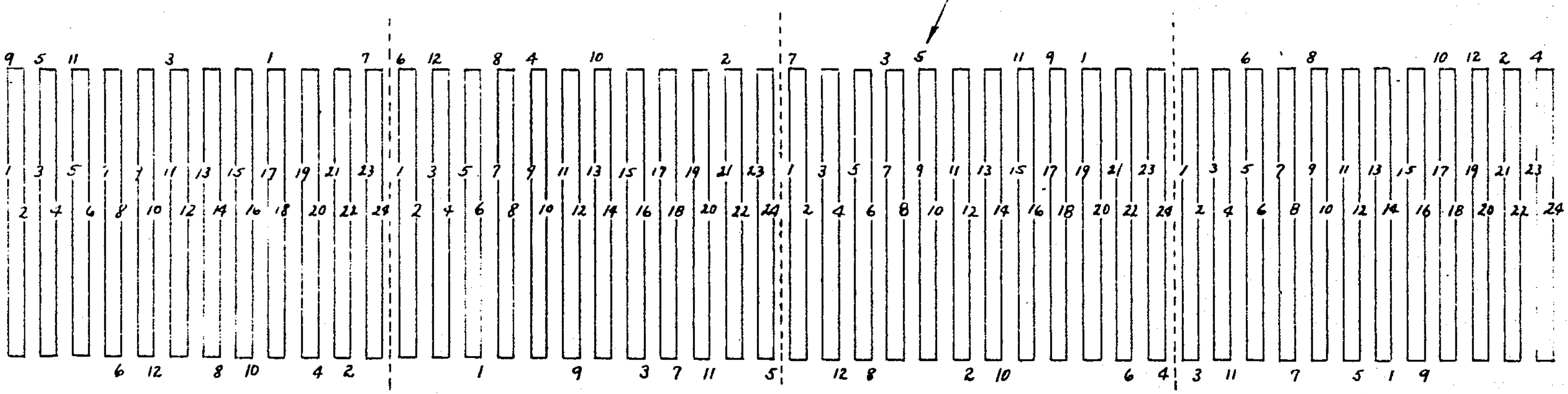


Fig 18. Sugar Beet Planting Layout for Four Experiments.

indicated that the wheel opener appeared to be giving better results than the boat opener. Also it was desired to test a heavier compaction than any of those indicated on Fig. 18. Consequently a fifth experiment was made, utilizing the wheel opener only. The layout of this experiment and the variables are shown on Fig. 19.

Test results-four field experiments. Two hundred-inch stand-counts of emerged beets were made on each row, both for the experimental and the paired check rows. Planting dates for the first four experiments were made on May 2, May 22, June 16 and July 20, 1948. Analyses of variance were made of all data. The results of a comparison of experimental treatments with paired check rows for four experiments is shown in Table 5. A comparison of experimental treatments only is shown in Table 6. The experimental variables were as follows:

O_1 - Wheel opener. (See Fig. 9)

O_2 - Boat opener. (See Fig. 10)

P_1 - Bicycle wheel, 58 pounds force on soil. (See Fig. 16)

P_2 - Bicycle wheel, 100 pounds force on soil.

P_3 - Drag-in only.

P_1	T_1	1
P_1	T_2	2
P_2	T_2	3
P_2	T_1	4
P_3	T_1	5
P_3	T_2	6
P_4	T_2	7
P_4	T_1	8

T_1	Rotary Tillage in front of Opener
T_2	No Rotary Tillage
P_4	Drag-in only
P_1	Bicycle Wheel. 58 Lbs. force on Soil.
P_2	Bicycle Wheel. 100 Lbs. force on Soil.
P_3	Bicycle Wheel. 155 Lbs. force on Soil.

Planter Combinations

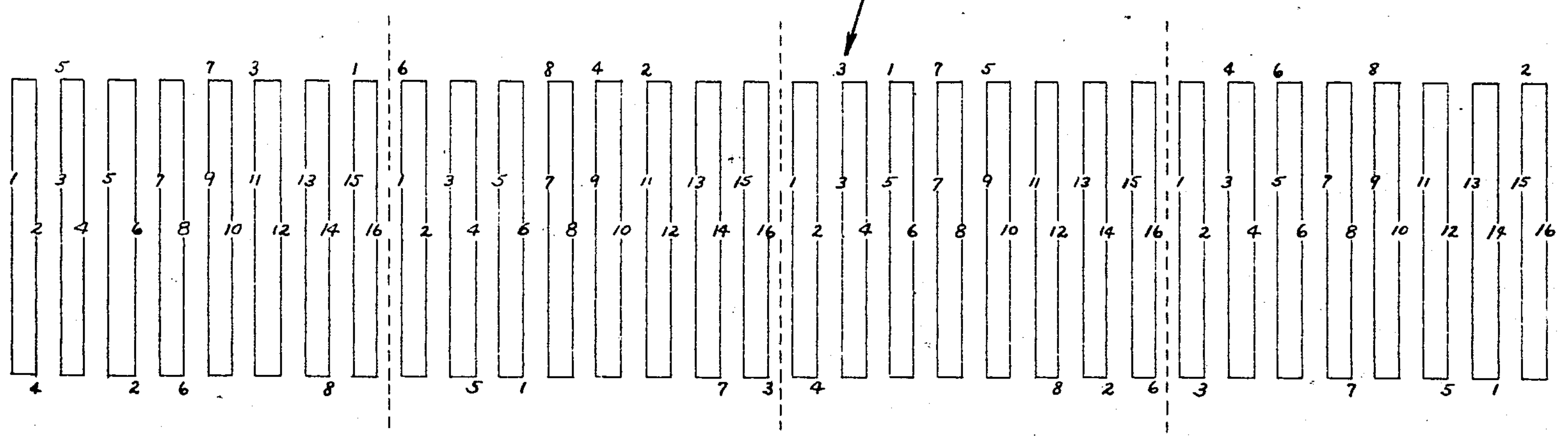


Fig. 19. Experimental Sugar Beet Planting Layout.

Table 5 A Comparison of Experimental Treatments Against Paired Check Rows for Four Experiments.

The figures which are shown under "Diff." represent the difference between the total for four replications of the designated experimental combination and the total for the four paired check rows. A (+) value indicates a greater number of plants in the experimental rows. A (-) value indicates a smaller number of plants in the experimental rows.

Planting Date								Net for 4 Experiments		Experimental Treatments	
5-2-48		5-22-48		6-16-48		7-20-48					
Comb.	Diff.	Comb.	Diff.	Comb.	Diff.	Comb.	Diff.	Comb.	Diff.	Treat. No.	O P T
3*	+ 26	10*	+ 49	5**	+ 57	3	+ 9	3	+ 79	1	1 1 1
4	+ 22	11*	+ 46	4	+ 45	2	+ 2	4	+ 68	2	1 1 2
2	+ 4	6	+ 43	6	+ 26			5	+ 62	3	1 2 2
6	+ 1	3	+ 30	3	+ 14	1	0	6	+ 61	4	1 2 1
		12	+ 30	7	+ 9	10	0	2	+ 24	5	1 3 1
1	- 23	5	+ 29	11	+ 3	5	- 1	11	+ 17	6	1 3 2
5	- 23	1	+ 20			11	- 5	10	+ 11	7	2 3 2
9	- 23	2*	+ 20	2	- 2	4	- 7			8	2 3 1
10	- 25	7	+ 19	10	- 13	6	- 9	12	- 23	9	2 2 1
11	- 27	4	+ 8	12	- 14	9	- 34	1	- 29	10	2 2 2
8	- 38	9	+ 7	8	- 22	8	- 47	7	- 72	11	2 1 2
12	- 39			1	- 26	7	- 59	9	- 86	12	2 1 1
7	- 41	8	- 39	9	- 36	12	Lost	8	-146		

* Indicates that the experimental treatment was significantly better than the paired check rows.
** Indicates that the experimental treatment was highly significantly better than the paired check rows.

T_1 - Rotary tillage in front of opener.

T_2 - No rotary tillage in front of opener.

Table 6 Summary of the Analyses of Variance for the Four Experiments.

Comparison		Planting Date			
		5-2-48	5-22-48	6-16-48	7-20-48
Comparison of experimental treatments only.	O	O_1**	O_1**	O_1**	O_1**
	P	----	----	----	----
	T	----	T_2*	T_2*	----
	O x P	*	----	----	----
	O x T	**	**	----	----
	P x T	----	----	----	----
	OxPxT	----	**	**	----
Experimental treatments better than paired check rows.		3*	10* 2* 11*	5**	----

* Significant (at 5% point)

** Highly significant (at 1% point)

The comparison of experimental treatments only indicates that the total for the wheel opener (O_1) was better at every date than the boat-type opener. Without pre-seeding rotary tillage (T_2) was equal to or better than rotary tillage. The comparison of experimental treatments with paired check rows indicates no experimental treatment being better for all planting dates. A summary of the variables in the five treatments showing significance follows:

Treatment number	Opener type	Pre-seeding rotary tillage	Force on soil by bicycle wheel
2	wheel	no	58 lbs.
3	wheel	no	100 lbs.
6	wheel	yes	drag-in only
10	boat	no	100 lbs.
11	boat	no	58 lbs.

A study of the data shown in Table 5 shows that in 23 cases out of 48 the experimental counts were greater than for the paired check rows, even though the differences may have or may not have been statistically significant. A summary of the number of times each variable occurs in the 23 instances shows:

The wheel opener appears 16 times

The boat opener appears 7 times

Without pre-seeding rotary tillage appears 15 times

With pre-seeding rotary tillage appears 8 times

Compaction - 100 pounds wheel force appears 10 times

58 pounds wheel force appears 6 times

Drag-in only appears 7 times

<u>Test results-fifth experiment</u>. The layout for the fifth experiment is shown in Fig. 19. The comparison of experimental treatments with paired check rows is shown in Table 7. The code for experimental treatments is also given for convenience in comparison. Table 8 shows a comparison of experimental treatments with each other.

The analysis of variance for the experimental treatments also showed:

1. Pre-seeding tillage was not significant.
2. 155 pounds force (by the bicycle wheel) was highly significant over 58 pounds force and over drag-in only. There was no significant difference between 155 and 100 pounds force. There was no difference between 58 pounds force and drag-in only.

Table 7 A Comparison of Experimental Treatments with Paired Check Rows for the Fifth Experiment.

The figures which are shown under "Diff." represent the difference between the total for four replications of the designated experimental treatment and the total for the four paired check rows. A (+) value indicates a greater number of plants in the experimental rows. A (-) value indicates a smaller number of plants in the experimental rows.

Treatment No.	Diff.	Variables P	Variables T
3*	+47	2	2
5	+24	3	1
4	+ 7	2	1
6	- 4	3	2
1	-10	1	1
7	-11	4	2
2	-18	1	2
8	-30	4	1

P_4-Drag-in only.

P_1-Bicycle wheel, 58 lbs. force

P_2-Bicycle wheel, 100 lbs. force

P_3-Bicycle wheel, 155 lbs. force

T_1-Pre-seeding rotary tillage

T_2-No rotary tillage.

* Indicates that the experimental treatment was significantly better than the paired check rows.

Table 8 A Comparison of Experimental Treatments with Each Other for the Fifth Experiment.

Fac-* tors	Treat. No.	Count for 4 reps.	Comparison
P_3 T_1	5	212	H.S. over 1, 8. Sig. over 7, 2. No diff. 5, 6, 3, 4.
P_3 T_2	6	197	H.S. over 1, 8. No diff. 6, 3, 4, 7, 2.
P_2 T_2	3	184	H.S. over 8. Sig. over 1. No diff. 3, 4, 7, 2.
P_2 T_1	4	182	H.S. over 8. No diff. 4, 7, 2, 1.
P_4 T_2	7	177	H.S. over 8. No diff. 7, 2, 1.
P_1 T_2	2	174	H.S. over 8. No diff. 2, 1.
P_1 T_1	1	150	No diff. between 1 and 8.
P_4 T_1	8	125	

H.S. = Highly significant (at 1% point)

Sig. = Significant (at 5% point)

No diff. = No difference between.

* Note that the heaviest compaction (P_3) was best in this experiment.

Note that all four top treatments are the heavier packings.

Compaction tests. A measure of relative compaction effect on the soil was obtained during the winter trials by by means of air permeability tests. The method of air permeability was not deemed satisfactory for field tests since a small break in the soil would prevent the proper functioning of the unit. In order to test the relative compaction effects of different treatments the recording compaction unit shown in Fig. 20 was designed and constructed. Its function is as follows:

Crank "a" is turned, which by means of a rack and pinion arrangement forces tube "b" downward. Cylinder "c" and line "d" contain oil. A piston in the lower part of cylinder "c" is connected to rod "e". Soil probe "f", which is attached to "e" is forced into the soil as crank "a" is turned. As soil probe "f" is forced into the soil oil pressure causes the recorder arm to indicate the force required to push the probe into the soil. In order to obtain a record of the force at any given depth the chart "g" is caused to rotate by means of the string "h". The string "h" passes around a drum which in turn is attached to the rear of the plate to which the chart is fastened. Soil probes of different diameters may be readily installed since the rod "e" is threaded at the lower end. Probes of five diameters were machined in order to provide sufficient flexibility for varying soil hardnesses. The diameters were 1, 3/4, 1/2,

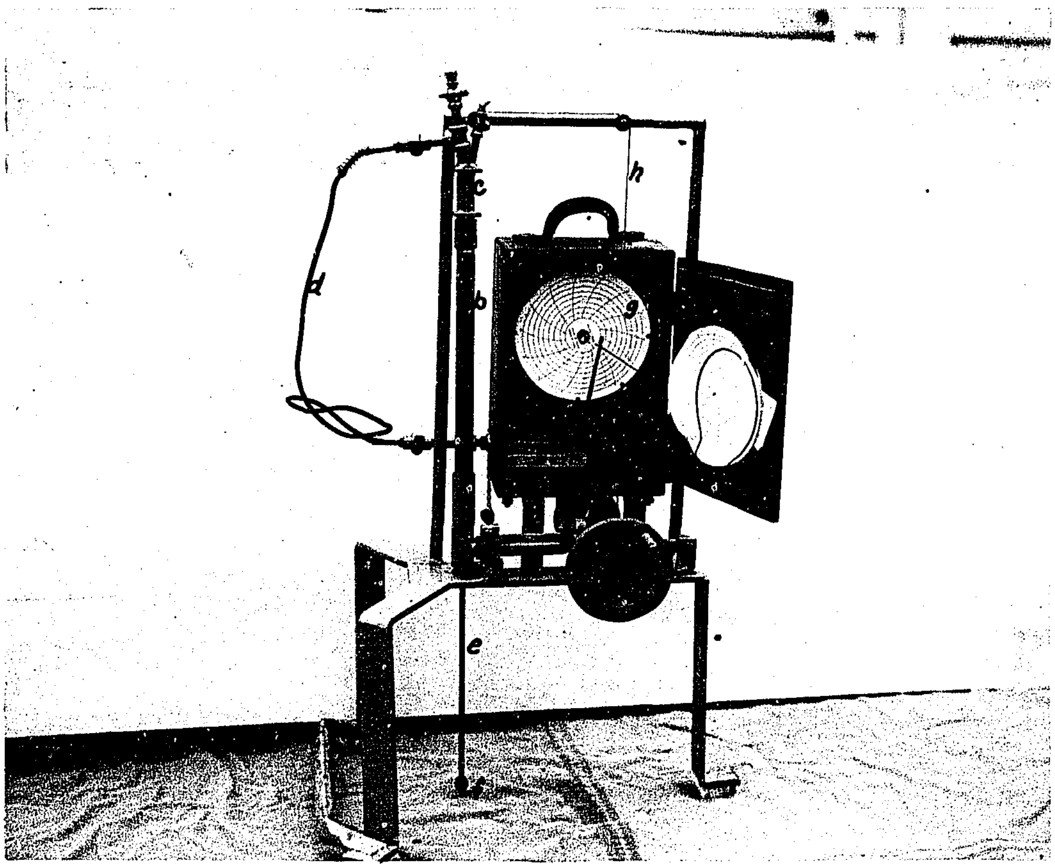


Fig. 20 Recording Soil Compaction Tester.

3/8, and 5/16 inches.

It was necessary to calibrate the unit for both depth and force in pounds. Suitable charts were made as shown in Fig. 21.

Fig. 22 shows the layout of the plots for field compaction tests. The plot was one of those used earlier in the season for emergence tests and the soil was classified

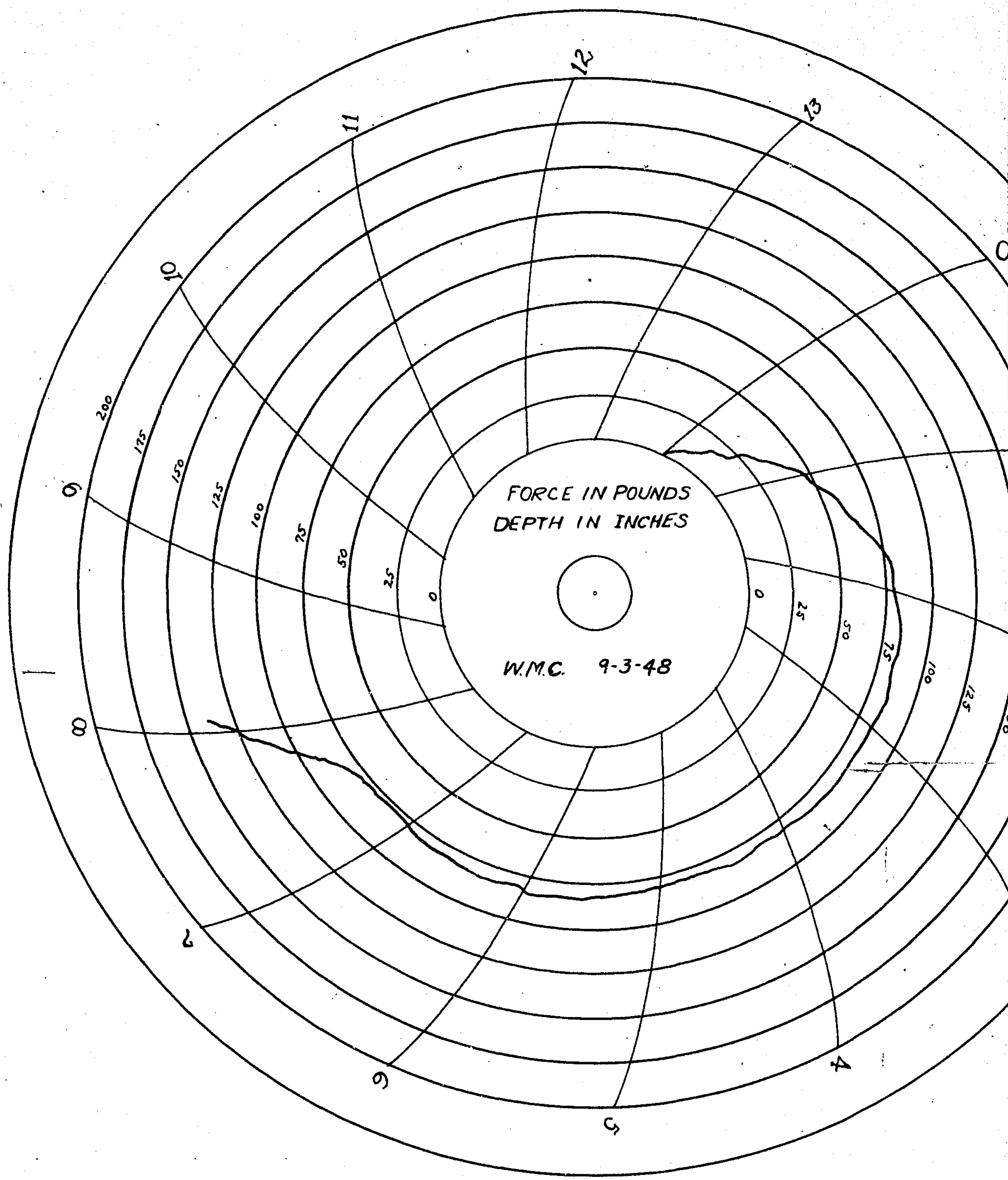
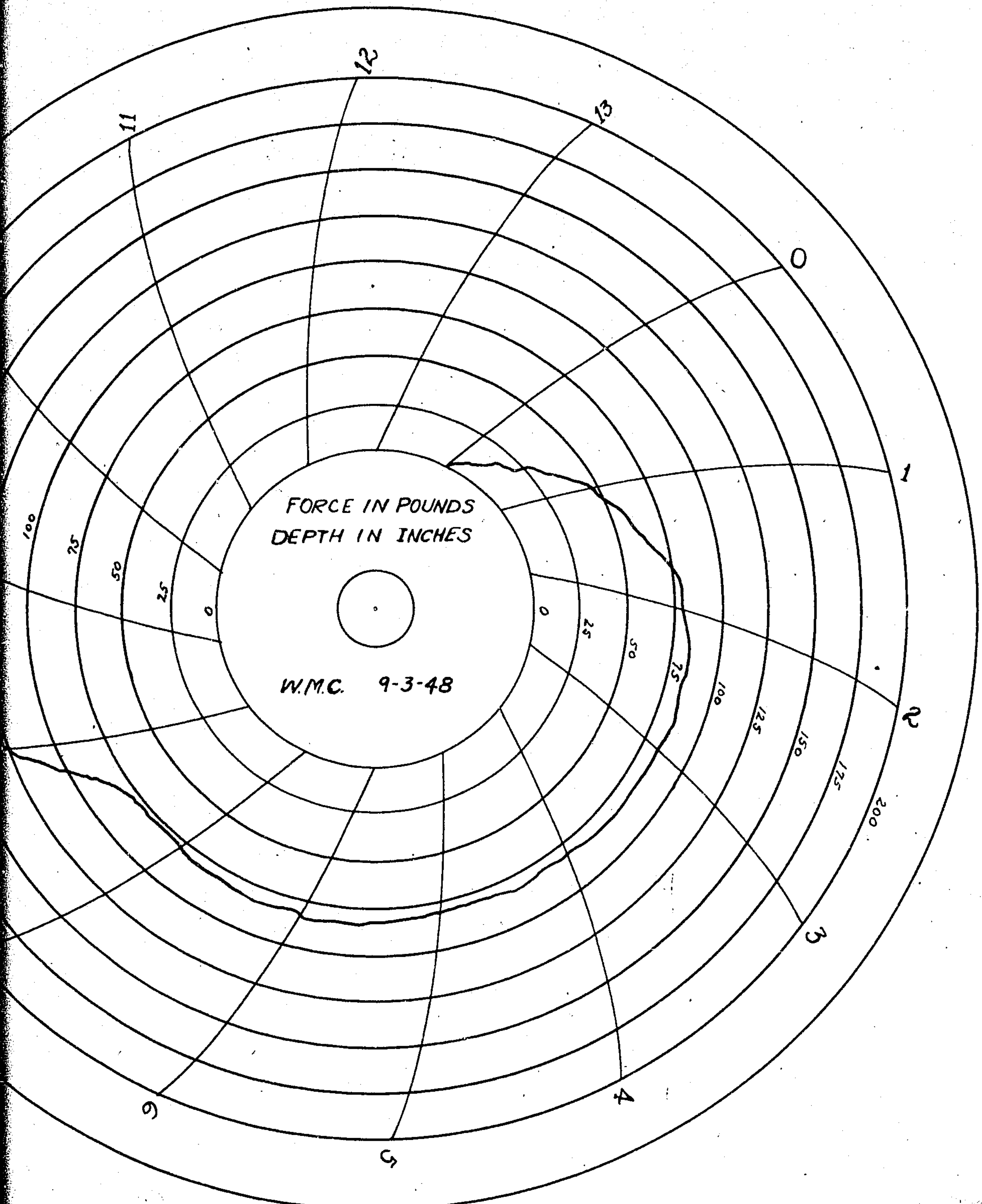
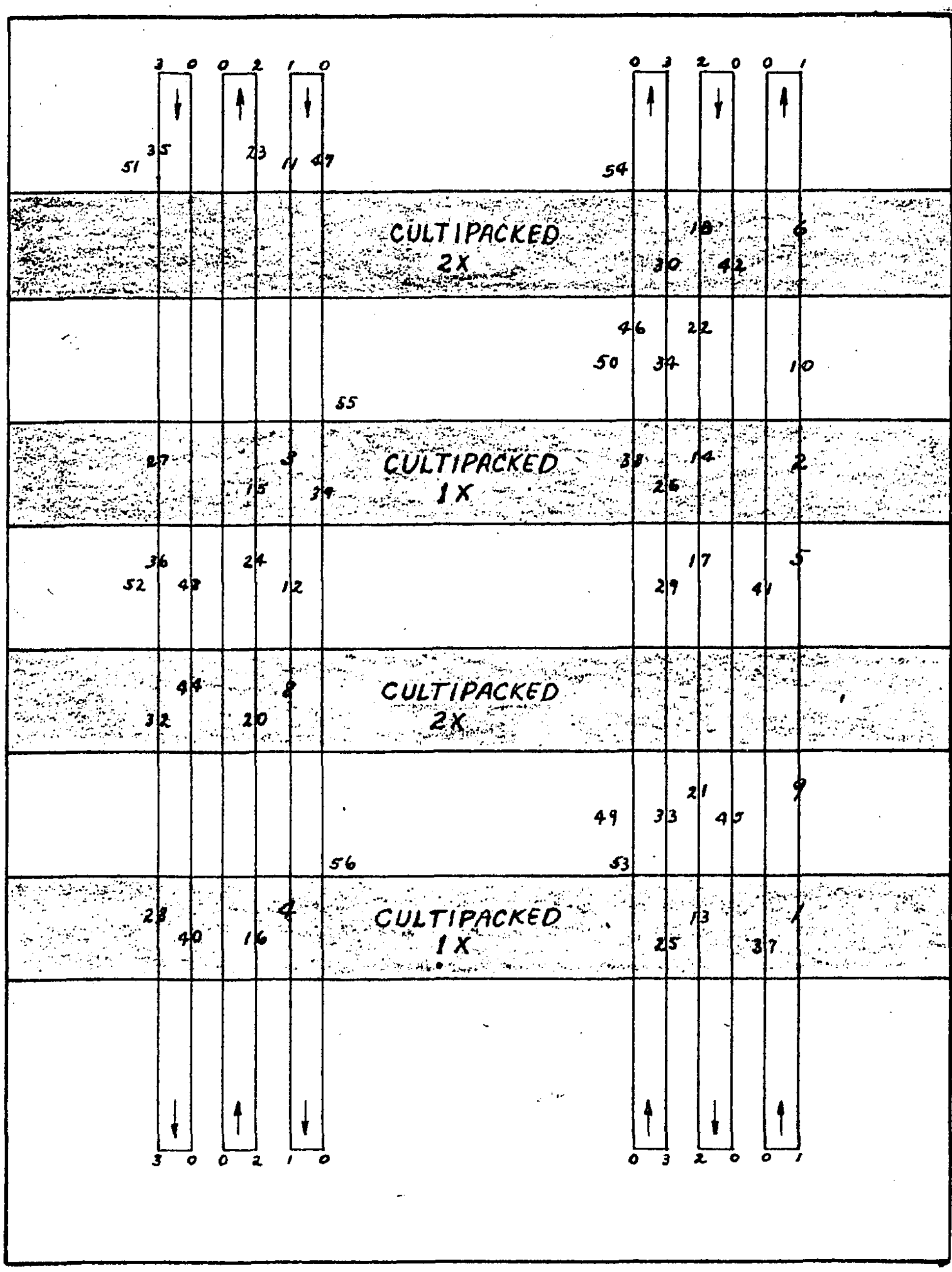


Fig. 21. Sample Chart for Recording Soil Compaction Tester.



21. Sample Chart for Recording Soil Compaction Tester.



Rows: 0 = Standard Opener & Press Wheels
1 = Exp't. Row. Bicycle Wheel, 58 Lbs. Force on Soil.
2 = " " " " 128 " " " "
3 = " " " " 207 " " " "
Probe: One inch diameter in all tests.

Soil
Plowed & Disced 9-14-48
Rain .23 inch 9-15-48
Dragged & Cultipack. 9-16-48
Compaction Tests 9-17-48

Fig. 22 Recording Soil Compaction Tester.

as a sandy loam. The complete plot was plowed, disced, and dragged. Portions were cultipacked as shown in Fig. 22. Two chart readings were taken at each number indicated on the figure. Each treatment was carried out in four places and since two chart readings were taken at each point there were eight tests or replications of each treatment. The variables used were:

Let: W_0 = Standard opener and press wheel unit.

W_1 = Experimental wheel opener. Bicycle wheel exerting 58 pounds force on soil.

W_2 = Experimental wheel opener. Bicycle wheel exerting 128 pounds force on soil.

W_3 = Experimental wheel opener. Bicycle wheel exerting 207 pounds force on soil.

O_0 = No opener (unpacked soil).

O_1 = Experimental wheel opener.

O_2 = Standard or conventional opener.

C_0 = No cultipacking.

C_1 = Cultipacked once.

C_2 = Cultipacked twice.

Table 9 shows the variables and locations for each treatment used in the compaction tests.

Table 9 Treatment Code for Compaction Tests

Treatment No.	Planter Compaction	Opener	Cultipacking	Treatment Locations on Fig. 22
1	W_1	O_1	C_1	1 2 3 4
2	W_1	O_1	C_2	5 6 7 8
3	W_1	O_1	C_0	9 10 11 12
4	W_2	O_1	C_1	13 14 15 16
5	W_2	O_1	C_2	17 18 19 20
6	W_2	O_1	C_0	21 22 23 24
7	W_3	O_1	C_1	25 26 27 28
8	W_3	O_1	C_2	29 30 31 32
9	W_3	O_1	C_0	33 34 35 36
10	W_0	O_2	C_1	37 38 39 40
11	W_0	O_2	C_2	41 42 43 44
12	W_0	O_2	C_0	45 46 47 48
13	No treatment after dragging			49 50 51 52
14	Tractor wheel packing, two times			53 54 55 56

Fig. 21 shows the chart for the first test at location number 47. This chart is a typical one of the group and shows the force rapidly increasing for the first two inches in depth and then remaining approximately the same until the probe reached plow depth. At plow depth the force started increasing rapidly and the indicator soon went off the chart if the test was continued. The 1 inch probe was used in all tests. Table 10 summarizes the readings at one inch depth.

Tests were made of the compacting effect of places where the rear tractor pneumatic tire had passed two times. The data shown in Table 10 were analyzed statistically. Table 11 shows a comparison of the treatments. The comparisons indicate that the effect of the tractor tire was very large as compared to any of the other treatments. It may also be noted that the effect of cultipacking tended to cause a higher reading than any of the forces exerted by the bicycle tire.

Table 10 Soil Compaction Tests. Penetration Force in Pounds at One Inch Depth

Treat-ment*	Replication 1	2	3	4	5	6	7	8	Treat-ment Totals
1	30	30	30	30	15	30	20	45	240
2	75	35	25	30	60	40	35	55	355
3	25	20	20	25	15	20	20	25	170
4	65	30	30	35	30	40	30	25	285
5	45	40	45	30	40	50	35	35	320
6	30	25	25	20	20	25	25	35	205
7	60	25	25	40	35	35	45	40	305
8	50	30	45	45	50	25	40	45	330
9	30	15	30	30	50	45	20	20	240
10	35	85	25	25	30	35	25	55	315
11	35	40	40	20	25	35	45	25	265
12	25	15	20	20	50	15	15	15	175
13	10	10	10	10	10	15	10	35	110
14	125	65	110	80	115	80	135	125	835
Rep. Totals	640	465	480	440	545	490	510	580	4150

* Treatment Code on page 59.

Table 11 Comparison of Soil Compaction Effects of Fourteen Treatments.

Lbs. Force on Soil by Experimental Wheel	No. Times Soil Cultipacked	Opener	Treatment No.	Total Lbs. for 8 Reps.	Comparison of Treatments		
Tractor wheels 2 x			14	835	H.S. over 2 to 13.		
58	2	E	2	355	H.S. over 6 to 13.	Sig. over 11.9.1.	No diff. 2 to 4.
207	2	E	8	330	H.S. over 6 to 13.	Sig. over 9.1.	No diff. 8 to 11.
128	2	E	5	320	H.S. over 12 to 13.	Sig. over 6.	No diff. 5 to 1.
----	1	S	10	315	H.S. over 12 to 13.	Sig. over 6.	No diff. 10 to 6.
207	1	E	7	305	H.S. over 12 to 13.	Sig. over 6.	No diff. 7 to 6
128	1	E	4	285	H.S. over 13.	Sig. over 12.3.	No diff. 4 to 6.
----	2	S	11	265	H.S. over 13.	Sig. over 12.3.	No diff. 11 to 6.
207	-	E	9	240	H.S. over 13.		No diff. 9 to 3.
58	1	E	1	240	H.S. over 13.		No diff. 9 to 3.
128	-	E	6	205		Sig. over 13.	No diff. 6.12.3.
----	-	S	12	175			No diff. 12.3.13.
58	-	E	3	170			
No treatment after dragging			13	110			

H.S. = Highly Significant, or Significant at the 1% point.
Sig. = Significant at the 5% point.

CONCLUSIONS

1. An experimental wheel-type furrow opener showed promise of improving emergence over that of the conventional planter. The wheel-type opener consisted primarily of a 3/4 inch thick circular piece of plate steel of 7 inches radius, the outer 1 inch being beveled to a thickness of 3/8 inch. Suitable depth control was provided and the opener rolled a seed path into the soil.

2. The maximum static pressure used for soil compaction in the laboratory planting tests was 4 pounds per square inch. Compactions resulting from a static pressure of 4 pounds per square inch were found to be statistically better, as measured by plant emergence, than compactions obtained by the application of lower pressures down to 1 pound per square inch.

3. The compaction of the soil at the bottom of the seed track made by the wheel opener was equal to that caused by a static pressure of about 2 to 3 pounds per square inch.

4. A comparison of experimental openers indicated the wheel opener to be much better than the boat-type furrow opener. The boat-type opener which received its name from the

rounded bottom and boat-shaped prow, was slid through the soil to form a rounded and compacted place for depositing the seed.

5. A pneumatic compaction wheel which imparted a uniform and consistent pressure upon the soil was found to be better than a cast-iron compaction wheel. The solid cast-iron wheel tended to cause cracks to be formed in the soil with resultant drying out of the seed bed. Greater unit pressures by the pneumatic wheel resulting in heavier soil compactions around the seed were found to give better emergence than the lighter compactions, especially under drier seed-bed conditions.

6. Air permeability tests, which consisted of determining the time required for a given volume of air to pass through a soil sample, were satisfactory for comparing soil compaction effects in the greenhouse but were not considered suitable for field use. A new machine was developed for accurately measuring soil compaction in the field and was successfully used to compare various soil compaction treatments.

7. The investigations indicated that pre-seeding rotary tillage was of little or no value.

SUMMARY

The production of sugar beets requires two principal labor peaks; one for spring blocking and thinning and the other for harvest in the fall. Much progress has been made in the mechanical harvesting of sugar beets and commercial machines are now available which will successfully eliminate hand labor. Progress has also been made in seeding machines and planting techniques but much hand labor is still the rule for spring work. This investigation was made to determine some of the factors which influence emergence of sugar beets and to devise ways and means of improving the emergence. The long-time objective is the elimination of hand work from the production of sugar beets.

Research on planting equipment has been carried on along two main lines:

1. Precision planting. As late as 1930 sugar beet drills were made to scatter along the row approximately 15 to 20 pounds of whole seed per acre. Machines now available are capable of metering and distributing about 4 pounds of segmented seed per acre.

2. The determination and improvement of those factors which may improve the effectiveness of planters or planting methods on field germination. Some progress has been made in this work but new devices or techniques must be proved in the field over a period of years.

A new type of rolling wheel furrow opener was designed and used in the experimental work. The results of field tests indicate that certain planting treatments which include this opener are better than conventional planting methods but final judgment must be reserved until the opener has been tried for more seasons.

A pneumatic compaction wheel was found to be better than a cast-iron compaction wheel. Larger forces by the compaction wheel resulting in heavier soil compactions around the seed were found to give better emergence than the lighter compactions, especially under drier seed-bed conditions.

Greenhouse tests were used to determine the comparative performance of the experimental openers with the performance of plantings made under conditions of known compaction. Compactions resulting from the application of a static pressure of 4 pounds per square inch on the soil were found to be better than compactions obtained by the application of 1 pound per square inch.

It was found that air permeability tests of soil were a satisfactory method in the laboratory of comparing the compaction effects of furrow openers with the effects of known static pressures on the soil. The checking of planting procedures by laboratory and greenhouse experiments permitted planter research to be carried out more rapidly than by usual summer field experiments only.

A machine was designed and constructed for recording the force required to push a probe into the soil. The machine was successfully used to evaluate compaction treatments used in the planting experiments.

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