IMPROVEMENTS IN DESIGN OF THE TILL-PLANTER

by

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B. S., Kansas State University
of Agriculture and Applied Science, 1959

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agricultural Engineering

KANSAS STATE UNIVERSITY
OF AGRICULTURE AND APPLIED SCIENCE

1960

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INTRODUCTION

In 1958 Stanley Joe Clark conducted an investigation of the performance of the 4M-21 till-planter for Kansas agriculture. The purpose of his investigation was to determine: (1) some of the problems connected with its use in Kansas, (2) crop response from till-planted crops as compared to other planting methods, and (3) power requirements of the till-planter for different soil conditions.

The International Harvester Company designed and built the 4M-21 till-planter (Fig. 2) as an experimental mulch planter in 1947. It was designed to prepare a seedbed, fertilize, and plant in a single operation in previously unworked soil. It was designed to plant any row crop that could be planted with a conventional planter, providing the crop was fast growing and the weeds could be controlled with chemicals or mulch cultivating equipment.

The till-planter originally consisted of two front-mounted tillage units with fertilizer attachments and a two-row rear-mounted planter with fertilizer units. Each tillage unit consisted of an upper 36-inch sweep, an 18-inch sweep mounted below and behind the upper sweep, four rotary-hoe wheels, an optional special packer-wheel attachment, a rolling coulter, a fertilizer unit, and trash rods. The large sweeps operate at two to three inches deep to undercut the weeds and the smaller sweeps loosen a rootbed to a depth of seven to eight inches at which depth the fertilizer is deposited. The rotary-hoe wheels were mounted behind the sweeps to produce an eight-inch wide seedbed and to drive the fertilizer units. The special packer wheels were mounted behind the rotary-hoe unit to aid in preparing the seedbed when the soil conditions required it. The rolling coulters cut the trash ahead of the sweep beams whereupon the trash rods mounted on each side of the sweep beams pushed the residue out away from the seedbed while allowing loose dirt to filter through.

The rear-mounted planter was a conventional stub-runner planter. The fertilizer units on the planter were equipped with split boots that placed the fertilizer shallow and close on both sides of the seed row.

It is evident that the till-planter was designed to reduce field operations and to take advantage of mulch tillage benefits.

The till-planter is not considered to be an experimental machine by the manufacturer, but it has not come into widespread use in any locality. The manufacturer, seed companies, experiment stations, several Midwestern colleges and universities, and a few selected farmers have tested the IHC 4M-21 till-planter according to literature from the manufacturer.

Detailed reports in regard to the above tests have not been widely published. Those few reports that have been published prior to Clark's work have largely been concerned with the agronomic problems rather than the mechanical problems connected with the till-planter.

To the best of the writer's knowledge, Clark initiated the use of the till-planter in Kansas.

PURPOSE FOR IMPROVING THE DESIGN OF THE TILL-PLANTER

Clark (1959) found that the power required for the till-planter for most soils could be expected to be from 32 to 57 horsepower at 3.5 mph including the slippage loss. With the slippage loss excluded the range was 29 to 46 horsepower. The range that could be expected to be required by the tillage units alone at 3.5 mph was from 20 to 35 horsepower. This ranged from 50 to 63 percent of the axle horsepower for the three soils tested.

Rear wheel slippage was high with a range from a low of 8 percent to a high of 24 percent for all of the individual tests. The average slip for each soil was 11.00, 14.45, and 17.43 percent for loam, silty clay, and clay soils respectively.

Other problems that Clark (1959) found were as follows: (1) the rotary-hoe and packer wheels clogged frequently, (2) sufficient depth of operation of the tillage units was unattainable under some conditions, (3) depth control was difficult at times, and (4) a weed problem resulted in most cases due to the uncut strip between the upper sweeps.

In view of the above findings and because of the previous lack of information concerning the problems connected with the till-planter, the purpose of this work was:

1. To redesign the till-planter to permit rear mounting thereby improving its performance and shortening the time required to mount and dismount it from the tractor.

2. To determine the effect of the new design on its performances with respect to wheel slippage, field stoppage, soil penetration, and depth control.
3. To determine the total vertical and horizontal components of the soil forces which act on the till-planter for different soils at varying speeds.
4. To determine the power requirements of the redesigned till-planter in different soils.
5. To continue the project Clark started on row crop response from till-planted crops as compared to other tillage and planting methods in Kansas.

REVIEW OF LITERATURE

The Minimum Tillage Concept

Interest in minimum tillage came about as a result of agronomists studying several interrelated problems: (1) better seed germination, (2) less erosion, (3) better moisture absorption, and (4) smaller weed populations, according to Fogarty (1959). The blame appeared to lie in the lap of compaction as a result of continuous movement of machinery across the field. The five aims of minimum tillage according to Aldrich (1956) are largely in agreement with the above. These are as follows:

1. To save labor by reducing the number of trips over the field.

2. To reduce soil compaction.
3. To increase the water infiltration rate of the soil by leaving the surface loose and open.
4. To reduce soil erosion by reducing water runoff and by leaving the soil in small aggregates or granules which are less easily carried off the field by water or wind.
5. To reduce weeds by leaving the soil surface too loose for annuals to germinate and by causing the broken rootsticks of perennials to lose contact with the soil and thus dry out and die.

Page, et al., of Ohio (1946) believe that a minimum amount of mechanical working of the soil is the most desirable. The tillage operation should loosen the soil so that the natural aggregates are separated without being destroyed and tillage beyond this point may be harmful. They also suggest that excess emphasis is being placed on seedbed preparation rather than rootbed preparation since seedbed requirements are not critical for the large seeded crops.

The problem of soil compaction is nationwide and its seriousness varies, according to research conducted by Nichols (1957) at the National Tillage Machinery Laboratory at Auburn, Alabama. Farmers are using more heavy equipment which is causing a greater compaction problem due to their greater weight and due to excess cultivations resulting from the ease and rapidity with which they can go over the land. It is also known that a slipping tire also causes greater compaction and sealing of the soil. Soil compaction reduces air and water infiltration which in turn affects crop yields. If the weight of equipment is not decreased, then its harmful soil compacting effect can be lessened by being more careful to perform the operations when the moisture content is low.

Soil compaction due to slippage can be decreased by improved mounting methods and weight transfer. Practice of the minimum tillage concept would decrease the compaction problem due to the reduced number of operations necessary to produce a crop.

Cook, et al., (1958) are advocates of minimum tillage and define it as the least amount of tillage needed for quick germination and a good stand. In Michigan this can be done with a moldboard plow alone, or with a moldboard plow with a light smoothing implement attached. Moldboard plowing greatly increases total pore space and quickly buries crop residues and trash making it possible to do an accurate job of planting right after plowing.

Water penetrates these loose soils readily, reducing runoff and erosion. At a workshop on slope practices held in 1956 at Purdue University, representatives of the Soil Conservation Service, the Agricultural Research Service, the Extension Service, and State Experiment Stations agreed that plow-planting (the least amount of cultivation and packing) reduces soil loss by 40 percent. This was explained at the conference as being due to the fact that such tillage "leaves soil in condition to absorb rainfall".

Mulch Farming of Row Crops

Mulch farming resulted from the dust storms of the early thirties and it is now practiced quite extensively in the semi-arid regions where wheat is the principal crop.

Duley (1939) observed in his studies that the rapid reduction in the rate of intake of water by bare soils as rain falls on the surface, is accompanied by the formation of a thin compact layer at the surface of the soil in spite of wide variations in texture and profile characteristics. The water seems to pass very slowly through this layer. He indicated that this layer is apparently the result of a severe structural disturbance due in part to an assorting action as water flows over the surface and the fine particles are fitted around the larger ones to form a relatively non-pervious seal. Lowdermilk (1953) attributed this slow rate of intake by the bare land to a plugging of the pores by the fine material settling into them from the muddy runoff water. Duley (1939) concluded from his studies that the thin compact layer which forms on the surface of bare soils during rains has had a greater effect on intake of water than has the soil type, slope, moisture content, or profile characteristics. He also concluded that the way to keep the immediate soil surface in condition to absorb water rapidly in practice is by maintaining a cover of crop residue on the soil surface.

Peterson and Engelbert (1960) found that the effect of mulch planting on reducing erosion and water loss during the summer growing season in Wisconsin was spectacular. In one storm, a two-inch downpour two days after planting resulted in a loss of 1.75 inches of water from the conventional planting as well as 10.3 tons of soil per acre. However, where the corn had been mulch planted, no appreciable soil or water was lost. They used the

International M-21 Till-Planter for their work.

From soil splash measurements taken in two years at Coshocton, Ohio, Harrold (1949) reported an average of 12.7 tons of soil splash per acre on plowed plots and 7.5 tons per acre on mulched plots. Soil splash has been considered to be a measure of the effects of rain drop energy on erosion.

Measurements at this same station for the period of May to September of 1944 gave 2.74 inches of runoff and 25 tons per acre soil loss on plowed watersheds as compared to 0.82 inches of runoff and 0.27 tons of soil loss per acre on mulched watersheds.

Lowdermilk (1953) states:

> Leaving crop litter, which is sometimes called stubble mulch or crop residue at the ground surface in farming operations is one of the most significant contributions to American agriculture. Certain adaptations of the method need to be made to meet the problems of different farming regions, but the new principle is the contribution of importance.

Effects of Tillage Methods on Corn

Mulch farming has not gained wide acceptance in the more humid areas possibly because crop yields are frequently higher with conventional plowing. This does not, however, eliminate minimum tillage practices entirely since some methods such as plow-planting employ the use of the conventional plow.

Several investigators, Hansen, et al., (1959) have worked with this method and believe that it has merit. In support of this they state:

> In humid regions the moldboard plow may be the only tillage tool needed to loosen the soil, break the sod, control weeds, dispose of trash and crop residue. Frequently, however, it may be necessary to pull a light-draft tillage tool behind the plow to prepare a satisfactory seedbed.

Hansen, et al., (1959) describe work started in 1957 at Michigan State University which resulted in building a one-row corn planting unit consisting of commercially available component parts. This unit consisted primarily of an initial press wheel, disk furrow openers, runner-type seed furrow opener, seed press wheel, and a rear press wheel. It was mounted on the front, right-hand cultivator frame of a tractor having wide spaced front wheels for better control. Fertilizer hoppers were mounted on both sides of the tractor engine and driven by the rear tractor wheels. Seed and starter fertilizer were placed in the crown of the center furrow which had been turned by the rear-mounted 3-bottom plow in the previous pass. If additional fertilizer was desired it could be dropped on the unplowed ground by the left hopper and turned under with the center plow bottom.

The plow plant unit was used in an exploratory nature in 1957 on 11 farms in 6 counties. Plots at each location extended across the entire length of the fields where farmers were either getting ready to or had begun planting corn. The yields obtained from these trials varied from 30.7 to 128.6 bushels of shelled corn per acre where the experimental unit was used and from 25.6 to 108.0 bushels per acre where the cooperator planted the corn. Average yields for the plow-plant plots were 10.9 bushels per acre higher than cooperator planted areas. A statistical analysis of these plots, using the fields as replications, showed that this difference was significant at the 1 percent level. Hansen, et al., (1959) believe this fact is of particular importance since several of the farmers were using the minimum tillage principle. They also made two other observations. A marked reduction in weed population was noted where the plow-plant unit was used and soil erosion was effectively controlled. Severe erosion occurred at two locations where the corn rows ran up and down the hills in the farmer-planted areas.

Browning and Norton (1945) have carried on extensive investigations on tillage practices as they affect corn production in Iowa. They found that plowing gave the highest yields of any of the methods of tillage. Their experiences also showed that the plow was the most satisfactory for seedbed preparation for corn on slowly-drained soils. Nitrogen and potash deficiencies were evident when the seedbed was prepared by subsurface-tillage methods.

The cause for the nutrient deficiencies is thought to be caused by micro-biological activity. Tillage studies were made in Iowa in 1952 and 1953 by Schaller and Evans (1954) for the purpose of determining the effects of crop residue placement on micro-biological activity and nutrient availability.

The 1952 tests on a Webster silty-clay loam soil showed that corn yields were higher where corn stalks were removed or plowed under. Yields were reduced by 21 percent on unfertilized plots and 28 percent on fertilized plots where the crop residues were left on the surface. Nitrogen deficiencies were more pronounced on mulch-tilled plots at silking time. Weeds were more of a problem on the mulch-tilled plots. Mulch-tilling as mentioned here refers to conventional planting in a seedbed prepared by subsurface tillage. The seedbed was prepared in two operations using 24-inch sweeps, first at a depth of three inches and later at seven inches.

In 1953 similar tests on a Nicollet silt-loam soil at Ankeny, Iowa, were conducted. The soil was lighter in texture than the Webster soil of the 1952 tests. All corn yields were high and there were no significant differences resulting from different tillage methods. No significant differences in nitrogen, phosphorus, and potash content were found in an analysis of young plants and of leaves collected at silking time as a result of tillage.

Increased yields have been reported in drier regions from mulch-tilled corn where subsurface tillage was used in preparation of the seedbed. Duley and Russell (1941) found that mulch-tilled corn yielded better than corn planted in a seedbed that had been plowed.

Baugh, et al., (1950) conducted tests in 1948 and 1949 on different treatments which included turning all of the crop residue under, mixing it with the top three inches, mixing it with the top six inches, and leaving all the residue on the surface. The various implements used included a special plow and disk, a cover-crop disk, an ordinary plow, a disk harrow, different sweep assemblies, and a lister bottom with spring-tooth cultivator for strips only. They concluded that the following problems need further attention for satisfactory mulching of corn in Indiana:

1. Developing or adapting implements that prepare a deep seedbed but leave sufficient residue to give adequate erosion protection throughout the growing season.
2. Developing or adapting implements that will plant in or through residues and still maintain the residues over the entire area.
3. Development of mulch-tillage fertilization practices that will overcome the temporary deficiencies of plant nutrients which tend to reduce corn yields with mulch culture.

Hines, et al., (1947) have done considerable research on mulch-tillage in Virginia. They used the double-cut plow which covered about half of the residue. As a result of their experience they felt that there was a need for a new mulch-tillage machine which would separate the dense vegetation from the soil, till and compact a four to eight-inch seedbed, and mix in an optimum amount of residue with the soil.

Browning (1950) adds:

> A machine is needed that will prepare a seedbed so that the nutrient deficiencies will be minimized, crop production maintained, and still provide the protective action of the residues on the soil surface. If we had this machine, then we would still have to sell the farmer on changing from his present machine to this new type of machine. Until we have the machine and can show that crop yields are not reduced, farmers generally will not accept the practice of leaving crop residues on the surface.

Reports on the Till-Planter

Experimental trials were established by Peterson and Engelbert (1960) to compare the mulch planting method with the conventional seedbed preparation on three major Wisconsin soil types for 1952 to 1955 inclusive. The conventional seedbed preparation, consisting of spring plowing, two diskings, and one or two harrowings prior to planting was compared with the once-over operation of the mulch planter. The mulch planter used for these tests was the IHC 4M-21 till-planter.

The fertilizer applications for both methods included 800 pounds of 10-10-10 per acre deep placed, 300 pounds of starter fertilizer placed near the row at planting time, and side-dressed with 250 to 300 pounds of ammonium nitrate per acre at the time of last cultivation.

They found that for the better corn growing areas of the state approximately equal yields were obtained with either the conventional or the mulch planting method when the plant populations were about the same.

They also found that rodent and pheasant damage was much more serious with mulch planting then with conventional methods. In some instances the corn had to be partially replanted two or three times by hand in order to obtain a satisfactory stand with mulch planting.

In addition, the power requirements for pulling the mulch planter varied greatly depending on the vegetative cover of the field, the moisture content of the soil, and particularly the depth of penetration of the bottom sweep. If there had been appreciable erosion so that the bottom sweep penetrated the subsoil (B horizon) the power requirements increased substantially. It was necessary to add additional wheel weights and fluid in the tractor tires to provide sufficient traction. If planting is in old sod it appears desirable to put tire chains on the tractor, and disk twice before planting in order to give the sweeps a better chance to penetrate the soil. It was unnecessary to disk grain stubble or corn stalks unless the material was so long that it clogged the mulch planter. Mulch planting would not be suitable for stony land since the bottom sweeps would be damaged.

The till-planter has been used by members of the Agricultural Engineering Department at the University of Nebraska for minimum tillage studies in 1958 and 1959. In 1958, minimum tillage for corn production was tried at six locations under dry land and irrigated conditions according to Wittmuss (1959). The yields and weed control were as good as those found under conventional practices. Under dry land conditions the best results were obtained with only a cultivating and harvesting operation following till-planting. Under irrigation a ridging operation was added.

Wittmuss (1959) also stated: "Better germination percentage and improved seedling vigor has been an encouraging observation of corn planted with the till-planter when compared to corn planted conventionally."

In another study in Wisconsin, Holmes (1955) found that when the sweeps were dropped off of the till-planter unit and the same planter was used for both conventional and mulch planting, the plant population averaged 4,000 more per acre on the till-planted plots. This was significant at the 5 percent level. The better stand on the till-planted corn is believed to be due to less structure damage and hence better aeration and possibly less surface crusting.

The till-planter was tested from 1950 to 1957 inclusive on a farm near Lafayette, Indiana, by Dr. Scarseth, Director of the American Farm Research Association. According to Scarseth (1956) (1958) the soil on the farm was a heavy silty-clay loam, low in organic matter with a very compact clay subsoil. The average harvested yield for the final year was 140 bushels per acre with a seven year average of about 90 bushels per acre. He started with a farm on which the soil was run down to see if it were possible to build up poor soil with corn. His fertilizer bill ranged from 46 dollars per acre the first year to 33 dollars per acre in 1957. No comparison with other tillage and planting methods was reported.

Aldrich (1956) conducted experiments in New York in which he compared the till-planter method of corn planting with several other minimum-tillage methods. He found that yields were reduced where a strip of sod was left between the rows, the greatest reduction being in dry years. To make up for the nutrients not released from the unplowed strips, extra fertilizer had to be applied. Several disadvantages were noted, these being: (1) only two-row operation, (2) the entire operation delayed until planting, (3) plant growth competes with sod strip, (4) extra fertilizer needed following sod, and (5) a special machine is needed which takes considerable power.

At Raleigh, North Carolina, tests have been performed by Brim and Johnson (1955) on a double-cropping system involving soybeans and wheat. The till-planter was used to plant the soybeans in the wheat stubble as soon as possible after the wheat harvest. Some difficulty was experienced where straw accumulation was heavy. However, where a straw shredder was used or where the straw windrows were baled, stoppage was held to a minimum.

In 1953 and 1954 a comparison was made between till-planting and conventional planting on soybeans. In 1954 there was no appreciable rainfall after planting for two weeks. Although the average yields were the same, the till-planted soybeans came up good while those that were conventional-planted required irrigation to obtain a good stand.

They stated that the till-planter required more power than was available on the average North Carolina farm, and that its use would also require an additional investment.

Determination of Power Requirements for Tillage Implements

There exists today two major conflicting views on the subject of power requirement measurements of tillage implements. One is that of performing the measurements under natural field conditions and the other is that of performing the measurements in controlled soil conditions.

According to Randolph and Reed (1938) the soil in any study must be treated as a dynamic material if the tests are to be used for correlation studies. They said this was true because the resistance of soil to the action of a tillage tool is constantly changing as a result of the effects of heat, light, water, bacterial and chemical action, and plant life. The resistance that a soil offers to a tool is also dependent upon the depth and character of the previous tillage. Therefore the tillage record of the test area must be taken into account.

Telischi, et al., (1956) stated that the main variables affecting draft are resistance to compaction, shear, friction, compression, cohesion, adhesion, and speed. These variables were functions of composition and percentage of colloidal content, moisture percentage, bulk density, and the speed of the implement. They made the following report from tests conducted under controlled soil conditions:

1. As the moisture and clay percentages increase, draft increases with ground speed quite rapidly; at low moisture percentage speed does not affect the draft appreciably.
2. Clay percentage does not affect draft at low moisture percentages; its effect increases with an increase in moisture percentage.
3. The effect of moisture percentage was noticeable only when the clay percentage was quite high. Draft increased to the lower plastic limit and then decreased as the upper plastic limit was attained.

The overall results indicated that clay content was the main contributing factor affecting draft, and that sand and silt contribute only weight and some surface friction.

To obtain reliable, consistent, and understandable results with different implements and soils, Nichols and Reaves (1955) stated that it is necessary to supplement and precede all tillage studies or tests of implements with physical measurements and studies of the soil material.

The correction of draft data with reference to bulk density, moisture content, and clay content does not completely eliminate variations according to Randolph and Reed (1938).

Clyde (1936) stated that in tillage tests conducted by the Pennsylvania Agricultural Experiment Station, soil conditions have not been controlled. The tests were made under conditions varying from easy to difficult in order that a range of forces which a tool is going to encounter under normal conditions might be known. Clyde did not consider a five percent error to be of much consequence in measuring and locating a force when soil conditions are not controlled and when judgment would be required in applying the data to implement design. Soil conditions were taken, however, to correlate results with those of the USDA Tillage Machinery Laboratory.

The soil reaction as well as any rotational forces can be determined if a tool is supported by a frame that is entirely supported by force measuring devices. The Pennsylvania Agricultural Experiment Station and the USDA Tillage Machinery Laboratory at Auburn, Alabama, have used such devices for several years. In both devices the tool being tested is attached to a triangular subframe which is attached to the main frame by six hydraulic dynamometers. Each dynamometer is connected to a pen on a strip-chart recorder which also records time and distance. Three cells support the subframe, two push it forward, and one holds it sideways.

The Pennsylvania test unit is known as the tillagemeter and can be moved from one field to another according to Clyde (1936). Lateral control is obtained by metal wheels which run on movable steel-channel tracks. The depth is controlled by two rubber-tired wheels that run on undisturbed soil.

The USDA Tillage Machinery Laboratory testing unit operated on rails which were located on the walls between soil bins. Nine soil bins each 20 feet wide, 250 feet long, and six feet deep provided places for testing in 11 selected soils. Equipment was available for preparing the soil, sprinkling it, and protecting it from the weather. This allowed testing under carefully controlled conditions. Such an arrangement was particularly suitable for repetitive tests involving the comparison of different designs or tool adjustments, according to Reed (1945).

Use of Strain Gages for Power Requirement Determination

<u>The Strain Gage Principle</u>. In 1856 Professor William Thomson (Lord Kelvin) reported in England that the electrical resistance of certain wires varied with the tension to which the wires were subjected. This resistance variation is due to the changes in the length and diameter of the wire resulting from changes in its tension (Perry, 1955).

Hooke's Law states that a constant ratio exists between stress and strain in various metals. This ratio is usually expressed as a constant and is called the modulus of elasticity. The stress can be calculated from the above relationship if the strain on a member is measured.

SR-4 is the trade name of a wide variety of electrical resistance type strain gages. The present form of these gages was made possible by a rigid control of manufacturing processes. It was found that these gages could be made with a uniformity of resistance and gage factor such that individual calibration was not necessary. Gage factor is a dimensionless relationship between the change in gage resistance and gage length. It is an indication of the sensitivity of the gage. The greater the gage factor the more sensitive the gage is to strain and thus the electrical output to the recording instrument is correspondingly larger.

SR-4 gages are primarily classified by the filament material and by mounting materials. The two predominant filament materials are advance wire and iso-elastic wire. Both have good linear relationships between the unit changes in resistance and in strain. The iso-elastic wire is, however, 50 to 100 times more sensitive to temperature than advance wire according to Schoenleber (1955). This disadvantage of iso-elastic wire is compensated for in many applications since it has about twice the gage factor of advance wire (Murray, 1958).

Two general types of mounting materials are used on filament carriers. These are paper impregnated with nitro-cellulose cement and paper impregnated with Bakelite cement.

The most popular type of gage has been the bonded wire strain gage which can be made very small and light. Its grid, consisting of a pattern of very fine wire cemented between two pieces of thin paper, may be one of several designs for different applications. The paper serves as a carrier of the grid and also insulates the grid from the metal surface to which it is bonded.

When it is desired to measure the strain in a machine component the gage is bonded to it by using an appropriate cementing material and it is then connected to an electrical instrument which will indicate small changes in resistance. The change in resistance will give the change in strain at the gage location in the direction of the grid axis due to the previously mentioned linear relationship.

Basic Instrumentation. Since the magnitude of the resistance change for the gage that is strained is only a few thousandths of an ohm it is not possible to measure this with a standard ohmmeter. It is therefore necessary to use a Wheatstone bridge type circuit to measure this change with sufficient accuracy. The bridge circuitry includes four resistors connected in a definite pattern, a current source, and a sensitive galvanometer. The basic circuit is shown in Fig. 1.

It can be shown that the following relationship is always true for the balanced condition: $R_1R_3 = R_2R_4$. This relationship is a convenient method for determining the arrangement by which strain gages should be connected to give the desired results. For example, if R_1 and R_2 are both increased by the same amount, the bridge will stay in balance. If R_1 is increased and R_3 is

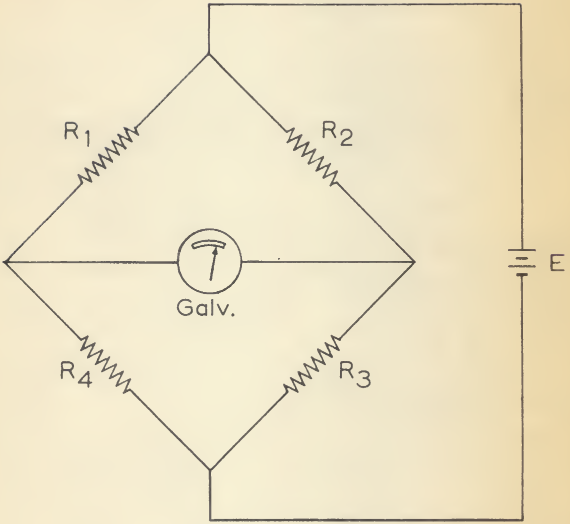


Fig. 1. The basic Wheatstone bridge circuit.

decreased by equal amounts the bridge will remain balanced. However, the bridge will become unbalanced if R_1 and R_3 are increased by equal amounts.

Therefore it is evident that if two active gages in a Wheatstone bridge are both in equal strain of the same sense, they must be placed opposite in the bridge to measure total strain. However, if the strains of the two gages are equal in magnitude but of opposite sense, the bridge will remain in balance. This is a convenient method of cancelling out the strains due to bending stresses.

The above principles also provide a convenient method for deciding where dummy temperature compensating gages should be placed in the bridge. The gage that is compensating for the changes in another gage due to temperature must always be adjacent to it in the bridge. It must also naturally be located as close as possible physically to the measuring gage, so that they will be at the same temperature.

Power Requirement Determinations. It is often necessary to determine the power that is transmitted through a rotating shaft. The use of strain gages facilitates this without losing any of the transmitted power and without disturbing the power train.

Theoretical analysis has shown that principal strains occur on 45 and 135 helixes on the shaft. Therefore strain gages placed along one of these helixes will be subjected to either tension or compression. This measured strain is in effect a measurement of the torque since the principal strain is proportional to the applied torque up to the elastic limit.

Most shafts are subjected to bending at the time they are transmitting torque. If the gage is to measure only the torsional strain this added strain on the gage due to the bending stress must be cancelled out. This is accomplished by using four active gages on the shaft to form a Wheatstone bridge. Two of the gages are placed diametrically opposite on a 45-degree helix, while the other two are placed on a 135-degree helix in the same manner. The two gages located on the same helix are connected as opposite legs in the bridge. This placement causes the gages in opposite legs of the bridge to sense the same magnitude of strain due to bending, but it is of opposite sense. Therefore the bridge is not unbalanced from the effects of bending.

Temperature compensation is not a problem, because all four gages are active and are closely located on the same member.

Some sort of collector is required to form a continuous circuit from the rotating bridge to the recording instruments. The slip ring and brush collector is satisfactory for some installations, however, its lower limit for accurate results is around 6000 psi in torsion according to Burrough (1953).

A mercury bath collector was designed and used by Burrough (1953) in measuring the power and torque distribution in farm machinery drive shafts. This collector gave the desired characteristics of stable contact resistance and equal resistance under static and dynamic loads. Laboratory tests showed that the resistance of the collector varied from .00585 ohms under static conditions to .00565 ohms at 2500 rpm. The lower limit for this collector was approximately 350 psi in torsion.

Jenson (1954) described a method for obtaining sufficient information to determine engine horsepower developed and the power requirements of implements simultaneously. A strain dynamometer was used to obtain the implement draft requirements. The dynamometer was simply a steel ring fastened to the front end of the drawbar with four gages placed on it so that two would be in tension and two in compression when pull was applied to the drawbar. Each of the two gages in tension was placed in opposite branches of the Wheatstone bridge circuit with the two compression gages placed in the same manner to complete the bridge. This arrangement provided self-compensation for temperature and for bending in the vertical and horizontal planes.

The dynamometer was calibrated in a tensile-testing machine for drawbar pull versus meter deflection.

The engine horsepower output was obtained by placing a strain gage bridge circuit on a reduced section of the transmission drive shaft and using a slip ring collector to complete the electrical circuit to the rotating bridge. The meters from the drawbar dynamometer and the drive shaft bridge circuits were mounted together with an engine tachometer, drive-wheel and front-wheel revolution counters, and a stop watch. Simultaneous recording of all the information was accomplished by photographing the panel with a 35 mm automatic camera.

Jenson (1954) also described a method for measuring the draft of integral tools mounted with three-point linkages by using a transducer element at each hitch point.

TILL-PLANTER DESIGN CHANGES

Changes in the till-planter design resulted from findings by Clark (1959) and other investigators and from convictions of the writer.

The primary disadvantage of the 4M-21 till-planter was the time required to mount it on a tractor and dismount it from a tractor as is evident in Fig. 2, although this point was not listed in any of the literature cited. This disadvantage is closely related to the complexity, total weight, and location of the machine.

Many investigators indicated that the high power requirement was of major importance. This is a very evident problem and at present one university is doing work with the till-planter concerning it, but their approach is to cut the widths of the upper and lower sweeps to about one-third of the original. The author does not feel that this is the solution because by doing so there is no means of controlling the initial growth of weeds. It seems the answer to the power problem would lie in basic design changes of the sweeps themselves. This should involve a complete investigation by itself, therefore, it was not included in this work. It was felt, however, that small improvements might be obtained in this regard and perhaps more pronounced benefits with regard to the traction problem by proper changes in the overall design of the till-planter.

Another problem Clark and other investigators experienced was adequate penetration and depth control. These and the other

Fig. 2. The original design and mounting of the IHC 4M-21 Till-Planter.

problems discussed above were given careful thought in an attempt to find a satisfactory solution.

Rear mounting seemed to be the answer, but this presented new problems which included tractor stability, length, and a method of attaching and raising the planting units.

Since the stability and length are interrelated problems they were studied simultaneously. Computations showed that a compact planting unit was necessary for stability. Several commercially available units were investigated but cost was prohibitive so further consideration was given to the available unit. Since the rotary-hoe and packer wheels created problems under some conditions (Clark, 1959) they were eliminated, which in turn permitted the necessary shortening. To compensate for the expected inferior seedbed resulting, the standard stub runners and boots were replaced with special ordered, regular runner-type furrow openers and boot assemblies with seed firming wheels which reportedly improves germination. The split-boot distributor for the starter fertilizer was sacrificed for the seed firming wheel. This necessitated a new location for fertilizer application. By rotating the fertilizer can supporting castings 180 degrees and then moving the chain drive sprocket and bevel gear back to their original positions rear delivery was accomplished. Cutting holes through the depth control brackets large enough to accommodate the fertilizer drop tubes permitted the placing of starter fertilizer immediately behind the seed firming wheels or between the seed covering disks.

Computation indicated that the planting units could not be lifted and carried by the tillage unit beams so cables were investigated. Several graphical analyses were made to determine the most convenient location and height of the cable supports, point to attach to planting unit, and location and means of attachment with respect to the tractor axle housing.

A suitable principal connecting linkage was determined by using the above method prior to and jointly with the above problem. To be suitable, this linkage had to include the following:

1. Be removable from the IHC fast-hitch drawbar since cost prohibited buying an extra one.
2. Be capable of supporting a specially designed tool-bar which would support the two tillage units and the three center cutting sweeps.
3. Be composed of vertical and horizontal sections of low cross sectional areas for strain gage installations having relative high output for low working stresses.
4. Be small enough to permit calibration of the strain gages in the tensile testing machines available.
5. Be high in bending resistance to adequately support the entire implement in the raised position.
6. Be able to vary the inclination angle of the sweeps.

The problems of attaining adequate penetration and horizontal operation of the upper sweep blades seemed to be lessened or eliminated by the proposed design.

After determining the approximate loads and including estimates for dynamic conditions for the various components of the connecting links and pin connectors, their sizes were determined. Two 3/16 inch steel plates the width of the drawbar section were welded on both sides of its vertical sections to permit drilling the two holes required to mount the connecting brackets (No. 6, Plate I) without excessive weakening of the drawbar. The above mentioned parts and the cable supports and end fasteners were then constructed.

It can be seen in Plate I that when the lift arms are lowered by the hydraulic system point No. 9, (Plate I) is forced to fold downward thereby leading the tillage units into the ground points first as shown in Fig. 3. The sweeps then level off when the working depth is reached as shown in Plate I. Figure 8 shows the till-planter at operating depth in the field.

Plate II shows an exploded view of the left side of the right supporting linkage.

The planting units were attached to the primary tillage units at a point directly below the front fertilizer boxes by specially constructed brackets as shown in Plate III. These brackets contained horizontal slots to permit the planting units to follow the furrows on contour work.

Standard cultivator shanks with 10 inch sweeps and fasteners were purchased for cutting the five inch strip left uncut between the rows by the large sweeps. These were mounted as shown by Plates III and IV.

The axle housing cable brackets as described and shown in Plate I are also shown clearly by Plate IV.

EXPLANATION OF PLATE I

Plate I shows a right view of the planter at working depth and how the right drawbar bracket fits over and bolts to the vertical section of the drawbar. The tractor wheel, rolling coulter, and depth control wheel, and right center running sweep have been removed for clarity. The numbered parts are as follows:

1. Axle housing cable bracket.
2. Cable lifting and supporting bracket for right side.
3. Mechanical shields for strain gages (new location).
4. Mechanical shields for strain gages (original mounting).
5. Right tool-bar supporting link.
6. Right drawbar bracket.
7. Adjusting screw for leveling sweeps.
8. Trash guard which fits over parts numbered 5, 6, 7.
9. Pivot point of the drawbar linkage.

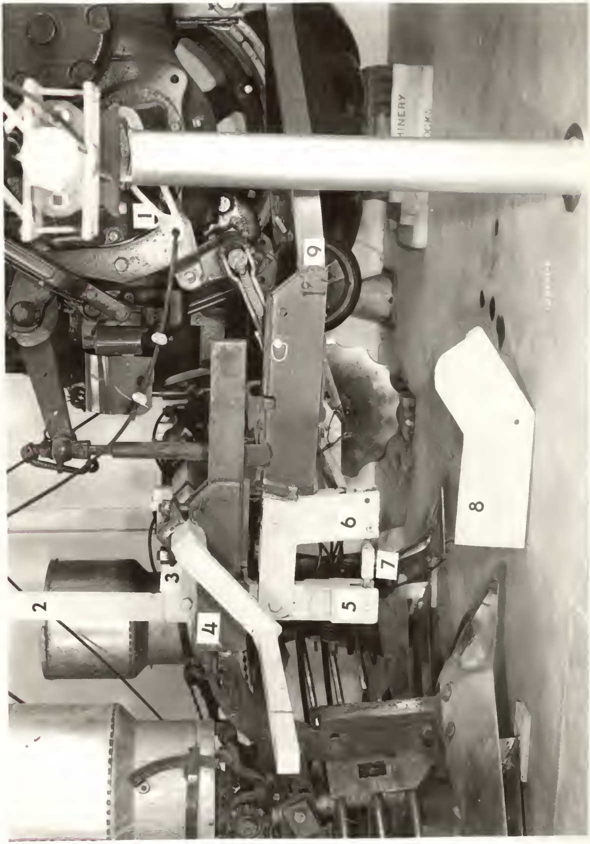


PLATE I

Fig. 3. The increased penetration angle of the sweeps upon initially entering the soil. Also shown is the connecting point between the planting unit and the tillage unit beams.

EXPLANATION OF PLATE II

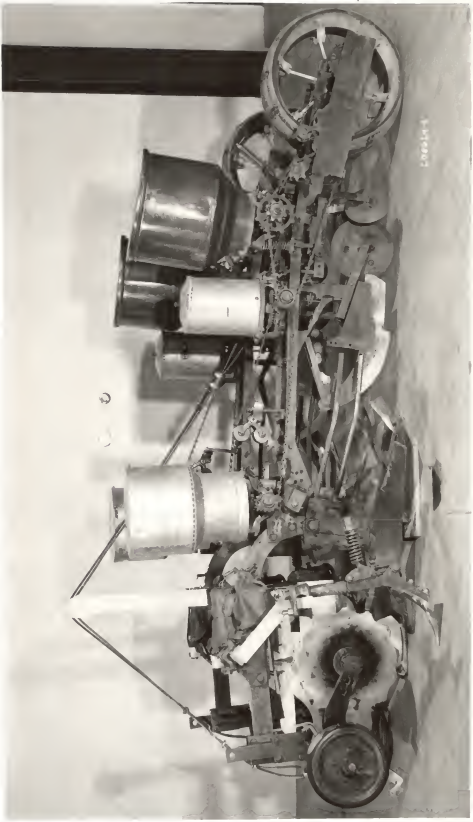
Left side view of the right supporting linkage. Each part is numbered the same as for Plate I except for No. 9 which refers to a bolt which provides an electrical ground for the electrical shielding on the pickup cables. This plate also shows some of the sponge rubber and masking tape used to keep air currents out of the strain gage areas due to the temperature problem.

PLATE II

EXPLANATION OF PLATE III

The left view of the redesigned till-planter.

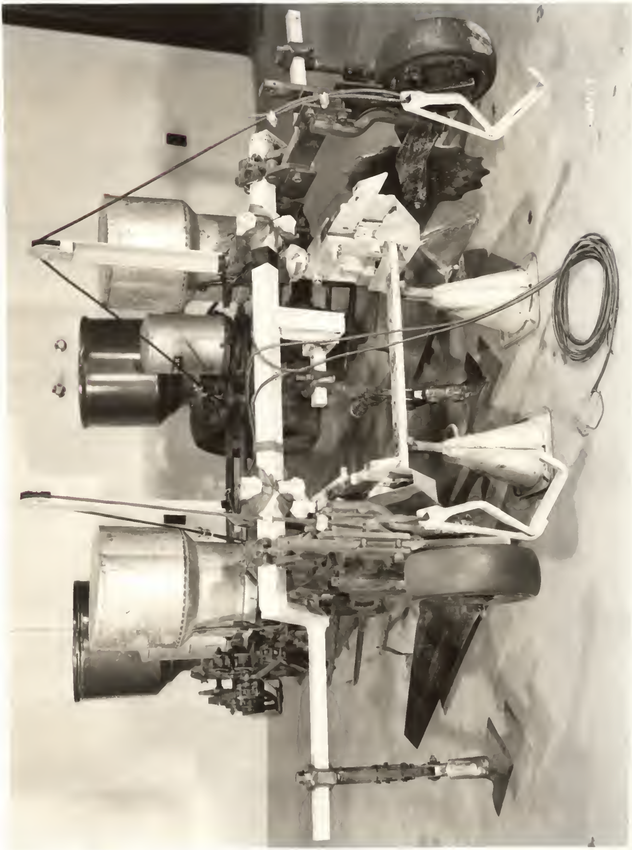
PLATE III



EXPLANATION OF PLATE IV

The front view of the redesigned till-planter.

PLATE IV



The front fertilizer boxes were driven from the planter shafts which in turn were driven from the rear press wheels. A chain tightener which had a wide range had to be installed for the drive chain on each side since the distances between the shafts varied greatly. This was due to the vertical distance between the fertilizer shaft and the mounting bracket on which the planter hinged and also to the horizontal slots in the mounting brackets described above.

TILL-PLANTER POWER REQUIREMENT MEASUREMENTS

Reasons for Conducting Power Requirement Tests

The review of literature and the writer's own experience with planting the test plots with the till-planter indicated that it had a high power requirement. Clark's work was the only one which included information concerning the power requirements.

Tests were conducted to find the following:

1. The total rear axle power required by the redesigned till-planter in different soils at various speeds.
2. The portion of the total axle power that was consumed by the tillage units in different soils at various speeds.
3. The effect, if any, of velocity on the vertical component of the soil force on the tillage units.
4. The slip of the drive wheels and the power lost due to slip in different soils at various speeds.

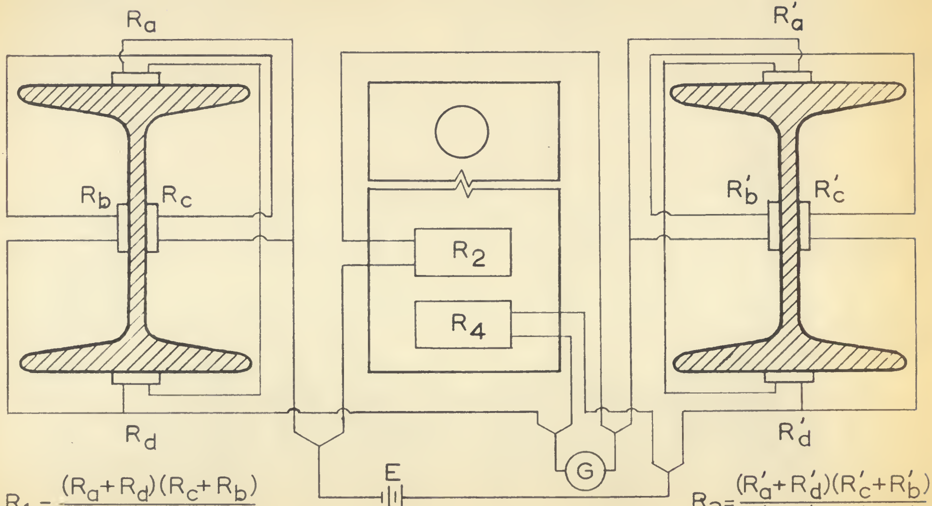
Method for Measuring the Horsepower Requirement of the Till-Planter

The tool-bar supporting links were constructed so the perpendicular components would be perpendicular and parallel with respect to the ground surface while at operating depth. Therefore the total draft required by both units including that required by the rolling coulters and planting units corresponded to the net forces being transmitted by the horizontal portions of the connecting links.

These sections of the connecting links are subjected to combined bending and compressive stresses under operating conditions. The same is true for the vertical sections of the connecting links under operating conditions.

Four C-1 strain gages were attached to these two sections of each I beam. They were placed on the neutral axes of the I beam, on the top, bottom, and each side of the beam. The center line of all four gages were in a plane perpendicular to the beam. Fig. 4 shows how these gages were wired to form a single 500-ohm resistor for one leg of the Wheatstone bridge circuit. The strains due to bending in the vertical plane cancel out since the top and bottom gages were wired in series. The strains resulting from bending in the horizontal plane cancel out for the same reason. Therefore, only strains resulting from compression are measured.

Since the signal from the horizontal or vertical sets of gages from each beam formed the active arms of the bridge, only two dummy gages were needed. These gages also were 500-ohm C-1



$$R_1 = \frac{(R_a+R_d)(R_c+R_b)}{(R_a+R_b+R_c+R_d)}$$

$$R_3 = \frac{(R'_a+R'_d)(R'_c+R'_b)}{(R'_a+R'_b+R'_c+R'_d)}$$

Fig. 4. Actual cross sections of the supporting links showing gage installation and schematic wiring diagram with R_1, R_2, R_3, and R_4 located within the bridge as they were in Fig. 2.

gages and were mounted on a separate piece of steel (No. 1, Plate V). This piece was secured to the beam by the bolt which holds the mechanical shields in place as shown in Plate V. The contact area between the piece of steel and the beam was polished to improve the heat transfer between them. This in turn would keep the dummy gages nearly at the same temperature as the active gages and thereby provide temperature compensation. Temperature changes were further guarded against by working sponge rubber into all openings at the ends of the mechanical shields and sealing all joints between the halves of the shields with masking tape as shown in Plate II. A piece of rubber from an inner tube was then cut to fit and wrapped over the shields and fastened with wire at the ends.

Metal shields (No. 3, Plates II & V) were constructed to cover the strain gage locations to: (1) provide the gages with protection from mechanical damage, (2) aid in keeping all of the gages at the same temperature, and (3) to provide the gages with additional moisture protection.

All of the gages were given coatings of Cerece Microcrystalline Wax according to directions to seal out moisture.

The leads from each dummy gage and from the four-gage active unit were made long enough to extend out of the shields (Plate II) for the following reasons:

1. The shields did not have to be removed to permit attaching the leads to each other and to the pickup cable leading to the amplifier.

EXPLANATION OF PLATE V

Gage installation on right supporting link viewed from the left side. The wires leading to the left are for the draft measurements and the wires on the right are from the vertical gage installation as shown. The triple wire connection is the common point in the bridge between the two leads from one end of the active gage unit and one lead from the dummy gage. The single lead is the other end of the dummy gage and the two leads connected together are from the other end of the two arms of the active gage unit.

The components are numbered as follows:

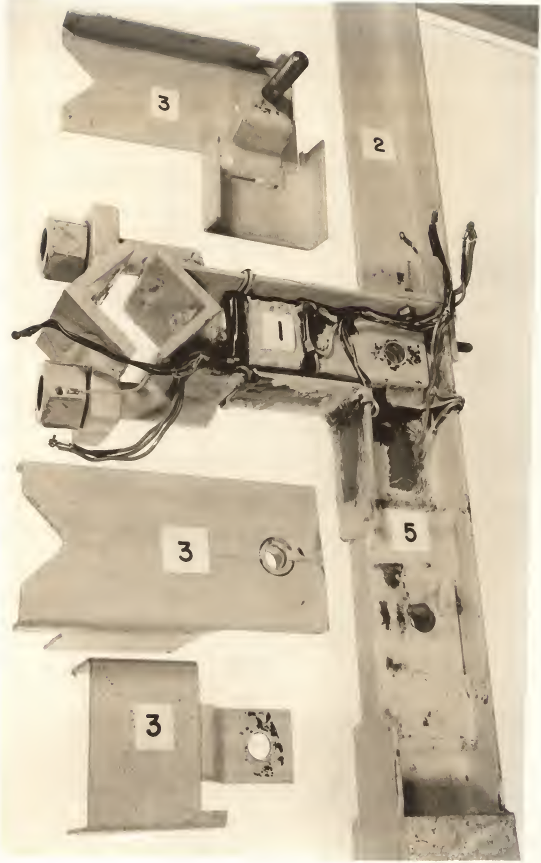
1. Plate on which the dummy gages are mounted.

2. The removable cable lifting and supporting link.

3. Shields for all of the gages.

4. The right tool-bar supporting link.

PLATE V



2. An active gage unit and a dummy gage unit could be used from each beam to form a bridge circuit that measured total draft without removing the shield or making solder connections.
3. The chances for short circuits were minimized since the terminals were all outside thereby preventing excessive congestion under the shields.

When the gages are connected as shown in Fig. 4 to form a Wheatstone bridge the strain on the beam due to draft can be measured. The measured strain is in effect a draft measurement up to the elastic limit if the calibration factor is known.

If the draft and velocity of the beams are known the power requirement of the complete till-planter can be obtained by the following formula:

$$H.P. = \frac{F \times V}{33{,}000}$$

where: F = Draft in pounds

V = Velocity in feet per minute

The average draft was obtained by using a planimeter to measure the area in terms of square inches included between the draft curve and the neutral axis along the chart paper from the point at which the test started to where it was completed. The length of the above area was measured in terms of inches. The measured area was divided by the test length to obtain the average pen deflection in inches. This value was multiplied by the number of chart lines per inch to obtain the average deflection in terms of lines. To obtain attenuator lines the average deflection in chart lines was multiplied by the attenuator setting. Total draft in terms of pounds was obtained by multiplying the attenuator lines by the calibration factor found to be 89.686 pounds per attenuator line when the beams were calibrated simultaneously.

The velocity was obtained by dividing the test length in feet by the time required for the test in minutes.

Method for Measuring the Tractor Axle Horsepower Required by the Till-Planter

A measurement of the power transmitted through one of the rear axles should be one-half of the total power transmitted to the rear wheels since a conventional differential equally divides the torque between the axles. Therefore, two CR-1 Baldwin Lima strain gage rosettes were mounted on the right rear axle of the tractor. They were placed approximately midway between the axle housing and the wheel hub and diametrically opposite on the axles. Each rosette was orientated so that each strain gage element would be aligned on a principal strain axis.

Accurate orientation and cementing of the strain gage rosettes on the axle was accomplished by a specially constructed template made of paper gasket material. Alignment lines for orientation of the rosettes and lines showing the rosette outlines were laid out on a strip of material six inches wide and of a length equal to the circumference of the axle. The material that was enclosed by the outline of the rosettes was removed to permit cementing of the gages to the axle with the template in place. Pressure was applied to the newly cemented rosettes by wrapping a strip of sponge rubber around the axle and then wrapping with cardboard and string to retain the pressure.

The four individual elements of the rosettes were connected as shown by Fig. 5 to form a Wheatstone bridge circuit. This permitted the measurement of the principal strain while cancelling out the effects of bending stresses and temperature changes as pointed out in the review of literature.

Since the Wheatstone bridge circuit was on the axle, a method of transferring the rotating circuit into a stationary circuit was needed. This was accomplished by using a mercury bath collector similar to the one mentioned in the review of literature. This collector had four individual cells to accommodate the four leads from the bridge. Each of the four leads terminated at a brass disk where it was soldered to the disk. The disks were glued to a plastic sheath which was slipped over the copper tube shaft. The disks rotate in a pool of mercury and the circuits are completed to the outside terminals by copper rings that encircle the inside of each cell.

The collector is No. 14 in Plate VI. A removable shield was constructed to provide the gage rosettes with mechanical protection. These gages were also waterproofed by an application of Cerece Microcrystalline Wax. Special plexiglas disks were constructed and cemented to the plastic covered collector shaft. An AN connector was fastened to these disks to provide a connection between the leads from the bridge to the collector to facilitate

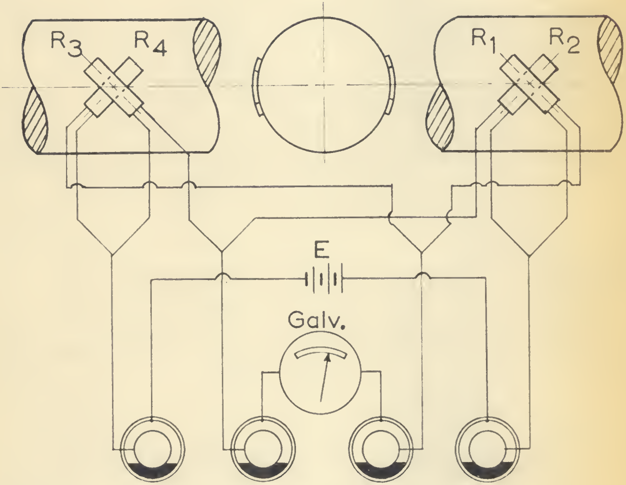


Fig. 5. Schematic wiring diagram of the bridge circuit utilized in measuring axle torque with R_1, R_2, R_3, and R_4 located as shown in Fig. 1.

EXPLANATION OF PLATE VI

The tractor axle and housing as viewed from the rear with the wheel removed.

The components numbered are as follows:

1. The bracket which fastens the lifting cables to the axle housing by hooking over it and held by a single cap screw.

10. The shield constructed to protect the strain gage rosettes mounted on the tractor axle.

11. Supporting frame for the mercury bath collector.

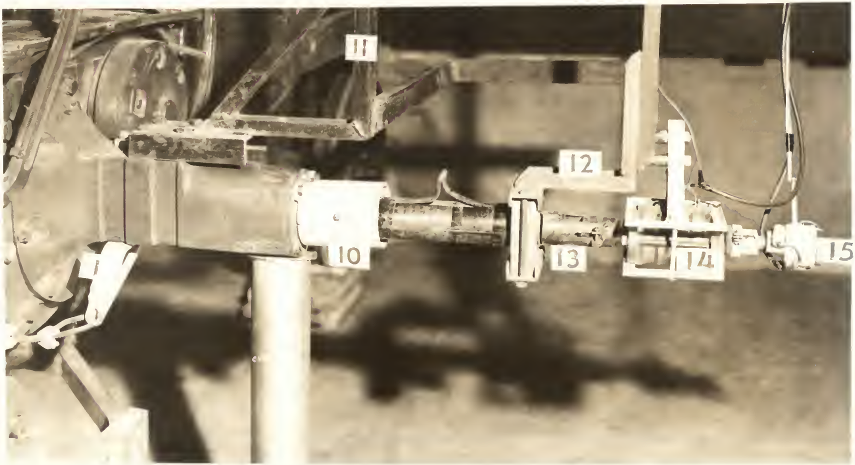
12. Outer support for the collector supporting frame.

13. The connector between the tractor axle and the collector which also drives the collector. An AN type plug connection is enclosed by it.

14. The mercury bath collector.

15. The right rear wheel counter as connected to the outer end of the collector shaft.

PLATE VI



removal. Friction tape was wrapped onto these disks to allow for non-alignment and to dampen vibration. The above is shown in Plate VI.

Since the bridge circuit was designed to measure only the principal strain resulting from torque, the measured strain is a measurement of torque up to the elastic limit of the shaft metal if the calibration factor is known.

If the axle torque and rpm are known, horsepower being transmitted can be obtained by the following formula:

$$H.P. = \frac{T \times n}{5{,}252}$$

where: T = Foot-pounds of torque

n = Revolutions per minute

Electrical revolution counters as shown in Plate VI, No. 15, were attached to the end of each axle to measure the rear wheel revolutions. The point in the counters made contact ten times per revolution of the counter shaft. Therefore the number of counts as recorded on the counter recorders had to be divided by ten to obtain the wheel revolutions. Axle rpm (n) was then obtained by dividing the axle revolutions, by the time required per test as recorded on a stop watch. The average torque for each test was obtained in the same manner as the average draft was obtained.

Method for Measuring the Vertical Component of the Soil Reaction on the Till-Planter

The strain gages used to measure the vertical component of the soil reaction on the till-planter were type C-1 gages and they were mounted to the vertical sections of the connecting links in the same manner as they were mounted on the horizontal sections. This is shown in Plate V. The supporting links (No. 5, Plate V) were constructed from standard 3 I 5.7 stock. The circuitry and gage location with respect to the beams' cross-section is shown in Fig. 4.

Force Versus Strain Calibration of the Till-Planter Supporting Links

Each of the till-planter supporting links were removed from the supporting linkage and placed in a tensile testing machine for calibration. Each link was calibrated individually by subjecting it to compressive loading that was applied at a uniform rate. A Brush Universal Amplifier and penmotor recorder were used to amplify and record the signal from the gages. As the load was applied the chart paper was marked for 500 pound increments up to 6000 pounds. The same procedure was followed in unloading the link. Three such calibrations were run on each active gage unit for each of the supporting links. Three dummy gages were required to complete the bridge for these individual calibrations.

Since the active gage units that had common locations on both links were to comprise one bridge for the field tests, both links were then inserted in the testing machine and calibrated simultaneously following the same procedure as for the single calibrations. The calibration constant obtained in this manner checked with the previously obtained value which was 11.15 attenuator lines for each 500 pound increment of load per beam. This is equivalent to 44.863 pounds draft per link per attenuator line or 89.686 pounds total draft per attenuator line.

The calibration constant obtained for the gage units for measuring vertical forces was 12.50 attenuator lines per 500 pound load per link which is equivalent to 40.00 pounds per link per attenuator line or 80.00 pounds total per attenuator line. The singular and simultaneous calibration values agreed.

For the field tests, two Brush amplifiers, Model BL-520, and a Brush four channel penmotor recorder, Model 247, were used. One amplifier and channel were used to record the total draft and another amplifier and channel were used to record the total vertical soil reaction on the till-planter. A third amplifier and channel were required to record the rear axle torque of the tractor during tests.

For the above mentioned calibrations and field tests, the amplifiers were balanced and calibrated according to instructions provided by the manufacturer. The calibration constant (Kc) for the gage installations on the supporting links could be obtained from the following formula provided:

$$Kc = \frac{1}{SN} \times \frac{R}{Fm(Rc + R)}$$

where: Kc = calibration point in attenuator lines.
S = sensitivity in strain per attenuator line.
N = number of active gages.
R = resistance of each strain gage.
Rc = the calibration resistance (390,000 ohms).
Fm = gage factor of strain gage.

Any sensitivity can be assumed, but for matters of convenience one micro-inch per inch strain per chart line was chosen as suggested. This sensitivity is for an attenuator setting of one; when the attenuator setting is changed, the sensitivity changes to the same value as the attenuator setting in terms of micro-inches per inch of strain per chart line.

Both Wheatstone bridge circuits from the supporting links had the following constants:

$$R = 500 \text{ ohms}$$
$$N = 2$$
$$Fm = 3.20$$

With the above constants substituted into the equation Kc was found to be 200.3. Therefore with the calibrate switch engaged the pen deflection in terms of chart lines times the attenuator setting should always be equal to 200.3. Since an attenuator setting of "10" was used for calibration, a pen deflection of 20.03 chart lines was required.

The leads from the strain gages were attached as shown in Plate VII to form a remote bridge circuit one-half of which was on each supporting link. This plate also shows how the signal from each half of the bridge was carried to the amplifier by a single four-wire shielded cable. This method was used for both the vertical and the horizontal gage installations.

Strain-Torque Calibration of Tractor Axle

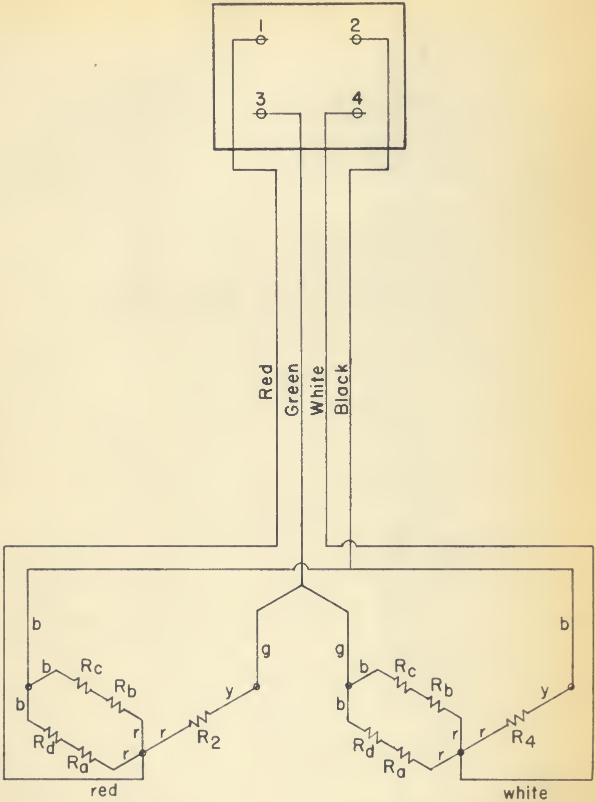
The setup for making the strain versus torque calibration on

EXPLANATION OF PLATE VII

Schematic wiring diagram of the remote bridge half of which is located on each beam and the means by which the signals were carried to the amplifier with one shielded cable. Plane intersecting points of intersection of wires indicate soldered connections while intersections having a little circle drawn around them indicate mechanical connecting means. The gages are denoted in the same manner as those were in Fig. 4. The lower case letters refer to the wire colors used which were red, green, black, white, and yellow. This schematic refers to both the vertical and the horizontal gage installations on the supporting links.

PLATE VII

Amplifier Input Box



Left Beam

Right Beam

the axle of the Farmall 560 Diesel tractor is shown by Plate VIII. Two 6⊔8.2 steel channel section beams were used to construct the lever. The beam was then bolted to the inner side of the right tractor wheel on a line that intersected the center-line of the axle. The beam was extended forward with respect to the tractor so that torque could be applied to the axle in the same direction as it would be under normal conditions.

At a distance of eleven feet from the center-line of the tractor axle a small rod was welded on to the bottom edge of the beam thereby simulating a knife edge and permitting concentration of the force applied at that point by a hydraulic jack. The tractor was jacked up so that the right rear wheel would clear the floor. Blocking was inserted under the left tire to prevent the tractor from rolling and to raise it enough to compensate for the jacking of the left wheel. The front end of the tractor was then raised with a hydraulic floor hoist until the front tires were about one foot from the floor. After balancing the scale in this position the right brake was locked and the load was applied in 100 pound increments by lowering the front end with the hydraulic hoist. The hydraulic jack supporting the end of the beam on the scale was only used to compensate for the slight lowering of the scale platform as the load increased. This made it possible to keep the loading beam level at all times which in turn insured its effective length to remain constant.

Leads from the collector were extended to a third amplifier and recorder channel to record the axle bridge output. The

EXPLANATION OF PLATE VIII

Equipment and instrumentation lay-out for calibration of the tractor axle.

PLATE VIII

amplifier was balanced and calibrated in the same manner as it was for the beam calibration. The values for calculating the calibration constant which differed were as follows:

$$Fm = 3.29 \text{ (gage factor)}$$
$$N = 4 \text{ (number of active gages)}$$

From the above value the calibration factor is found to be 97.30 attenuator lines. Therefore the amplifier should be calibrated to give an oscillograph pen deflection of 19.46 chart lines for an attenuator setting of "5".

After the proper balancing and calibration procedure had been carried out, repeated runs were made to determine the relationship between torque and strain. For the loading described above and limited to 500 pounds on the eleven foot lever arm it was found that each 1100 foot-pounds of torque increased the deflection 154 attenuator lines which is equivalent to 154 micro-inches per inch strain. An attenuator setting of "20" was used for these tests.

Therefore the torque-strain relationship was found to be 1100 foot-pounds torque per 154 micro-inches per inch or 7.15 foot-pounds of torque per micro-inch per inch strain.

Installation of Equipment Required for Testing

The equipment required for running the field tests was mounted on the tractor rather than on a separate test vehicle for the following reasons: less equipment and personnel required, more mobility, closer contact between the instrument and tractor operators, and the greater possibility of the instrument operator being aware of the reason or reasons for abnormalities in a given test.

The instrument carrier was relocated and altered as shown in Fig. 6. The new location had the following advantages over the previous one:

1. Improves stability by adding some weight in front of the axle.
2. Provides a smoother ride for the instruments.
3. Adds less to the bulk of the tractor.
4. Improves communications between the tractor and instrument operator since they are facing each other.
5. Permits the instrument operator to observe the operation of the till-planter.

No significant disadvantages were observed during field testing except for the reduction in the tractor operator's visibility. Another possible disadvantage would be stray signal interference if a spark ignition type tractor were used instead of the diesel. Engine vibration did not present any problems partially due perhaps to the one-quarter inch plywood strips which were inserted between the tractor frame and the attaching brackets of the instrument carrier.

The plywood cabinet was altered to accommodate the third amplifier while keeping it in a convenient location. The wheel-revolution counter recorders and the counter control switch were also relocated for convenience. Each instrument was supported by a plywood platform containing recesses for the instrument's rubber

Fig. 6. The instrument carrier, its location, and method of mounting to the tractor. Also shown is the location of the three amplifiers within the instrument cabinet, the oscillograph, wheel counter recorder switch, the wheel counter recorders, and the left wheel counter attached to the end of the tractor axle.

supporting gourmets. These platforms were further cushioned by supporting them in the vertical and horizontal directions with foam rubber.

To prevent 60-cycle alternating signals from being picked up the pickup cable shields had to be grounded to the amplifiers and to the element on which the gages were mounted at the pickup end. In the case of the axle it was grounded to the steel support for the collector.

The top amplifier was used to take the strain from the horizontally located active gage unit and one dummy gage for both supporting links. The second amplifier was employed to do the same for the vertical gage installations. The bottom amplifier was employed to amplify the strain signal from the bridge mounted on the right rear axle.

The power for the amplifying and recording instruments used was supplied by a 120 volt, 500-700 watt, alternating current, engine driven generator. It was mounted on a simple frame which was constructed specifically for mounting to the tractor frame on the right side of the engine as shown in Plate IX. This location permitted the amplifiers and oscillograph to be plugged in directly to the outlets of the generator if their cords were passed through under the fuel tank. No signal pickup from it was observed.

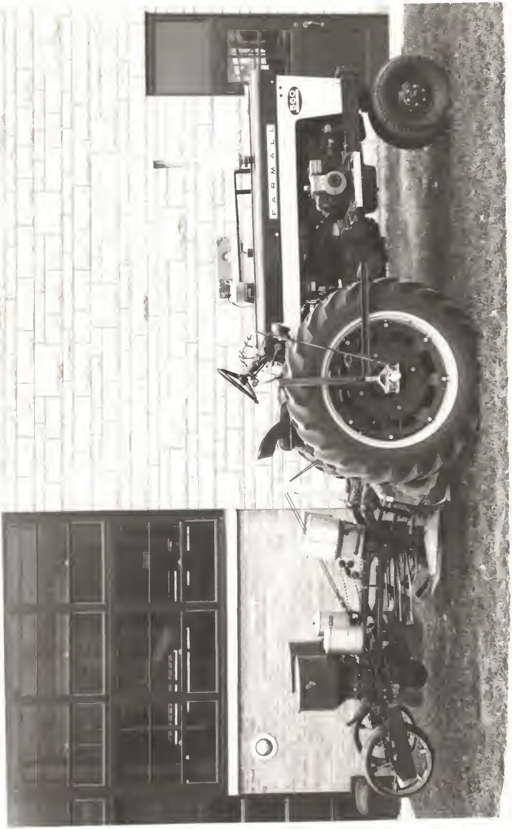
Field Testing Procedure

1. The testing area at each location was chosen where the

EXPLANATION OF PLATE IX

The tractor as it was equipped for the redesigned till-planter power requirement test.

PLATE IX



land had little or no slope and was uniform in both directions if slope existed.

2. Six stakes were driven at the edge of the test area to define three 100-foot test lengths with approximately 40-foot intervals between the test lengths. Six additional stakes were driven on a line approximately perpendicular to the first row and about 20 feet to one side of each stake.
3. A trial run was made to make depth adjustments by means of the adjustable depth quadrant stop on the tractor. The supporting linkages had previously been adjusted so that the upper sweep blades were horizontal when operating at a depth of two inches or slightly more. The fast hitch leveling crank had also been adjusted so that both sweeps units were operating at the same depth.
4. Three replications were made for each testing speed and tests were made at six speed ranges for each test series. Where the power requirement was low enough additional tests were run in each range of fourth gear. At two locations the power requirement test series were run both with and without the three ten-inch sweeps. The large upper sweeps as modified by Clark (1959) were used for all tests. All of the tests were made in the same direction and down the slope if a slope existed.
5. The following data were recorded for each test:
   a. The horizontal strain and the vertical strain in the

till-planter supporting links were recorded on the first and second channels of the oscillograph respectively. The strain due to torque on the right rear axle was recorded on the third channel of the oscillograph. All three amplifiers were calibrated in the manner previously described. The beginning and end of each test was marked on the chart paper by depressing one calibrate switch as the two stakes at the beginning and end of each test length lined up visually for the tractor operator.

b. The time taken for each test was recorded on a stop watch which was started and stopped as the two stakes at the beginning and end lined up visually for the tractor operator. The tractor operator signaled with his hand simultaneously with starting and stopping the stop watch.

c. The instrument operator turned the switch for the wheel revolution counters on simultaneously with depressing the calibrate switch at the instant he saw the tractor operator signaling and starting the stop watch. The wheel counter switch and calibrate button were again turned off and depressed respectively at the hand signal from the tractor operator which simultaneously denoted the end of the test and stopping of the stop watch. Therefore, the counter recorders indicated the wheel revolutions turned by each wheel for each test.

Some power requirement tests were made at each location with the till-planter raised to determine the power required to roll the tractor at a few different speeds and for the various soil conditions.

Results of Field Tests

Descriptions of Soils at Testing Sites. It was desired to run tests on three different soil types, but of the three testing sites available there were only two different soil classes. The third location was used anyway because it was felt that other variables present such as moisture content might prove to be significant.

The soil was sampled at a few different locations for each test area and Table 1 contains the averages for each location of the particle size analysis, liquid and plastic limit, moisture percentage, and bulk density tests run on each sample.

Table 1. Summary of soil test results from the three test sites.

Site	Soil Class	% Clay	% Silt	% Sand	Plastic Limit	Liquid Limit	% Moisture	Bulk Density Wet	Bulk Density Dry
A	Silt Loam	20.8	61.5	17.7	31.84	40.35	29.16	1.65	1.27
B	Sandy Loam	4.5	30.3	65.2	23.70	17.30	13.18	1.59	1.40
C	Silt Loam	16.4	62.2	21.4	24.34	29.45	22.64	1.73	1.41

The bulk density measurements were run in the field by means of the sand and core method. All tests were run on representative samples of soil from the surface to a depth of eight inches. The particle size analysis tests were made by the hydrometer method. The clay, silt, and sand percentages are based on the U. S. Bureau of Soils System in which clay is defined as percentage of particles smaller than two microns, and silt is defined as percentage of particles in the range of .002 to .05 millimeters in diameter.

The power requirement measurements were made during October and November of 1959. Tillage that had been done on the test sites previous to testing varied.

A small grain crop had been removed from site A the summer immediately preceding the tests. It had been mowed a few times after harvest to keep the weeds down and at the time of testing it was covered with fox-tail grass as shown in Fig. 7.

A wheat crop had been harvested from site B the summer immediately preceding the tests and it was immediately plowed and disked. There was some volunteer wheat and weeds growing on it at the time of the tests.

A sorghum crop had been harvested from site C a few weeks before the tests were run. This soil probably was compacted some since the soil was moist when it was being field chopped and hauled off the field with trucks. The tests were run in the direction of the rows with the large sweeps operating between the sorghum stubble rows.

<u>Testing Data Calculations</u>. Data were taken as previously

Fig. 7. The draft tests at site A showing the grassy cover, the condition in which the soil is left, and the space left between individual test runs to prevent the traction tires from running over the soil a second time.

Fig. 8. The till-planter shown at operating depth for draft tests at site C with the sorghum stubble visible in the background.

outlined and calculations were made for the following:

1. Average rpm and percent slip of the rear tractor wheels.
2. Average torque being transmitted by the right rear axle.
3. The average horsepower being transmitted by both axles (axle H. P.).
4. The horsepower as measured above minus the horsepower lost to slip (available H. P.).
5. The total average draft of the entire till-planter (till-planter H. P.).
6. The velocity in terms of feet per minute and miles per hour.
7. The average horsepower consumed by the till-planter.
8. The total average vertical component of the soil reaction on the till-planter.

The average torque, rpm, horsepower transmitted by the axle, till-planter draft, average vertical soil reaction, and velocity for each test were as outlined in the previous sections on methods.

The percent slip was calculated for each test from a form of the following percent slip formula:

$$\text{Percent slip} = \left(\frac{\begin{matrix}\text{Advance per wheel} \\ \text{revolution with no pull}\end{matrix} - \begin{matrix}\text{Advance per wheel} \\ \text{revolution with pull}\end{matrix}}{\text{Advance per wheel revolution with no pull}} \right)$$

Repeated tests showed that the wheels made 6.7 revolutions while traveling the 100-foot test length without any load which resulted in the following formula:

$$\text{Percent slip} = \left(\frac{14.92 - 100/\text{Wheel revolutions when pulling}}{14.92}\ 100 \right)$$

The average horsepower consumed by slippage was found for each test by multiplying the axle horsepower by the percent slip. The axle horsepower refers to the average horsepower being transmitted through both axles and it is obtained by doubling the calculated value of the average horsepower transmitted by the right axle. This is possible because of reasons mentioned previously. The difference between the axle horsepower and the horsepower lost to slippage will be referred to as the available horsepower.

The difference between the available axle horsepower and the till-planter horsepower could only have been absorbed by the rolling resistance of the tractor.

Figures 9, 10, and 11 show axle, available axle, and till-planter horsepower versus velocity for the test sites A, B, and C respectively. The three small sweeps were mounted on the till-planter at site C but were removed for the tests at sites A and B from which the curves in Fig. 9 and 10 were plotted. Tests were also run at site A with the small sweeps mounted, but clogging was a problem and a limited number of complete tests were run free of clogging. Figure 12 is a plot of the items mentioned above for these tests which were run at site A with the sweeps mounted.

Some rather wide variations are shown on the curves and these were due to the dynamic nature of the soil and perhaps slight variations in operating depth. The relationship between horsepower and velocity appeared to be linear. This would be expected since neither the draft of the tillage units nor the axle torque appeared to increase with velocity. More will be included concerning this later.

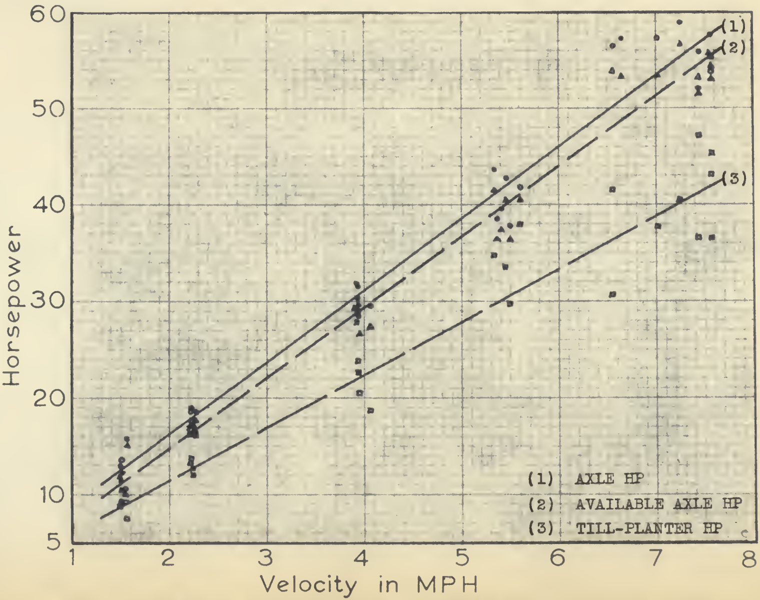


Fig. 9. The axle, available axle, and till-planter required horsepower versus speed curves for tests at Site A.

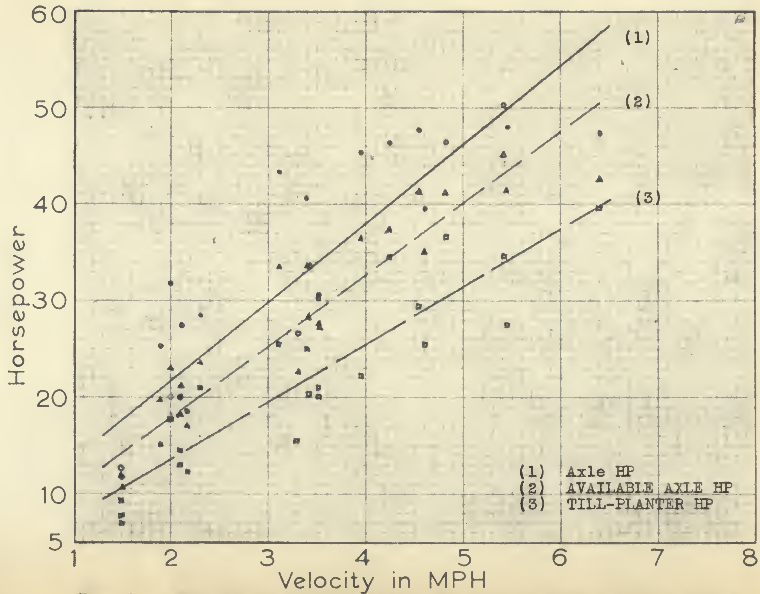


Fig. 10. The axle, available axle, and till-planter required horsepower versus speed curves for tests at Site B.

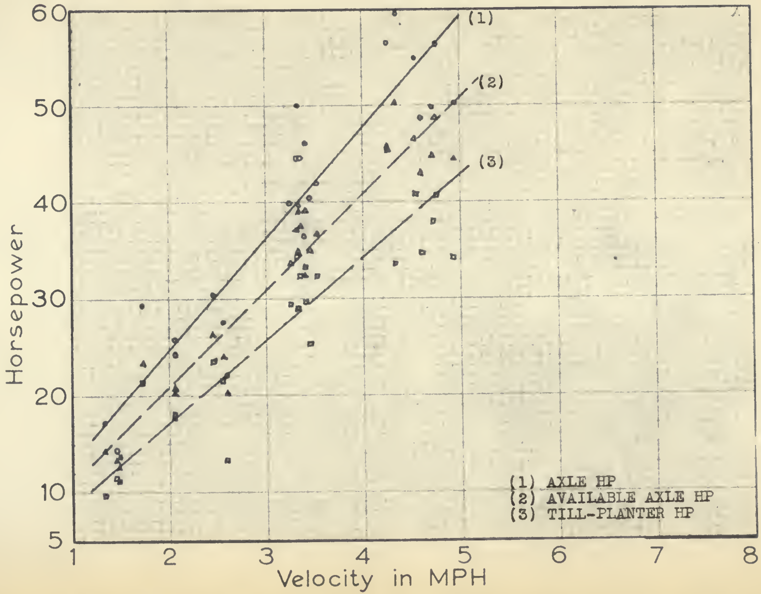


Fig. 11. The axle, available axle, and till-planter required horsepower versus speed curves for tests at Site C with extra sweeps mounted.

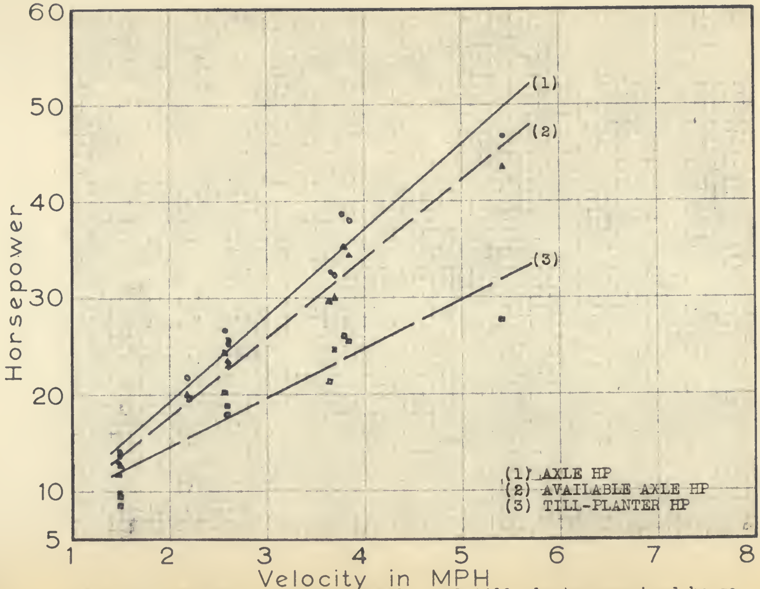


Fig. 12. The axle, available axle, and till-planter required horsepower versus speed curves for tests at Site A with extra sweeps mounted.

Linear regression statistical methods could be applied to determine the slope of the respective curves and to locate them since a linear relationship was assumed for horsepower versus velocity. The sample regression equation of Y on X is written as follows:

$$Y - \bar{y} = b(X - \bar{x})$$

$$\bar{y} = \frac{\sum Y}{n}$$

$$\bar{x} = \frac{\sum X}{n}$$

where: n = number of tests
b = sample regression coefficient

The sample regression coefficient is the slope of the line. The procedure for finding the regression coefficient is as follows:

$$b = \frac{\sum xy}{\sum x^2}$$

$$\sum xy = \sum XY - \frac{\sum X \sum Y}{n}$$

$$\sum x^2 = \sum X^2 - \frac{(\sum X)^2}{n}$$

Regression formulae in the form: $Y = a + bX$ were developed by the Experiment Station Statistical Laboratory for the total axle horsepower, available horsepower, and till-planter horsepower for each of the four sets of data. In this equation the variables are Y and X. The various horsepowers are represented by Y and the velocity in feet per minute is represented by X. The curve is located by a in the formula and b is the slope of the curve. The regression formula may be used to predict a value of Y for any given value of X and the Y value obtained by substituting in a value of X is an average value.

Variance formulae were not developed for all the tests because the expected ranges determined from them were so wide that they had little meaning.

The regression formulae obtained are listed in Table 2. Statistical correlations were run for the four sets of data to determine whether the draft and the vertical forces measured might be functions of the velocity. With one exception the tests resulted in probabilities of over 10 percent for both the draft and vertical force, indicating from a statistical standpoint that they are interdependent functions.

Table 2. Sample regression formulae obtained for axle, available axle, and tillage unit horsepower versus velocity in feet per minute.

Site	Soil	Horsepower	Number of Tests	Regression Formula
A	Silt-Loam	Axle	31	HP = 1.432 + .0845 V
		Available Axle	31	HP = 0.033 + .0832 V
		Till-Planter	29	HP = 0.752 + .0624 V
A*	Silt-Loam	Axle	12	HP = 1.737 + .1006 V
		Available Axle	12	HP = 1.462 + .0927 V
		Till-Planter	12	HP = 4.542 + .0575 V
B	Sandy-Loam	Axle	23	HP = 5.739 + .0922 V
		Available Axle	23	HP = 3.276 + .0838 V
		Till-Planter	23	HP = 1.734 + .0676 V
C*	Silt-Loam	Axle	25	HP = 1.500 + .1314 V
		Available Axle	25	HP = 0.769 + .1139 V
		Till-Planter	25	HP = 0.190 + .0970 V

* The three small, extra center-cutting sweeps were mounted during these tests.

The one exception was for the vertical force measurement data tested against velocity for the 25 field tests run. The probability in this case was between the .05 and the .02 level, which denotes significance, but on the basis of all the tests, it would appear that the draft and the vertical soil force acting on the tillage unit are not functions of velocity.

Figure 13 indicates the dynamic nature of the draft, vertical force and torque for a 100-foot test section on a site which was selected on the basis of its uniform appearance. The depth and speed were essentially constant for this test section which means that the soil itself must be responsible for the wide variation shown. The constants relating the deflection of the pen trace to the force or torque measured at any given point has been discussed previously in the section on calibration. It has not previously been mentioned that the instruments were balanced and the pen zeroed on some base line after the planter was at operating depth and at rest. Therefore the forces measured were merely the additional soil load experienced by the till-planter during operation.

The curves for Figures 9, 10, and 11 are summarized in Fig. 14. The axle horsepower increased more rapidly for the silt-loam soil at 22.6 percent moisture (Site C) than for the tests run at the other location which was also a silt-loam but at 29.2 percent moisture. This is not as expected and must be due to a more packed condition which is indicated by the wet bulk density readings which show it to be much heavier. The only other variable would be the soil cover which could influence the location of a curve but not its slope. It should be remembered that the small sweeps were mounted for the tests at site C but one would be hesitant to attribute the greater slope to their presence when the principal

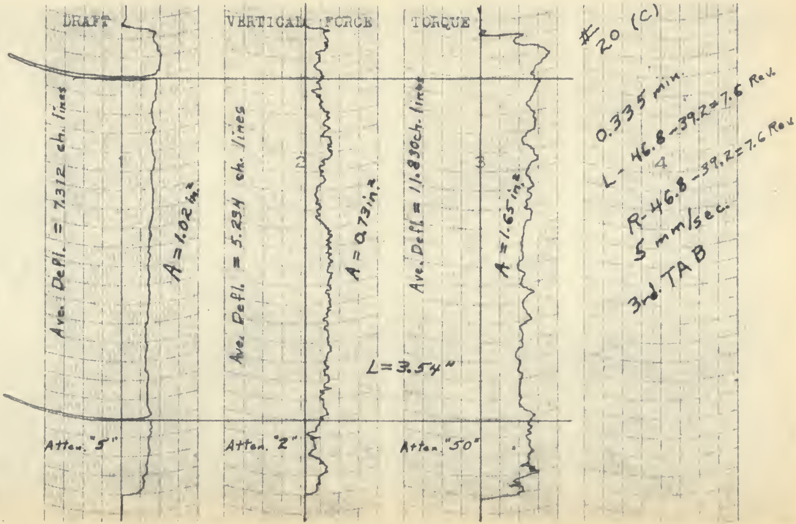


Fig. 13. The chart paper showing the pen traces and information recorded and measured for each test.

units are essentially large sweeps. The same increased slope for the total and available axle horsepowers from Fig. 12, which also has the extra sweeps mounted, are noted when compared to Fig. 9.

The initial axle horsepower for the dryer silt-loam and for the sandy-loam were nearly equal.

As mentioned before the difference between the available axle horsepower and the till-planter horsepower is equal to the rolling resistance and the curves indicate the expected trend, namely, lower initially and increasing at a slower rate for the more compact soils. The curves bear this out. The rolling resistance for site B, however, might have been expected to be lower than for the sandy-loam and probably would have been had it not been for the high moisture percentage and the mulch covering of the silt-loam soil at site A which would tend to permit the tires to penetrate more than for a bare, dry silt-loam soil.

The regression curves for axle horsepower as determined by Clark (1959) show a minimum rate of increase of 11 horsepower per mile per hour and a maximum rate of increase of 14 horsepower per mile per hour. The rate of increase of the axle horsepower for the redesigned till-planter as determined from Fig. 14 has a minimum of 7.5 and a maximum of 11.5 horsepower per mile per hour. The initial minimum and maximum axle horsepowers required for the original till-planter were 21 and 28 as compared to 16 and 24.6 axle horsepower that was required for the redesigned till-planter, both being taken at two miles per hour.

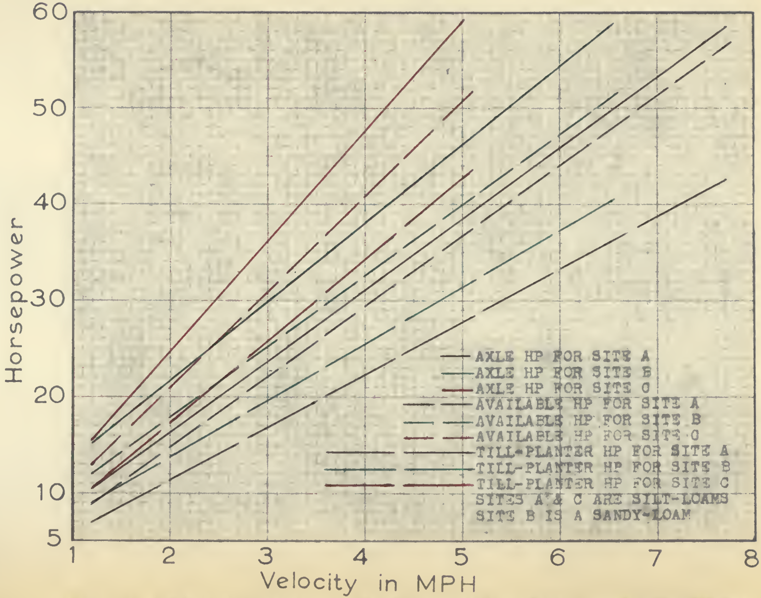


Fig. 14. The axle, available axle, and till-planter horsepower versus speed curves for the three testing sites as reproduced from Figures 9, 10, and 11.

The power lost due to slippage was also compared at two miles per hour and it ranged from 2 to 6 horsepower for the original planter as compared to 1.2 to 3.8 horsepower for the redesigned planter.

The rolling resistance cannot be compared because the difference between the available axle horsepower and the tillage unit horsepower as measured by Clark included the horsepower consumed by the planter units, the rolling coulters, and the rolling resistance of the tractor.

The above comparisons indicate that the slippage power loss was decreased. This should have been true since the total till-planter weight (1500 pounds) now is mounted entirely on the rear end of the tractor. The traction wheels also run on the soil loosened by the outer edge of the tillage units before alterations were made.

If rolling resistance comparisons could have been made they should also be favorable since the total weight of the till-planter was decreased approximately 1000 pounds and all of this added load came off the front wheels. Due to their smaller diameter they will require more draft.

The total weight of the tractor and mounted planter as tested (Plate IX) was 9000 pounds which included all instruments, two operators, a 76-pound front end weight, and four 72-pound wheel weights added to the right wheel to help compensate for instrument carrier mounted on the left side. The left rear tire had supported 170 pounds more than did the right one. When the planter was in raised position, 80 percent of the total weight was supported by the rear tires. The tractor used did not have any liquid in the tires as did the one that was used last year.

The total average downward vertical force transmitted to the tractor from the planter varied from 300 pounds to nearly 1500 pounds, which in turn transferred weight from the front to the rear of the tractor.

CROP PLANTING EXPERIMENTS

Till-Planter, Lister, and Plow Plant Methods of Planting Corn Compared at the Belleville Experiment Station.

This experiment was conducted in 1959 at the Belleville Experiment Station which is located in North Central Kansas. This experiment was started in 1958. The soil on the plot area was a silty clay loam. The previous crop grown was grain sorghum with little crop residue remaining. However, there was a thick stand of weeds over much of the area.

The plots were four and six rows wide depending on the location and 300 feet long. Nine plots were laid out so that these replications could be made for each test. The plots within each replication were designated randomly. The following planting methods were used in each replication:

1. Till-Planting
2. Listing
3. Plow-Planting

The tillage history of the plots prior to planting included plowing and disking for the listed plots, plowing, disking, and plowing again for the plow-planted plots, and no previous tillage for the till-planted.

All plots were planted June 3, 1959. The lister plots were planted with a conventional lister and the plow-planted plots were planted with a top planter mounted to a tractor and the planting was done outside the wheeltracks.

Fertilizer was applied at the rate of 43 pounds of nitrogen per acre. The front boxes on the till-planter were used to apply the fertilizer.

Since the direction of the plots had been switched from north and south to east and west, the till-planting had to be done over untouched ridges. This necessitated going deep enough with the upper sweeps to cut off the weeds between the ridges and left thick chunks of dirt cut from the ridges as the upper sweeps cut through them. It rained that night and many of the weeds in these displaced masses of dirt continued to grow.

Some field stoppage was caused by the center optional sweep shank mounted too close to the drawbar, but this was eliminated by moving it a few inches further back when the planter was returned to the laboratory.

The till-planted and listed plots crusted some hurting the stand considerably, especially so for the listed plots.

One cultivation was given each plot and it was difficult to do without a disk hiller of some kind for the till-planted.

The center two rows of corn were harvested for the full lengths of the rows and the yield was adjusted to a 14 percent moisture basis since the corn was very moist when harvested. The following data were recorded for each sub-plot:

1. A stalk count.
2. Plants lodged.
3. Total pounds of corn including that dropped or lodged.

Table 3. Summary of means obtained from the three replications for each planting method.

Planting Method	Total Stalks	Lodged Stalks	Corn Yield (bu./acre)
Till-Plant	4880	2360	21.10
Plow-Plant	8420	4520	29.10
List	2920	965	20.86

The Experimental Station Statistical Laboratory performed a complete statistical analysis on the data. An analysis of variance was run for total yields and for lodged stalks per acre. The sources of variation in each of the above analyses were the planting method, replications, and plot error.

The F test was employed to determine whether or not the variance was significant for each source; cut-off was set at the five percent level. F is a value expressed by the following relationship: $\frac{\text{Variance of source}}{\text{Overall Experiment Variance}}$. Its determination with regard to significance is obtained from an F distribution table.

In the analysis of the dropped and lodged corn, the planting method was significant and the replications were not significant at the five percent level. The replications having the highest amount of lodging were the blocks on either edge and this probably was due to a windstorm.

The highest average yield was for the plow-plant method and this was significant at the one percent level.

The F test has shown that differences due to planting methods exist but it did not show how large the differences had to be to be significant. Least Significant Differences or LSD's were computed by the Experimental Station Statistical Laboratory to compare the individual overall means of the broken and lodged stalks and the total corn yields. The LSD for the planting method with respect to yield was 3.59 bushels per acre.

The only difference occurring in the overall means of the corn yields was that of the plow-planted corn. The dropped and lodged corn was significantly lower for the till-planted corn as compared to the plow-planted and also for the listed as compared to the till-planted. From the wide ranges of total stalks per acre it would appear that differences in the broken and lodged corn might have been due to an increased plant population as well as to the planting method, but statistical analysis of this was not made.

Till-Planter, Plow-Planter, and Lister Methods of Planting Corn Compared at the Courtland Irrigation Experimental Field

The Courtland Irrigation Experimental Field is located in the same vicinity as the Belleville Experimental Station. The soil was a silty-clay soil also but it appeared to be somewhat lighter in texture. The previous crop grown was corn on the five north replications which bordered each other and were six rows wide and 100 feet long. It had been disked in the fall after harvest and a very heavy crop residue remained. The four south replications were situated two wide and bordering at the end. They in turn bordered the south end of the two east replications of the north block of five. The south block of four replications had soybeans on it the previous year and had been disked after harvest in the fall. Weeds were present and were 8 to 10 inches high on the south block. Very few weeds were present on the north block at planting time due to stalk mulch. The south replications were four rows wide and 225 feet long.

Nine replications were made in all for the three planting methods and the plots were randomized within replications.

No prior tillage, other than that already mentioned, was performed on the listed or till-planter plots. The plow-planter plots were plowed only several hours before planting.

The plots were all planted on June 9, 1959. The planters were all set to deliver as near to 17,000 kernals of corn per acre as was possible. The listing and plow-planting were done with commercially available equipment. Thirty pounds of 33.5 percent nitrate was applied to the till-planter plots with a grain drill prior to planting. A deep application of 70 more pounds of the same was applied during the planting operation with the till-planter. The plow-planter and lister plots had a hundred pounds of 33.5 percent nitrate applied before planting with no additional amounts being applied during the planting operation.

The germination appeared about the same for the till-planted and plow-planted plots but was noticeably poorer for the listed plots. The till-planted corn was more uniform than either the other plots but would average slightly shorter than the plow-planted. There were noticeably less weeds in the till-planted than in the listed or plow-planted. Figure 15 is a sample shot taken July 16, 1959, showing the corn stubble mulch, cloddy surface condition, and weed emergence to date in a till-planted plot. Figure 16 shows a sample shot of the plow-planted plot bordering the till-planted plot shown in Fig. 15.

The first and only cultivation was performed after these pictures were taken but on the same day. No weed control spraying applications were made. Weed control was satisfactory in the plow-planted and till-planted plots, but it was inadequate for the listed plots particularly in the south block of plots.

Furrowing for irrigation was performed late in July and in turn the first application was late. Three applications were made for a total of about 12 inches of water.

Fig. 15. Weed emergence, soil condition, and surface mulch for the till-planted corn at the Courtland Irrigation Experimental Field.

Fig. 16. Weed emergence, soil condition, and surface mulch for the plow-planted corn at the Courtland Irrigation Experimental Field.

The two center rows were harvested from each plot for a distance of 65.3 feet thus amounting to one-hundredth of an acre. The length harvested was located approximately at the center of the row with respect to the plot lengths. A stalk count of the total stalks, lodged stalks and stalks broken below the ear was taken prior to harvesting the plots. A summary of the mean values obtained for the three planting methods is shown by Table 4.

Table 4. Summary of the harvesting data from the irrigated corn plots at the Courtland Irrigation Experimental Field.

Planting Method	Stalks per Acre	Lodged and Broken Stalks per Acre	Total Yield Bu./Acre
Till-Plant	10,978	3011	77.5
Plow-Plant	12,089	4578	75.8
List	8,333	978	61.4

The same statistical analysis was made on this data as for the previous experiment. An analysis of variance was performed for the lodged and broken stalks per acre and for the total yields. The sources of variation for each of the analyses were planting methods, replication, and error.

The F test was used for the determination of the significances of the difference with the five percent level as the cut-off point. Both the planting method and replication differences were found to be insignificant for yields but it was very close to significance between listed and the till-planted as shown by a difference of 16.1 bushels per acre from the table and an LSD of

16.66. The F test showed that the lodged and broken stalk differences for planting methods were lower for the listed plots. It was significant at the one-half percent level. The lower lodging and breaking rate for the listed plots might have been due to the lower stand which would have offered less resistance to a windstorm which hit that locality before the corn was harvested.

Till-Planter, Plow-Planter, Lister, and Surface-Planter Planting Methods Compared on Grain Sorghum at the Belleville Experimental Station

Three replications of the four planting methods were laid out on a nearly flat location. The soil was a silty-clay type. The previous crop was sorghum and little residue remained.

The plots were four rows wide and 243 feet long. Randomization was used to designate the plots within each replication for the planting methods.

The listed and till-planted plots had no previous tillage. The plow-planted plots were plowed prior to planting and the surface planted plots were disked, duckfooted, and disked before they were planted. All of the plots were planted June 9, 1959. It was attempted to obtain a seed spacing of 2.75 inches for each method.

The plots were again planted at right angles to the old ridges which created the same problem mentioned for the corn plots at this location. As a result the weed control was not satisfactory for the till-planted plots possibly because no disk-hillers or other means of cultivating mulch-planted crops were available. Conventional shovel-type cultivators cannot handle the surface residue satisfactorily and this was the only cultivator available. All the plots received the same number of cultivations. Fertilizer was applied to all the plots at the rate of 180 pounds of 33 percent ammonium nitrate per acre or 60 pounds of nitrogen per acre.

The plots were visited July 16, 1959. There was little height difference but the surface-planted sorghum was slightly bigger. Both the surface-planted and the plow-planted plots had good stands and color. The till-planted plots had a stand superior to the listed plots but more uneven. Due to the above mentioned reason the till-planted plots were the most weedy.

The center two rows were harvested for their full length by a combine. The overall means of the plant populations and yields for the four replications are shown in Table 5.

Table 5. Summary of the harvesting data at the Belleville Experiment Station.

Planting Method	Overall Mean Plant Population	Overall Mean Yield in Bu./Acre
Till-Plant	25,430	38.7
Surface-Plant	33,750	47.1
Plow-Plant	25,880	50.6
List	17,950	50.3

A statistical analysis of variance was again performed for plant populations and yields. The sources of variation were planting method, replications, and error.

The F test showed no significance for either planting methods or replications for both the plant populations and yields.

The Least Significant Difference was found to be 13.66 bushels per acre. From Table 5 it can be seen that the major difference occurring was between the till-planted and the plow-planted plots. This overall mean difference is 11.9 bushels per acre which lacks about 1.8 bushels per acre of being significant.

Till-Planting, Surface-Planting, and Wheel Track Planting Methods Compared on Grain Sorghum at the Kansas State University Agronomy Farm

The Kansas State University Agronomy Farm is located about one mile north of the campus. Plots were laid out to provide for three treatments replicated eight times at this testing site. The plots were 20 feet by 145 feet. The planting methods were randomized within each replication.

The surface-planted plots were plowed April 15, 1959, disked twice and harrowed prior to planting. The wheel track planted plots were plowed a few hours prior to planting and planted in the tractor wheel tracks with a three-row planter. The till-planter plots had no previous tillage. All of the planting was done June 12, 1959, and the weeds were about two feet high over much of the area. The ground was very hard, dry, and cracked.

This provided a good test for the till-planter's penetrating ability. No difficulty was experienced in getting the planter to operate at the desired depth. Difficulty was experienced, however, in preventing the small center sweeps mounted on the cultivator shanks from tripping. A few of the shanks were bent also. The shanks were not designed to operate under primary tillage conditions. This resulted in weeds being left between the rows. They were later reinforced.

The seedbed was quite cloddy but a nearly perfect stand was obtained in it. Excessive skips were evident in surface-planted plots. This was probably due to more pronounced crusting and washing resulting from a 1.5 inch rain occurring on June 21, 1959. The plots were rotary hoed on July 11, 1959, and it was evident that the till-planted plots were growing faster than the other plots.

All of the plots were hoed by hand on August 21, 1959. It was reported by the individuals who hoed them that the till-planted plots were the mellowest, that is, the surface was loose and uncracked while other plots, primarily the wheel track planted plots were sealed over with a hard crust and some large cracks were appearing at this time. At this time the surface-planted plots were well behind the latter.

With respect to the weediness it was reported that the weeds in the till-planted plots were hardest to remove but once removed, these plots required no noticeable hoeing over conventional or wheel track planting methods.

The following fertilizer applications were made: 200 pounds of ammonium nitrate per acre applied prior to any tillage, and 58 pounds of 11-48-0 was applied at planting time.

The plots were all thinned so the plant population should have been constant. The center two rows were harvested over their total length with a combine. A summary of the mean values obtained from this harvesting data is shown in Table 6.

Table 6. Summary of the harvesting data from the sorghum plots at the Kansas State University Agronomy Farm.

Planting Method	Overall Mean Yield in Bu./Acre
Till-Plant	41.30
Surface-Plant	46.98
Wheel Track Plant	35.80

The F test showed significance for the replication at the five percent level and for the planting method at the one percent level. Therefore these tests show the surface-planting method to be superior and the wheel-track planting method the least desirable. This is on the basis of yield alone since no manpower and horsepower hours per acre differences were considered.

Double Cropping with the Till-Planter

Double cropping is done to some extent in Kansas, especially when the moisture conditions are favorable or where irrigation is used. Since till-planting is a once-over operation it lends itself nicely to this practice due to the importance of time.

The redesigned till-planter was used at the Ashland Agronomy Farm during the summer of 1959 to plant about two acres of soybeans in wheat stubble. Stoppage occurred due to the loose condition of the sandy-loam soil which permitted the rolling coulters to push the straw into the soil without cutting it. Since the rolling coulters had no depth adjustment the entire planter was run deeper resulting in leaving less residue on the surface than was desired.

Plate X shows the soil condition after planting and after emergence of the soybeans. The soybeans were planted July 9, 1959, and Fig. 2 (Plate X) was taken July 22, 1959. A nearly perfect stand was obtained but a month of drought conditions followed planting which inhibited the growth.

The soybeans were cultivated August 10, 1959, and again the last of August largely to control the volunteer wheat rather than the weeds.

The soybeans were last inspected October 9, 1959. The drought damage was evident and they were only 12-14 inches high at this time. They were set on well and were beginning to mature at this time. No yield data was taken however.

EXPLANATION OF PLATE X

Fig. 1. The seedbed and surface condition of till-planted soybeans in wheat stubble.

Fig. 2. The stand and soil cover thirteen days after planting.

PLATE X

Fig. 1

Fig. 2

SUGGESTIONS FOR FURTHER WORK

Several changes and additions should be made to the redesigned till-planter to improve its performance. The rolling coulter should have added depth adjustment and the depth gage wheels could be removed since they are not needed to maintain a uniform depth. One or two rotary hoe wheels should be mounted on each side of the front end of the planter runners with the tops leaning outward permitting the bottoms of the wheels to break the clods in the center of the furrow left by the tillage units. They should be made easily removable since they are only needed under dry, hard soil conditions. When the soil is very moist they pick up soil causing field stoppage and should be removable since they are not needed under these conditions any way.

Much could also be gained by designing the till-planter for mounting on a three point hitch system. This would solve the trash problem and make it a more universal machine. The cable connecting brackets would be the only thing which would have to be custom made for the different tractors. The same tool-bar could be used and merely make similar angle clamps for the tool-bar or weld three vertical steel plates onto the tool-bar at the standard spacing for the three pin-connected hitching links. No pitch adjustment for the sweeps would be needed since this is incorporated in nearly all three point hitching systems. If the lower hitching pins were mounted on steel plates clamped onto the tool-bar an interesting study could be made to determine what effect the spacing of these hitching points had on the trailing characteristics of a tillage tool of this nature under various conditions.

The writer had the problems worked out for mounting the till-planter on a three point hitch and would have done so had a tractor been available.

The trash problem could be eliminated for the present hitching system by cutting link 6 (Plates I and II) and the drawbar off at the horizontal weld location between the two fastening bolts shown in these plates. The lower portions of the drawbar and links would be discarded. The upper portions of links 6 would be welded to the left and right drawbar hitching components and a horizontal member would be welded between them at the point where the upper fastening bolt is presently located in each link. Vertical expanding links mounted between this horizontal member and the tool-bar would provide pitch adjustment. Link 5 (Plate II) would then be cut off just below the point where it is connected to link 6 by means of a bolt. Link 7 would be eliminated on both connecting linkages and the trash guards (No. 8, Plate I) would no longer be needed since point 9 (Plate I) would be lower than any portion of the mounting linkages. These changes would provide adequate trash clearance and simplify the design while sacrificing a drawbar.

Further work should be done in connection with the high power requirements by investigating possible tillage unit design changes which would not sacrifice initial weed control and seedbed preparation.

Additional work could be done in an attempt to determine the reasons for the wide variations in the vertical forces acting on the till-planter. These variations might be decreased by using the original upper sweeps in place of the modified ones used for this work.

The crop experiments should be continued for at least a few more years with more planting methods included. The man-hours and approximate horsepower-hours should be recorded for each planting method since this would give an indication of the economics of the till-planter as compared to other planting methods.

Work should also be done to develop satisfactory cultivating equipment for mulch planted crops in order to preserve the protective soil cover and still control weeds and grass.

Studies should also be made to determine water run-off and soil erosion for the various planting methods and their long-term benefits if any.

SUMMARY

The till-planter was redesigned, constructed, and field tested. The initial field test indicated that it would maintain a uniform depth, penetrate easily, and produce an adequate seedbed.

The first plots were of corn planted at the Belleville Experimental Station at right angles to the previous ridges. In spite of the up-and-down motion of the front end of the tractor

the planter remained on an even plane showing that it possessed adequate flexibility. Some plugging occurred between the center sweep shank and the drawbar. This was eliminated when the planter was returned to the campus by moving the shank four inches to the rear. The sweeps' spring release broke back frequently and created another problem which was remedied. Weed control was poor due to the large masses displaced with small weeds attached by the sweeps from the old ridge. Some crusting occurred on the till-planted and more on the lister and neither method provided a satisfactory stand.

The Courtland corn plots were then planted and no difficulty was experienced. Good stands were obtained for both the till-planted and plow-planted plots but it was poor for the listed plots. The till-planted corn had fewer weeds than for any other method.

The redesigned till-planter was tried in a five year old stand of irrigated alfalfa which was about 14 inches high. The small sweeps were removed due to the weak cultivator trip and shank. The same tractor that was used for a similar trial last year did not exhibit excessive slippage or lack of power in second gear with the sweep blades operating level and two inches deep. A year ago it was found that the sweeps would not penetrate adequately and that sufficient traction or power was not available in low gear.

After moving back to the Belleville Station, the grain sorghum plots were planted with the same procedure as for the corn but no stoppage occurred. The surface-planted sorghum was slightly ahead of the other plots. The till-planted plots had a stand superior to the listed plots but more uneven.

Sorghum plots were planted on the Kansas State University Agronomy Farm June 12, 1959, along with surface-planting and wheel track planting. The ground was very hard and dry and afforded a good test for the till-planter's penetrating ability, but no difficulty was experienced. The only difficulty was the tripping and bending of the cultivator shanks which supported the three small sweeps. This accounted for skipping some of the weeds which it normally undercuts.

The plot-plant method of planting corn was found to have a significantly higher yield at the Belleville Station.

The till-planted plots of corn at the Courtland Irrigation Field had the highest average yield but it lacked about 0.5 bushels per acre of being significant.

No significance was evident for the Belleville sorghum plots but the surface-plant was the highest at the Kansas State University Agronomy Farm and it was significant for the planting method at the one percent level.

Till-planter power requirement tests were conducted at three locations which included two silt-loam soils and one sandy-loam soil. The axle, available axle, and till-planter horsepower were determined at various speeds at each location.

Since the relationship between horsepower and velocity appeared to be linear, linear regression statistical methods were used to locate the power velocity curves. By comparing the curves obtained for the redesigned till-planter with those obtained by Clark for the original till-planter, it was found that the newly designed version produced axle horsepower curves having a minimum rate of increase of 7.5 to a maximum rate of increase of 11.5 horsepower per mile per hour as compared to a minimum rate of increase of 11 and a maximum rate of increase of 14 horsepower per mile per hour for the original design.

The power lost to slippage was also compared at two miles per hour and it ranged from 2 to 6 horsepower for the original planter as compared to 1.2 to 3.8 horsepower for the redesigned planter.

The overall average percent of wheel slippage for the tests run with the original planter was 13.3 percent and it was 9.2 percent for the redesigned planter.

The statistical analysis of the vertical forces measured indicated that they were independent of velocity.

The additional advantages of the redesigned till-planter over the original are as follows:

1. Much simpler to mount and dismount on the tractor.
2. Better penetration of the tillage units.
3. More uniform depth control.
4. Greater simplicity with reference to the two extra hydraulic lifting cylinders on the original planter.
5. Better weight distribution resulting in less wheel slippage and easier handling.
6. Better weed control.

The major disadvantages noted were:

1. Trash problems under some conditions.
2. Inadequate seedbed under dry, hard soil conditions.
3. Inadequate supporting shanks for the three extra sweeps.

ACKNOWLEDGMENT

The author wishes to express his appreciation to Professor G. E. Fairbanks, Department of Agricultural Engineering, for his cooperation, guidance, and assistance in this investigation. Appreciation is also extended to Dr. G. H. Larson, Head, Department of Agricultural Engineering, Kenneth W. Snelling, Graduate Research Assistant, Agronomy Department, Mr. Bob Sloan, Director, Belleville Experimental Station, Mr. Robert Raney, Director of the Courtland Irrigation Experiment Field, and Mr. Harry L. Manges, Irrigation Engineer, Mr. Clarence Swallow and Mr. Tom Kauer for their cooperation and assistance in this investigation.

Without the assistance and cooperation of the International Harvester Company and Mr. Richard Hart, the I. H. C. blockman for this area, this work would not have been possible. The IHC 560 Diesel Tractor used for this work was loaned to the Agricultural Engineering Department by the Company without charge and the till-planter was granted to the same Department.

My deepest appreciation and thanks is extended to my wife, Joanne, for her faithful assistance in preparing this manuscript.

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IMPROVEMENTS IN DESIGN OF THE TILL-PLANTER

by

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B. S., Kansas State University
of Agriculture and Applied Science, 1959

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agricultural Engineering

KANSAS STATE UNIVERSITY
OF AGRICULTURE AND APPLIED SCIENCE

1960

The purpose of this work was to redesign the till-planter in an attempt to improve its performance and to determine what effect the redesign had on the power requirements. The work Clark started on crop response as affected by planting methods was also continued.

After studying the problems connected with the operation of the till-planter, a rear mounting of it seemed to be the solution. A suitable connecting and supporting linkage was arrived at by graphical analysis. The various components of the linkage were then constructed and the till-planter was mounted on the tractor. After an initial field trial which proved the new design satisfactory, the till-planter was used to plant test plots for determining the effects of various planting methods on crop response at four different locations. The planting methods included till-planting, conventional surface-planting, listing, plow-planting, and wheel track planting.

The various plantings were made in randomized test blocks that were replicated three to nine times depending on the space available.

All the plots at the various locations received the same treatment with respect to fertilizer rates applied and cultivation.

Differences in plant growth were noted during the early part of the growing season but disappeared after the corn tasselled out. At the Kansas State University Agronomy Farm sorghum plots the regular planted matured first followed by the till-planted, and then the wheel track planted.

Weed control was poorest for the till-planted plots at the Belleville Station but seemed to be the best at the Courtland Field and compared favorably at the local sites.

Statistical analyses of the yields showed the greater yield for the plow-planted corn at the Belleville Station to be significant at the five percent level. The yield differences at the Courtland Station were not significant and this was also true for the sorghum plots at the Belleville Field. The overall mean yields were highest for the surface-planted sorghum at the Manhattan site and they were followed by the till-planted and wheel track planted. These differences for the planting methods were significant at the one percent level.

The till-planter was used in a wheat-soybean double cropping system to determine the potential of the till-planter in this area.

Field stoppage due to inadequate cutting of the straw by the rolling coulters was encountered. This could be eliminated by providing for greater depth adjustment for the rolling coulters and sharpening the coulter blades. A good stand was obtained but a drought period followed planting and yield data was not taken.

Strain gages were utilized in performing power requirement tests for the till-planter with the necessary instrumentation mounted on the tractor. SR-4 strain gages were attached to the tool-bar supporting links and to the right rear axle to measure the total soil reaction on the till-planter and the total axle torque respectively. A mercury bath collector was used to transfer the rotating circuit on the axle into a stationary circuit.

Brush analyzing equipment was used to amplify and record the signals from the three strain gage Wheatstone bridges. Electrical wheel counters were utilized to facilitate the wheel rpm and slip calculations for the rear wheels.

The supporting links were calibrated in a tensile testing machine and the axle was calibrated by applying known forces in equal increments on a specially constructed 11 foot level fastened to the tractor wheel.

Field tests were run at three locations which included two silt-loam soils and a sandy-loam soil.

Horsepower versus velocity plottings were made for the horsepower delivered to the rear wheels, the horsepower delivered to the rear wheels minus the horsepower lost to slippage and the till-planter horsepower for each location.

Statistical methods were used to locate the curves and to determine their slope since the relationship between the required horsepower and velocity appeared to be linear. Statistical correlations were run for the four sets of data to determine whether the draft and the vertical forces measured could possibly be functions of the velocity. With one exception, the tests resulted in probabilities of over 10 percent for both the draft and vertical force, indicating from a statistical standpoint that they are interdependent functions.

Some major advantages of the redesigned till-planter in comparison to the original machine are:

1. Much simpler to mount and dismount on the tractor
2. Better penetration of the tillage units.
3. More uniform depth control.
4. Greater simplicity with reference to the two extra hydraulic lifting cylinders on the original planter.
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