# THE EFFECT OF DEEP CHISELLING, DEEP FERTILIZER PLACEMENT, AND SOIL BULK DENSITY ON CROP YIELDS

by

DOYLE EUGENE PEASLEE

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# INTRODUCTION

There are certain Kansas soils which have properties that would seem to restrict water and/or root movement downward through the subsoil. This restriction may be due to a claypan, a dense clayey subsoil, or a dense compact layer located in the soil profile. The cause is usually peculiar to a given locality.

Crop yields from soils with these restricting layers are sometimes below those which would be expected from them. Consequently, it is necessary to know whether or not the shattering and breaking of these restricting layers will increase the crop yields from these soils. The effect of deep placement of fertilizer and/or soil amendments on root development and on subsoil physical conditions should be determined also.

There is considerable controversy as to whether deep tillage and deep fertilizer placement would be beneficial. It would seem that a fertile surface soil should suffice as a plant feeding area. Water intake could conceivably be increased if rain fell while the chisel marks were still open. Once these chisel marks became covered by a layer of soil, such as after discing or after the marks have become closed by the flowing and swelling of the soil, it is doubtful that any significant increase of moisture movement will occur. It should be pointed out also that ideal conditions for soil moisture losses through evaporation exist after the deep chiselling operation, before any subsequent tillage has been conducted to seal the surface.

More air movement is allowed through the shattered areas around the chisel mark. When the humidity of the atmosphere is low and surface air movement is high, there could be a considerable loss of moisture from the soil.

Many deep tillage trials have been conducted since 1860, both in the United States and in other countries. Even if the results of the earlier studies had demonstrated that deep tillage was advisable, farmers would have been unable to do a satisfactory deep tillage job, because they lacked the power necessary to accomplish the operation properly. In the past few years, powerful farm tractors and rugged tillage machinery have been developed and have made deep tillage a possibility. Placement of fertilizer deep below the surface can be accomplished also. As a consequence, renewed interest in these procedures has been developing. Accordingly, new experiments have been started near Hays, Garden City, Colby, Green, Alta Vista, and Pratt. These locations in Kansas represent a variety of soils, each with its own problems. This report will cover the field experiments at Green and at Alta Vista.

These two field experiments were designed in an effort to determine the economic soundness of deep tillage and deep placement of fertilizer. These experiments were begun on two Eastern Kansas claypan soils. One soil, classified as the Ladysmith silty clay loam, is located approximately 20 miles south of Manhattan, Kansas, in Geary County. The location of the second soil, Idana silty clay loam, is approximately 40 miles northwest of Manhattan, Kansas, in Clay County. The effects of deep tillage and deep placement of fertilizer were studied on both wheat and milo yields.

Crops growing on soils with high bulk densities should be seriously handicapped when compared to those growing on a soil having a lower bulk density. To gain information on the effect of soil compaction on crop yields, a greenhouse experiment with soil bulk density as the only limiting factor was undertaken. Spring wheat was chosen as the crop to be used in the trial. Treatments to determine the effects of continuously moist conditions and alternate wet and dry conditions were included in this greenhouse experiment.

## REVIEW OF LITERATURE

Deep tillage is a general term and includes three primary methods: (1) deep plowing, (2) deep discing, and (3) deep chiselling. Combinations of these treatments are also used. Each of the three has its own characteristics, advantages, and disadvantages. Reference will be made to all three methods, although the experiments reported in this paper are concerned only with deep chiselling.

Goodale (7) proposed in 1860 to the Maine Department of Agriculture the theory that deep tillage would permit deep root penetration to food and moisture. Goodale apparently was one of the earliest, if not the earliest, to propose the practice of deep tillage and subsoiling.

Deep tillage was put to trial at least as early as 1891, when Latta (12) of Indiana tried plowing depths of up to 18 inches for corn. No significant increase in yield was found beyond the eight inch depth. Similar results were reported from deep tillage with other crops. Work at the Ohio Experiment Station by Williams and Welton (19) showed that deep plowing and subsoiling failed to increase corn, oat, wheat, or clover yields when compared to ordinary plowing.

A report by Bell (2) concluded from Montana results that subsoiling 18 to 20 inches did not increase yields of spring wheat, winter wheat, barley, oats, spring rye, winter rye, corn, flax, potatoes, or sugar beets on Scoby silt loam, when compared with yields from six to eight inch plowing. Zook and Burr (21) reported on a Nebraska experiment conducted on a fine sandy loam soil. These results show that a plowing depth of 14 inches had no advantage over depths of 7 to 10 inches. Data from a 15 year period from the Akron, Colorado, station were compiled by Brandon (4). The soil on this station was a light to dark brown sandy loam with a clay to clay loam subsoil interspersed with sand pockets. Subsoiling to 16 inches failed to increase yields of winter wheat, spring wheat, oats, barley, or corn over yields obtained by normal tillage methods.

Osborn and Mathews (16) released information from Lawton, Oklahoma, studies including yields from plots receiving eight-inch plowing plus a subsoiling of 10 to 12 extra inches as a deep tillage treatment. These data revealed that subsoiling did not increase yields of winter wheat or sorghums. Cotton yields from 1917 to 1931 indicated a possible increase due to subsoiling, but from 1933 to 1949 no response was noted. Corn yields following subsoiling were consistently high, and averaged higher than yields from fallow plots.

Laws (13) conducted tillage studies on a Houston clay soil in Texas. Methods ranged from plowing four to six inches with a disk plow to 16 to 18-inch chiselling. Neither method nor season of tillage affected corn yields in this trial. A three-year average of cottonseed yields also failed to show any increase due to deep tillage. Furthermore, the moisture content of the soil was not increased by deep tillage.

On the other hand, Merrill (14) found that plowing 12 inches deep on the experimental farm in Washington County, Utah, increased yields. Yields from a clay loam near Nephi, Utah, were studied by Harris, et al. (9). Methods of tillage used were subsoiling 18 inches, subsoiling 15 inches, plowing 10 inches, and plowing 5 inches. Data for eight years indicated that there were no differences in the yields, and that plowing 5 to 10 inches would probably be preferable.

Hume (10) of South Dakota reported in 1940 that corn and wheat yields increased with depth of tillage up to 12 inches. The deep tillage was accomplished by using a disk tiller when preparing a seed bed for corn. Jamison, et al. (11) used shallow, medium, and deep tillage on two Alabama soils, a fine sandy loam and a clay soil. Cottonseed yields were increased significantly by deep tilling the fine sandy loam soil, but no effect was noted on the clay soil.

A report on an extensive comparison of plowing and running a subsoiler at the bottom of the furrow to a total depth of 16 inches, versus normal plowing to eight inches, was released in 1918 by Chilcott and Cole (5). Tests were conducted at 12 stations in Montana, North Dakota, South Dakota, Nebraska, Kansas, Texas, and New Mexico. A total of 353 comparisons were studied. Higher yields on the subsoiled plot occurred in 153 sets, in 15 sets there was no difference, and in 185 sets the plots not subsoiled yielded the highest. On the basis of these results, the authors stated that subsoiling on the Great Plains was not beneficial. An examination of the results revealed three interesting facts:

1. No consistent results were experienced with any particular soil. Heavy clay soils with impervious subsoils might respond to subsoiling at one station and show decreased yields or no benefit at another station.

2. Crops were variable in response to subsoiling, especially from one year to another.

3. At Hays, Kansas, and Moccasin, Montana, the crops tended to respond to subsoiling. The Hays results may have shown significant increases, but the increases were not sufficient to pay for the deep tillage operation.

Millar and Weideman (15) experimented with deep tillage on a Hillsdale sandy loam soil in Michigan. They used 4, 7, and 10-inch depths of plowing. In the rotation of corn, barley, clover, and wheat, deep tillage decreased corn yields and clover yields, with no effect on wheat yields. Barley yields were increased. It was also found that the 10-inch plowing had over twice as much draft as did the four-inch plowing.

Deep placement of fertilizer was included in the deep tillage trials in Missouri by Woodruff and Smith (20). These studies were conducted on an infertile, droughty, claypan soil. The rotation consisted of corn, oats with lespedza, and barley with sweet clover. All plots received three tons of lime. Treatments consisted of normal plowing, normal plowing plus subsoil plowing, and the subsoil plowing with two tons of lime and 200 pounds of 8-20-10 fertilizer mixed in the subsoil. The small grains were given 100 pounds of 0-20-10. They found that deep plowing and deep plowing plus fertilizer increased corn yields. Barley yields were decreased by deep plowing alone. Oats were not significantly influenced and all yields were low.

Harper and Brensing (8) found milo and cottonseed yields could be increased greatly by deep plowing certain sandy soils in Oklahoma. The soils found to benefit from deep plowing were those having an extremely sandy surface, but with substantial clay content in the subsoil. Much of the benefit likely resulted from wind erosion control.

## METHODS AND PROCEDURE

The three studies conducted were: (1) wheat yield and its protein content from the Ladysmith silty clay loam as affected by deep tillage and deep fertilizer placement, (2) milo yields from the Idana silty clay loam as affected by deep tillage and deep fertilizer placement, and (3) spring wheat yields in the greenhouse as affected by soil compaction level and soil moisture condition. These studies will be referred to in this sequence throughout this manuscript.

Field Investigations

The deep tillage wheat experiment was situated on a soil tentatively correlated as Ladysmith silty clay loam. This soil occurred extensively on the broad, nearly level to gently rolling, upland flats of southeastern Geary and adjacent counties. This was a very dark grayish-brown acid soil, having a clay pan beginning at a depth of from 10 to 15 inches below the surface and extending to a depth of two feet or more. This soil, of loessial origin, frequently contained a buried profile. Limestone or shale bedrock often occurred within five or six feet of the surface.

A randomized complete block design with five replications and four treatments was used in the deep tillage experiment on the Ladysmith soil. Treatments were as follows: check, deep chiselled, deep chiselled with fertilizer broadcast, and deep chiselled with fertilizer placed deep. Individual plots were 250 feet long by 18.3 feet wide.

Deep chiselling for the wheat project was accomplished in July, 1954, using a D-4 Caterpillar with a mounted single chisel spike operating at a depth of 20 to 24 inches. The chisel marks were placed 44 inches apart. This allowed five evenly spaced marks per plot. The heavy fertilizer applications mentioned in the treatments were applied at the time of chiselling. The broadcast fertilizer was applied with a combination grain-fertilizer drill at the rate of 330 pounds per acre of ammonium nitrate and 320 pounds per acre of triple superphosphate. A special piece of equipment manufactured by the Pittsburg Forging Company was used to place 290 pounds per acre of ammonium nitrate and 233 pounds per acre of triple superphosphate at a depth of approximately 10 inches below the soil surface. The fertilizer was deep placed by using the equipment after the chiselling operation and some fertilizer probably sifted to the bottom of the shattered area.

The original plans for the experiment called for similar rates of fertilizer application on the broadcast and deep placed plots. As shown by the figures above, however, the deep placed rates were less. Alternate cloddy and loose surface of the field prevented the feeder drive wheel on the Pittsburg applicator from turning at a constant rate. The irregular feeding could not be corrected, and consequently the amount of deep placed fertilizer used per plot was less than that used on the broadcast plots. The assumption was made that the fertilizer used was applied uniformly over the plots.

All plots in this Geary County study were planted to wheat by the cooperator in the fall of 1955. Starter fertilizer was applied at the rate of 75 pounds of 16-20-0 ammonium phosphate per acre.

The wheat was harvested in July by cutting samples, using a hand sickle. Ten areas for sampling within each plot were chosen, with an attempt to select areas representative of the plot. From each of these areas, four rows five feet long were cut. Bundles from each area were threshed separately, weights taken, and the yields calculated. All grain from each plot then was combined and was run through a mixer and divider. One portion of the sample was ground and used for protein analysis. Protein analysis was carried out according to the modified Kjeldahl-Winkler method for nitrogen determination given by Piper (17).

During November, 1955, an attempt was made to measure comparative infiltration rates of the no-treatment and the chiselled plots on the Ladysmith soil. It should be pointed out that no attempt was made to determine any absolute infiltration rates. An infiltrometer patterned after the one designed by Diebold (6), Soil Scientist, Soil Conservation Service Operations Division, was used. Two primary changes were made in the infiltrometer. The size of the Fairbanks-Morse pump was increased to one handling three-quarter-inch fittings, and the experimental area used was 18 by 36 inches.

Type "F" nozzles, used by Diebold and on this infiltrometer as well, gave a favorable simulation of raindrop action. The line pressure was held as nearly as possible at 34 pounds per square inch, which gave an average application of five inches per hour on the experimental area. Water was applied at this rate for one hour. Runoff from the experimental area was measured at intervals of 10 minutes and the collection from the rain guage was measured every 15 minutes. The actual experimental area was raked lightly before applying water in order to give the area a uniform slope.

The milo deep tillage study was located on Idana silty clay loam. This soil occurred on the gently sloping to undulating uplands in eastern Clay County and adjoining counties. The A horizon usually was less than 10 inches thick on cultivated areas of 3 to 4 percent slope. The medium blocky, slowly permeable, silty clay B horizon was approximately 20 inches thick.

The procedure used in the milo study was the same as that used in the wheat trials with respect to the experimental design, plot size, treatments, chiselling operation, and fertilizer application methods. The rates of fertilizer application were somewhat different, however. For milo, both the broadcast and deep placed rates were 320 pounds per acre of triple superphosphate and 320 pounds per acre of ammonium nitrate.

Little tillage was conducted on the area of the milo plots between the chiselling operation and the planting operation. The milo was planted in the spring of 1955 in a very rough, cloddy seedbed without starter fertilizer. No subsequent fertilizer was applied.

The plots were harvested with a self-propelled combine in November, 1955. A strip 14 feet wide (four rows) and 176 feet long was harvested from each plot. The weight of the grain from each strip was recorded and yields were calculated.

## Greenhouse Investigation

Soils for the compaction study in the greenhouse were collected from the Agronomy Farm in March, 1955. Two soils that theoretically should react differently to compaction were selected.

Sample 1 was taken from the surface of a nearly level, well drained, alluvial soil on the Agronomy Farm. It was a dark grayish-brown, friable, light silt loam with a weak, very fine granular structure. It had an acid reaction (pH 5.5).

Sample 2 was a subsoil sample procurred from a 4 to 5 percent slope on the Agronomy Farm. Sheet erosion had removed the surface, exposing the subsoil at this location. This soil was a brown, firm, moderate blocky silty clay. The reaction was slightly acid (pH 6.0).

A randomized complete block design was used, with each soil constituting a separate experiment. There were six treatments: (1) 1.0 compaction level, alternately wet and dry; (2) 1.0 compaction level, continuously moist; (3) 1.3 compaction level, alternately wet and dry; (4) 1.3 compaction level, continuously moist; (5) 1.5 compaction level, alternately wet and dry; and (6) 1.5 compaction level, continuously moist. These six pots made up one replication and there were four replications for each soil. A total of 24 pots per soil, or 48 pots for the trial, was used.

Moisture contents of the samples were determined. Amounts of moist soil were calculated so that bulk densities of 1.0, 1.3, and 1.5 could be obtained when the soil was packed into upright tiles. Bulk density referred to the grams of oven dry soil per cubic centimeter. The soils were packed into the tiles by tamping successive additions of soil with a pipe.

When the tile were being filled with soil, Bouyoucos soil moisture blocks were placed eight inches below the surface of the soil. These were to be used as an aid in maintaining the proper moisture level. To eliminate the nutrient supply as a limiting factor, 10.0 grams of ammonium sulfate and 3.7 grams of triple superphosphate were added to each pot and mixed with the top four to five inches of soil. This was approximately equivalent to 440 pounds per acre of ammonium sulfate and 160 pounds per acre of triple superphosphate.

Each pot was seeded with 60 kernels of spring wheat on April 16. After germination was completed, the plants were counted and thinned to 10 plants per pot. The watering procedure followed the general pattern of watering the moist pots daily, and the dry pots every second day or every third day.

In harvesting, the total above-ground plant material was removed and weighed. Later the grain was threshed from the heads by hand and weighed.

## RESULTS AND DISCUSSION

### Field Investigations

The wheat was planted a few months after the deep tillage operation. Relatively little precipitation occurred during the fall and early winter, but a beneficial snow during the winter, plus sufficient moisture and cool weather in the spring, promoted excellent yields.

The fact that the plots had to be tilled for seedbed preparation shortly after chiselling and before any significant moisture could be received was not conducive to a good response from chiselling. Tillage with discs and harrows would tend to pulverize the soil surface and pack back together the shattered soil to a certain depth. The surface condition of the soil has been recognized for some time as one of the most important of the factors controlling infiltration.

Mean yields of the wheat from the tillage experiment are presented in Table 1. Detailed yield data are given in Table 4 (Appendix) and detailed results of grain protein analyses are found in Table 5 (Appendix). In the discussion, the letters A, B, C, and D refer to the treatments as follows: check, deep chiselled, deep chiselled with broadcast fertilizer, and deep chiselled with deep placed fertilizer, respectively.

The data indicated higher yields from treatment B than from treatment A. However, the difference between mean yields of treatment A and B was not significant. Nor was the difference between the yields of C and D significant. The results of these two comparisons discounted the value of deep tillage and deep placement of fertilizer. Comparison of the yields of the non-fertilized versus the fertilized plots revealed that the difference between the average means of the two groups was very highly significant. A smaller amount of fertilizer on treatment D than on treatment C could explain the lower yield from treatment D.

Table 1. Mean yields of wheat and milo grain (bushels per acre) and mean percent protein content of wheat.

| Treatment | Grain yield: Wheat | Grain yield: Milo | % protein, wheat |
|---|---|---|---|
| A Check | 30.4 | 3.8 | 10.4 |
| B Deep chiselled | 32.7 | 6.2 | 10.6 |
| C Deep chiselled, broadcast fertilizer | 48.2 | 4.4 | 13.2 |
| D Deep chiselled, deep-placed fertilizer | 46.4 | 6.4 | 13.5 |
| L.S.D. (P= 0.05) | 2.6 | 2.1 | 0.4 |

Protein contents of the wheat samples were not unusually high even where liberal nitrogen had been applied to the plots. The only significant difference found was between the unfertilized and fertilized treatments. The protein content of grain from those plots receiving fertilizer was much greater than from those having no fertilizer treatment.

The infiltration rate data from the Ladysmith soil are given in Table 2. Although it is difficult to draw conclusions from this amount of information, considerable time and effort was consumed in gathering information on this part of the study. These three particular replications, III, IV, and V were used in this study because they had been used in measuring infiltration rates a year previously by other workers. The last 30 minutes of the sprinkling in the present study revealed that infiltration rates from both treatments became virtually the same, and tended to level off.

Table 2. Relative infiltration rates in inches per hour on Ladysmith silty clay loam soil by 10 minute intervals in a one hour simulated rain storm.

| Replication | Treatment | Infiltration rate (in./hr.) in successive 10 minute intervals | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0-10 | 10-20 | 20-30 | 30-40 | 40-50 | 50-60 |
| III | Check | 4.59 | 2.48 | 1.62 | 1.38 | 1.36 | 1.32 |
| | Deep chiselled | 4.69 | 4.03 | 1.94 | 1.57 | 1.54 | 1.48 |
| IV | Check | 4.98 | 2.66 | 1.80 | 1.58 | 1.55 | 1.49 |
| | Deep chiselled | 4.45 | 2.26 | 1.80 | 1.56 | 1.52 | 1.52 |
| V | Check | 4.37 | 1.98 | 1.68 | 1.58 | 1.53 | 1.54 |
| | Deep chiselled | 4.47 | 3.61 | 2.09 | 1.83 | 1.70 | 1.11 |

With little reserve moisture in the fall of 1954 and with little winter precipitation, the milo crop on the Green experiment was seeded under very unfavorable conditions. Rain following planting did not favor good yields, either. In fact, most milo fields in the area yielded no grain. The yields on the experimental plots were low, but they gave some indication of the effect of deep tillage.

The mean milo grain yields are given in Table 1. Table 6 (Appendix) contains the milo yields from individual plots. Yields from treatments B and D, though not different from each other, were significantly greater than the yield from treatment

A. This indicated that deep tillage increased yields, but that the fertilizer did not increase yields further.

It would appear obvious that fertilizer did not have an opportunity to assert itself because of the dry weather. The deep chiselling, on the other hand, was favored under these conditions. The chisel marks laid open and rough over the winter and spring until planting time. This afforded an opportunity for snow and rain to be caught in the chisel marks. If deep tillage increased yields, some explanation for the lack of response to treatment C must be made. From the mean yields alone it could be surmised that perhaps the heavy fertilizer in the surface soil caused a high salt content in the soil solution and caused detrimental effects on the plants. The deep placed fertilizer could not do this damage, since considerable growth would need to take place before the roots would contact the fertilizer. An examination of the individual plot yields in Table 6 (Appendix) would cast doubt on the possible salt damage because of the variability of the yields, especially from treatments B and D.

## Greenhouse Investigation

The temperature in the greenhouse was extremely warm during the early growth of the plants. A long period of cloudy, cool weather allowed the plants to make excellent, rapid growth later in the growing period. The emergence of the different pots varied generally from 66 to 86 percent, but there were no consistent trends related to the treatments. The frequency of watering was increased during the periods of high temperature, and decreased during the cool periods. Inconsistent readings of resistances for the moisture blocks were experienced soon after the experiment was started. Readings were taken throughout the experiment but they continued to be erratic. An average frequency of watering was settled upon and used during the experiment, as stated in the procedure, instead of depending on moisture block readings as an indication of the moisture level.

The plants on the clay soil with the highest bulk density could be distinguished easily throughout much of the latter half of the plant growth. When heading was well completed and filling started, lodging became quite prominent. Observations on the degree of lodging were made on July 8, 1955. There seemed to be no correlation between lodging and treatment.

In Table 3, the yields of straw plus grain grown on sample 1 have been listed with the least significant differences. The yield data for each plot are found in Table 7 (Appendix). Mean results reveal that, with one exception (treatment 1), the yields were highest on the 1.0 compaction, second highest on 1.3, and lowest on 1.5. Although there were few significant differences between yields of the various treatments, the mean yields showed a definite inverse linear relationship between compaction and yield. The low yields in treatment 1 and 3 easily may have been caused by lack of water. The mean yields in the case of the 1.0 and 1.3 compaction levels indicated that additional water increased the yields.

Data for straw plus grain yields on sample 2 subsoil are given in Table 3 also. Table 8 (Appendix) contains the individual plot data for the straw plus grain yields on sample 2. The data showed that additional water was detrimental on the 1.5 compaction level, but the decrease in yields was not significant. The inverse relationship between compaction level and yield which occurred on soil sample 1 held true in the case of sample 2 yields.

Table 3. Mean wheat yields in grams per pot from greenhouse compaction study pots.

| Treatment[1] | Yield of straw plus grain | | Yield of grain | |
|---|---|---|---|---|
| | Soil 1 | Soil 2 | Soil 1 | Soil 2 |
| | grams | grams | grams | grams |
| 1 | 45.68 | 52.60 | 11.93 | 14.28 |
| 2 | 66.98 | 64.20 | 17.99 | 17.00 |
| 3 | 51.88 | 39.80 | 14.16 | 12.13 |
| 4 | 56.33 | 46.70 | 14.68 | 12.73 |
| 5 | 35.88 | 11.80 | 10.52 | 2.65 |
| 6 | 36.38 | 9.33 | 10.12 | 1.88 |
| L.S.D. (P= 0.05) | 11.30 | 16.34 | 3.83 | 6.89 |

[1]1- 1.0 compaction level, alternately wet and dry
2- 1.0 compaction level, continuously moist
3- 1.3 compaction level, alternately wet and dry
4- 1.3 compaction level, continuously moist
5- 1.5 compaction level, alternately wet and dry
6- 1.5 compaction level, continuously moist

Table 3 includes the grain yields from soil sample 1. The detailed data are given in Table 9 (Appendix). The grain yields followed the same trends as had the grain plus straw yields. Again, yields from treatment 1 were unreasonably low, but the other 1.0 compaction level treatment had higher yields than any other treatment. Yields from both 1.3 compaction levels were virtually the same. Treatment 6 resulted in a yield that was significantly lower than those of treatments 2, 3, and 4. Yields on treatment 5 were significantly lower than those on treatments 2 and 4. The yield from treatment 1 was not significantly greater than yields from treatments 5 and 6; however, it was significantly less than that of treatment 2.

Grain yields from treatments on the sample 2 subsoil are given in Table 3. The detailed data are found in Table 10 (Appendix). The L.S.D. value for this study revealed no significant differences between yields of treatments 1, 2, 3, or 4. All four of these treatment yields were significantly higher than yields from treatments 5 or 6. This indicated that perhaps there was a critical level of compaction on sample 2. The grain yields from the 1.5 compaction level were approximately one-fourth as much as yields from the other compaction levels.

## CONCLUSIONS

In evaluating the results of the field studies, it must be kept in mind that these data are from one year only. Present plans call for continuing the field experiments until conclusive evidence is at hand to uphold or reject deep chiselling and/or deep fertilizer placement as beneficial soil management practices.

On the basis of the one year of field results, however, the following conclusions may be drawn:

1. Deep tillage cannot be recommended as an economically sound practice for growing wheat on soils having the characteristics of the Ladysmith silty clay loam.
2. Although starter fertilizer was applied, the heavy fertilizer application greatly increased the wheat grain yield and the grain protein content regardless of placement.
3. Deep chiselling operations on the Idana silty clay loam did not increase milo grain yields consistently when compared to normal tillage.

The following conclusions may be drawn from the greenhouse studies:

1. Crop yields were decreased less on soil sample 1 than on subsoil sample 2, when the soil bulk density was around 1.5 and when the nutrient levels were equal.
2. When the single limiting factor on crop yields was bulk density, there tended to be an inverse relationship between the bulk density and the crop yield.
3. Wheat yields may be reduced by a bulk density somewhere between 1.3 and 1.5 on subsoils like sample 2. Below this density, yields may not be reduced so drastically on such subsoils. This same tendency held true for soil sample 1, but the effect was not as pronounced.

## SUMMARY

Field experiments on the effect of deep tillage and deep fertilizer placement on crop yields, and a greenhouse study on

the effect of soil compaction on crop yields were conducted.

Two deep tillage field experiments using wheat and milo were instigated on a Ladysmith silty clay loam and on an Idana silty clay loam, respectively. Treatments on these soils included: check, deep chiselled, deep chiselled with heavy fertilizer application broadcast, and deep chiselled with heavy fertilizer application deep placed. Relative infiltration rates of the chiselled and the check plots on the wheat deep tillage experiment were measured.

The greenhouse trial was designed using three bulk densities (1.0, 1.3, and 1.5) and two moisture levels at each bulk density as the six treatments on each of two soils. For the first moisture level, one set of each of the bulk densities was kept constantly moist. The second moisture level consisted of allowing the remaining three pots in each replication to dry until considerable cracking occurred, and then adding ample water.

Wheat grain yields from the field investigations revealed that deep chiselling did not increase yields over those of the check plots, nor was the protein content of the grain increased by deep chiselling. Heavy fertilizer applications increased wheat grain yields and protein content regardless of the fertilizer placement.

Deep tillage appeared to increase milo grain yields over the check plot yields. The yield increase was not enough to make deep chiselling an economically sound practice. Fertilizer applications did not significantly affect the milo grain yield. The yields were very low due to lack of moisture, which probably was a greater deterrent to crop growth than low fertility.

Relative infiltration rates on the Ladysmith soil did not seem to be influenced consistently by deep tillage. The rates were nearly identical after 30 minutes of sprinkling.

The greenhouse study indicated that there was a tendency for the wheat yields to be inversely proportional to the bulk density of the soil on which they were grown. The yields from subsoil sample 2 were decreased more by a 1.5 bulk density than were yields from soil sample 1. Yields from the 1.5 bulk density on sample 2 were sharply lower than those from the 1.3 bulk density, indicating a possible critical density somewhere between 1.3 and 1.5. Yields tended to be decreased by continuously moist conditions on subsoil sample 2 at the 1.5 bulk density.

Crop yields are apparently decreased by high soil bulk densities. Results from one year of field investigations indicate that deep chiselling cannot be expected to increase crop yields from those soils having highly compacted subsoils.

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# APPENDIX

Table 4. The effect of deep chiselling and deep fertilizer placement on wheat grain yields in bushels per acre. Alta Vista, Kansas, 1955.

| | Yield of wheat (bushels/A) | | | | | |
|---|---|---|---|---|---|---|
| Treatment | Rep I | Rep II | Rep III | Rep IV | Rep V | Mean |
| Check | 28.8 | 31.1 | 30.9 | 29.4 | 30.7 | 30.4 |
| Deep chiselled | 33.2 | 31.7 | 31.1 | 32.8 | 34.9 | 32.7 |
| Deep chiselled, broadcast fertilizer | 44.7 | 52.0 | 49.5 | 44.9 | 46.7 | 48.2 |
| Deep chiselled, deep-placed fertilizer | 48.8 | 47.4 | 45.9 | 45.8 | 44.2 | 46.4 |

Table 5. The effect of deep chiselling and deep fertilizer placement on the protein content of wheat. Percent on dry basis. Alta Vista, Kansas, 1955.

| | Protein content (percent) | | | | | |
|---|---|---|---|---|---|---|
| Treatment | Rep I | Rep II | Rep III | Rep IV | Rep V | Mean |
| Check | 10.2 | 10.6 | 10.3 | 10.3 | 10.4 | 10.4 |
| Deep chiselled | 10.5 | 10.3 | 10.6 | 10.6 | 10.9 | 10.6 |
| Deep chiselled, broadcast fertilizer | 12.7 | 13.3 | 13.1 | 13.9 | 13.2 | 13.2 |
| Deep chiselled, deep-placed fertilizer | 13.2 | 14.0 | 13.4 | 13.5 | 13.5 | 13.5 |

Table 6. The effect of deep chiselling and deep fertilizer placement on milo grain yields in bushels per acre. Green, Kansas, 1955.

| Treatment | Yield of milo (bushels/A) | | | | | |
|---|---|---|---|---|---|---|
| | Rep I | Rep II | Rep III | Rep IV | Rep V | Mean |
| Check | 2.8 | 3.8 | 3.4 | 4.6 | 4.3 | 3.8 |
| Deep chiselled | 4.7 | 3.8 | 9.1 | 5.4 | 8.1 | 6.2 |
| Deep chiselled, broadcast fertilizer | 4.7 | 4.7 | 4.4 | 4.1 | 4.0 | 4.4 |
| Deep chiselled, deep-placed fertilizer | 3.7 | 8.3 | 5.2 | 7.0 | 7.6 | 6.4 |

Table 7. Effect of bulk density of soil sample 1 on wheat straw plus grain yields from greenhouse study. Yields in grams per pot.

| Treatment[1] | Yield of straw plus grain (g/pot) | | | | |
|---|---|---|---|---|---|
| | Rep I | Rep II | Rep III | Rep IV | Mean |
| 1 | 53.8 | 36.9 | 52.3 | 39.7 | 45.68 |
| 2 | 72.6 | 78.1 | 49.6 | 37.6 | 66.98 |
| 3 | 50.7 | 57.4 | 45.1 | 54.3 | 51.88 |
| 4 | 50.7 | 50.9 | 59.6 | 64.1 | 56.33 |
| 5 | 43.1 | 24.7 | 34.8 | 40.9 | 35.88 |
| 6 | 29.7 | 39.2 | 46.2 | 30.4 | 36.38 |

[1]
1- 1.0 compaction level, alternately wet and dry
2- 1.0 compaction level, continuously moist
3- 1.3 compaction level, alternately wet and dry
4- 1.3 compaction level, continuously moist
5- 1.5 compaction level, alternately wet and dry
6- 1.5 compaction level, continuously moist

Table 8. Effect of bulk density of soil sample 2 on wheat straw plus grain yields from greenhouse study. Yields in grams per pot.

| Treatment[1] | Yield of straw plus grain (g/pot) | | | | |
|---|---|---|---|---|---|
| | Rep I | Rep II | Rep III | Rep IV | Mean |
| 1 | 52.9 | 46.2 | 54.2 | 57.1 | 52.60 |
| 2 | 50.4 | 63.6 | 64.5 | 78.3 | 64.20 |
| 3 | 30.8 | 49.8 | 14.1 | 64.5 | 39.80 |
| 4 | 58.4 | 39.4 | 29.5 | 59.5 | 46.70 |
| 5 | 4.1 | 10.7 | 28.4 | 4.0 | 11.80 |
| 6 | 13.7 | 14.3 | 7.6 | 1.7 | 9.33 |

[1]See footnote Table 7.

Table 9. Effect of bulk density of soil sample 1 on wheat grain yields from greenhouse study. Yields in grams per pot.

| Treatment[1] | Yield of wheat grain (g/pot) | | | | |
|---|---|---|---|---|---|
| | Rep I | Rep II | Rep III | Rep IV | Mean |
| 1 | 14.31 | 8.16 | 14.99 | 10.27 | 11.93 |
| 2 | 22.06 | 20.37 | 11.96 | 17.58 | 17.99 |
| 3 | 14.88 | 14.89 | 10.45 | 16.44 | 14.16 |
| 4 | 15.53 | 12.22 | 13.46 | 17.51 | 14.68 |
| 5 | 12.23 | 6.80 | 12.06 | 11.01 | 10.52 |
| 6 | 8.92 | 11.00 | 13.05 | 7.50 | 10.12 |

[1]See footnote Table 7.

Table 10. Effect of bulk density of soil sample 2 on wheat grain yields from greenhouse study. Yields in grams per pot.

| Treatment[1] | Yield of wheat grain (g/pot) | | | | |
|---|---|---|---|---|---|
| | Rep I | Rep II | Rep III | Rep IV | Mean |
| 1 | 14.32 | 11.26 | 14.66 | 16.86 | 14.28 |
| 2 | 11.53 | 14.94 | 19.67 | 21.85 | 17.00 |
| 3 | 9.51 | 15.29 | 2.61 | 21.12 | 12.13 |
| 4 | 12.45 | 12.57 | 8.51 | 17.38 | 12.73 |
| 5 | 0.56 | 2.18 | 7.67 | 0.20 | 2.65 |
| 6 | 3.15 | 3.00 | 1.37 | 0.00 | 1.88 |

[1]See footnote Table 7.

THE EFFECT OF DEEP CHISELLING, DEEP FERTILIZER PLACEMENT, AND SOIL BULK DENSITY ON CROP YIELDS

by

DOYLE EUGENE PEASLEE

B. S., Kansas State College of Agriculture and Applied Science, 1952

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Some soils in Kansas contain restricting layers within the profile. Such layers often cause reductions in crop yields. Deep tillage had been suggested as a means of increasing available moisture and root penetration at least as early as 1860. Advancements in tillage machinery design and the production of more powerful tractors have caused a renewed interest in the use of deep tillage to shatter the restricting layer, and thus increase the crop yields.

In order to determine the advisability of deep tillage, two field experiments using wheat and milo were instigated on a Ladysmith silty clay loam soil and on an Idana silty clay loam soil, respectively. Treatments on these soils included: check, deep chiselled, deep chiselled with heavy fertilizer application broadcast, and deep chiselled with heavy fertilizer application deep placed.

Relative infiltration rates of the chiselled and check plots on the Ladysmith soil were measured using an infiltrometer.

A soil compaction study was set up in the greenhouse. Three relative rates of compaction (bulk densities of 1.0, 1.3, and 1.5) were used, along with two moisture levels for each compaction rate. One moisture level consisted of keeping the pot constantly moist, while the second moisture level consisted of allowing the pot to dry out considerably, then using liberal additions of water.

Deep tillage did not increase yields of wheat grain or protein content. Heavy fertilizer application increased both yield and protein content regardless of placement. Infiltration rates of the Ladysmith soil were not consistently increased by deep tillage, according to the first 30 minutes of sprinkling. Rates during the last 30 minutes were nearly identical for the check and the chiselled plots.

Deep tillage did not consistently increase milo yields. Mean yields showed a significant increase due to deep tillage which was not economically important.

The greenhouse study indicated that there was a tendency for wheat grain yields to be inversely proportional to the bulk density of the soil on which they were grown. The yields from soil sample 2 were decreased more by a 1.5 bulk density than were yields from soil sample 1. Yields from the 1.5 bulk density on soil sample 2 were sharply lower than those from the 1.3 bulk density, indicating a possible critical density somewhere between 1.3 and 1.5. Yields tended to be decreased by continuously moist conditions on soil sample 2 at the 1.5 bulk density.

Although the greenhouse trials indicated that high bulk densities were definitely detrimental to crop yields, the results of one year of deep chiselling studies indicated that deep chiselling may not improve crop production on those problem soils.