SOIL COMPACTION BY AGRICULTURAL LAND PACKERS AND MODELS

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INTRODUCTION

Farmers in Canada have realized from practice that fields which have been packed after seeding generally produce more uniform crops and higher yields than those which have not been packed. They also claimed that post-seeding compaction treatments cause earlier emergence of crops from the soil. A possible explanation for these results may be that the soil is packed around the seed so that germination is hastened and the depth of soil above the seed is reduced which allows young plants to come up more rapidly. Johnson and Henry (4) reported that bulk density of the soil was related indirectly to seedling emergence in that any change in bulk density changed other factors such as oxygen diffusion rate and soil crust strength. They concluded that compacting a soil layer one inch above the seed, created a diffusion barrier which reduced the overall drying rate yet allowed favourable emergence because drying of the compacted layer was delayed.

There has been considerable research into compaction of soil due to wheels of farm machinery. However, there have been fewer studies on agricultural land packers used to promote crop response. The purpose of the study reported here was to evaluate the degree of compaction of the soil brought about by some packer arrangements.

RELATED LITERATURE

Numerous investigations have been made on the effect of field machine compaction on soil physical properties. Feldman and Domier (2) Nuttal and McGown (5) reported on this aspect. Schuring and Emori (6) approached the soil deforming process by dimensional analysis.

Van Bavel *et al.* (8) used gamma ray transmission methods to measure the soil dry bulk density. They went to the extent of developing a soil densitometer. Soane (7) examined certain practical aspects of a double energy gamma transmission method, the principle of which was based on the variation of the ratio between the absorption coefficients for water and soil at different gamma energies. Davidson, Biggar and Nielson (1) reported on gamma-radiation attenuation for measuring bulk density and transient water flow in porous materials.

Harrison (3) suggested that a width to depth ratio of approximately three for soil bins with rectangular cross-section would reduce the side effect of the sides or bottom.

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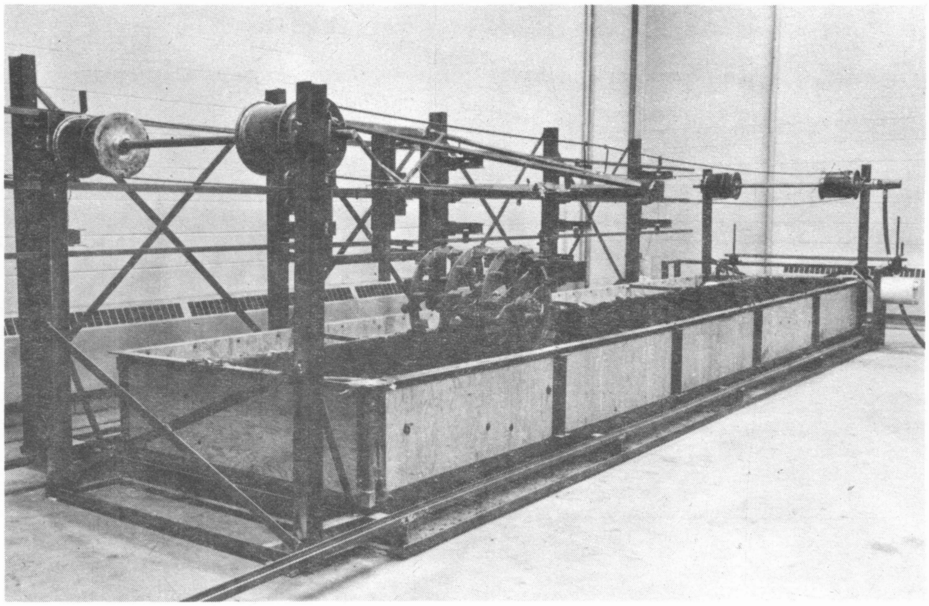

Figure 1 Soil bin.

EQUIPMENT

The soil bin used was 20 feet (6.1 m) long, 32 inches (81.3 cm) wide and 16 inches (40.6 cm) deep made out of ½ inch (1.3 cm) thick plywood (Figure 1). The soil box lined with a sheet of black plastic film was filled with clay loam soil with high organic matter (according to USDA classifications).

The *in situ* soil density measuring equipment consist of a gamma source of 2,000 millicurie of Cesium^{137}, a sodium iodide crystal detecting probe manufactured by Nuclear-Chicago and pulse height analyzer and scaler-timer model H.P. 5201L built into one unit by the Hewlett Packard Company. The gamma rays emitted by the Cesium^{137} passing through the intervening soil hit the NaI crystal resulting in voltage pulses. These were fed through the pulse height analyzer which was calibrated to pass only a band of energy levels centred around the peak produced by the Cesium^{137} source and to discard those of higher or lower energies. The filtered pulses were totalized for a precise present time period and the number of counts were displayed in digital form by the scaler-timer.

EXPERIMENTAL PROCEDURES

Calibration

Since there were two soil variables, one the dry bulk density and the other moisture content, the gamma density unit was calibrated by varying the dry bulk density for different levels of soil moisture content.

The soil was sieved with mesh opening of 0.132 inch (0.335 cm) and was thoroughly mixed with water to obtain a fairly uniform moisture content. The soil was carefully placed in six-inch (15.3 cm) diameter, 29 inch (73.7 cm) long aluminum cylinders. The soil in each cylinder was uniformly packed to different bulk densities, and to avoid loss of moisture to the atmosphere the ends of each cylinder were covered with plastic film. Each cylinder was then placed in the path of the gamma rays with the axis of the cylinder parallel to the rays. Gamma counts for two minutes were taken at 1/2 inch (1.3 cm) intervals across the center 2½ inches (6.3 cm) of a cylinder diameter. At each point (six in all) five consecutive readings were taken. Average of the 30 readings evaluated in counts per minute, I_s, gave the gamma count rate for the soil in the cylinder. Counts for three minutes through a standard plastic bar were taken five times before and after each set of readings. Here again the average of the readings yielded count rate through the plastic I_p. It was insured that the difference between counts through the plastic before and after did not exceed 300 counts in about 10,000 counts.

A plot on a semi-log paper of I_s/I_p against the dry bulk density of the soil in the cylinder yielded a family of straight lines for various moisture contents. The dry density of the soil in the soil box can be evaluated from these plots if the soil mineral particles do not shrink or swell with changes in moisture content (Figure 2). Knowing the moisture content of the soil in the box from the oven-dry method one can select the appropriate line which will be the calibration line of that soil. The dry bulk density corresponding to I_s/I_p can be determined by the use of this line (I_s becomes the count rate through the soil in the box). This method though very straightforward and simple, involved interpolation. Since the width (X_1) of the soil in the soil bin was not equal to the length (X_2) of the soil used in the aluminum cylinders, the density obtained was multiplied by a factor X_2/X_1.

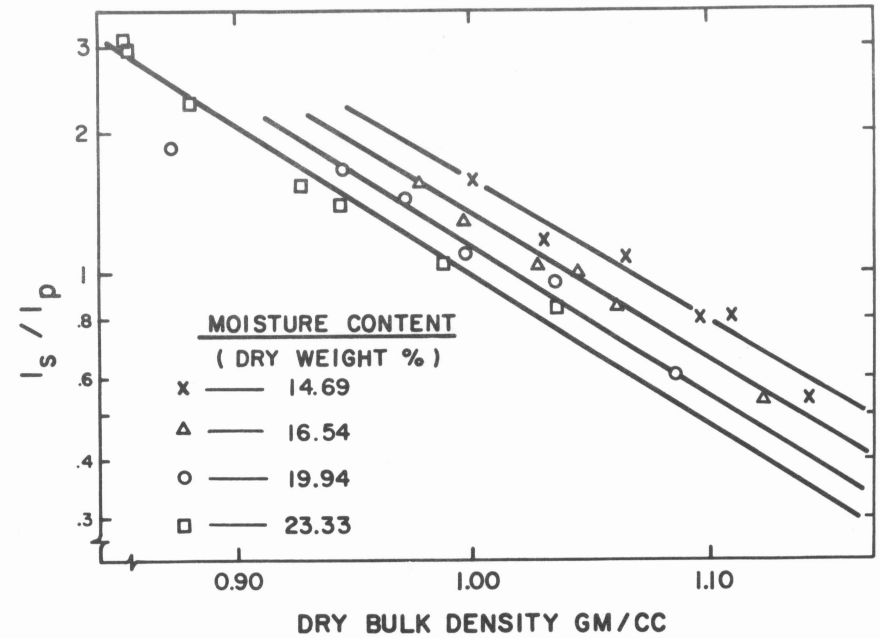

Figure 2 Calibration lines for soils in cylinders.

Model Tests

The packer models used were flat wooden discs stacked together on 30 inch (76.2 cm) shafts and loaded equally at both ends (Figure 3).

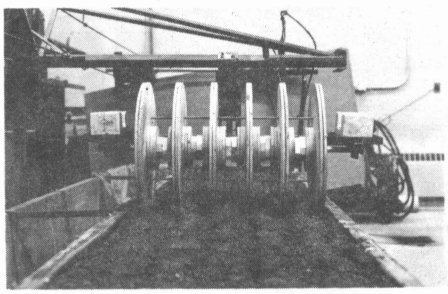

Figure 3 Model packer.

A series of experiments were conducted for two packer weights to determine the effects on the soil dry bulk density of wheel diameter, thickness and spacing.

Before each test the soil was moistened and allowed to dry to the desired moisture content. Soil samples for moisture measurement were taken at each depth to a depth of six inches (15.2 cm), two inches (5.1 cm) greater than the depth of cultivation. In some cases obtaining uniform moisture content involved physical transferring wet soil to regions of dry soil and vice versa. The soil was then cultivated with a 12 inch (30.5 cm) cultivator shovel attached to a hydraulic driven carriage. In all, six runs of cultivation at a 4 inch (10.2 cm) depth were made for each preparation. In order to prevent loss of moisture from the soil to the atmosphere during gamma ray measurements the soil box was covered with a conveyor belt immediately after cultivation and packing. This was done in such a way that the conveyor did not touch the soil.

A set of packer wheels with the appropriate loading was run once over the soil in the box. The schedule for the tests in shown in Table I.

Another series of tests were made with wheel diameter 24 inches (61.0 cm) and width one inch (2.5 cm) for the following spacings between adjacent wheels: one inch, two inches, three inches and five inches (2.5, 5.1, 7.6 and 12.7 cm).

Gamma counts were taken before and after each run at the depths 1½, 2½, 3½ inches (3.8, 6.3 and 8.9 cm) at each of the six stations selected along the length of the soil box. At each depth five consecutive one-minute counts were recorded. The cultivated soil surface level was used as the datum for all the depth measurements. Count rates through the standard plastic bar were taken before and after set of readings. The average count rate at one depth at each station was evaluated and the dry bulk density at that depth was determined after finding the moisture content of the soil at that station. One set of the gamma readings was taken after cultivation and another set after packing.

Land Packer Tests

Two types of packers were used. These were the conventional implements, and representative of general farm equipment used in packing operations. The crowfoot packer was two feet (61.0 cm) in diameter and two

TABLE I. SCHEDULE OF PACKER RUNS WITH ONE INCH (2.5 cm) SPACING BETWEEN ADJACENT WHEELS

	Pounds per Foot of Width			
	94.8		133.5	
Wheel Width (inches)	8 inches diameter	24 inches diameter	8 inches diameter	24 inches diameter
1/2	*	*	*	*
1	*	*	*	*
1 1/2	*	*	*	*

TABLE II. SCHEDULE OF PACKER WEIGHTS IN POUNDS PER FOOT WIDTH

No.	Crowfoot	Coil
1	60.0	80.0
2	97.5	97.5
3	135.0	135.0
4	160.0	160.0

feet (61.0 cm) wide, and had three wheels (Figure 4). The coil packer was 18 inches (45.7 cm) in diameter and 30 inches (76.2 cm) wide and was made of 1 3/8 inch (3.5 cm) square steel bar in helical form with five coils (Figure 5). A weight box system on the packers was used to adjust the weight to four different levels for each packer (Table II). Each packer system was run once over the cultivated and prepared soil in the box. Gamma readings were taken before and after packing. In this case, tests were performed for three depths of cultivation, viz. approximately four, five and six inches (10.2, 12.7 and 15.3 cm).

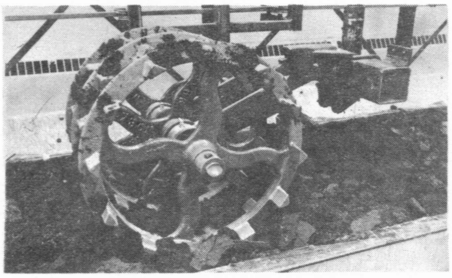

Figure 4 Crowfoot packer.

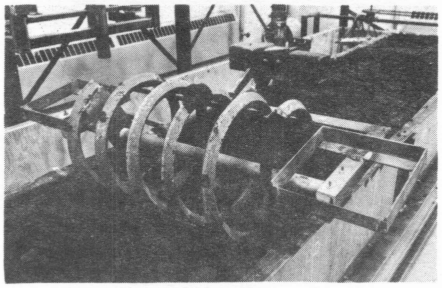

Figure 5 Coil packer.

RESULTS

Model Tests

The values of the dry bulk density of the soil after cultivation varied between the range of 0.88 gm/cc and 0.95 gm/cc (Table III and IV). After packing these bulk densities were increased to levels which had no relationship to the corresponding unpacked dry bulk densities. This indicated that for each arrangement the resulting packed dry bulk density was not related to the unpacked density. However, the packed density was less at the surface, 1½ inches deep (3.8 cm) due to cracks of the soil and the wheel sinkage.

In general, increase in packer weight resulted in an increase in dry bulk density. An increase of 41% in the packer weight resulted in an average increase of less than 1% in the dry bulk density.

At each depth the diameter of the packer wheels used had no significant influence on the resulting dry bulk densities. However, the soil surface developed a lot more cracks with the smaller diameter wheels.

Wheel widths of ½ inch, 1 inch and 1½ inch (1.3, 2.5 and 3.8 cm) did not make any appreciable difference to the dry bulk densities at depths of 1½ inches, 2½ inches and 3½ inches (3.8, 6.3 and 8.9 cm). There were slight variations (about 1%) between the measured densities. This was due to the heterogeneity of the soil. Also the ½ inch (1.3 cm) wheel, the thinnest, tended to sink into the soil more than the others.

There was no significant difference between the packed bulk densities obtained at each depth for the different wheel spacings used (Figure 6).

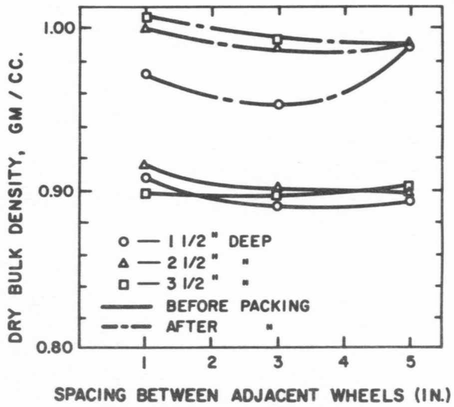

Figure 6 Wheel spacing vs. dry bulk density.

In the experiment, as the spacing between the wheels was increased (with the same wheel width) or as the thickness of the wheels was decreased (with the same spacing) the number of wheels on the packer length were accordingly decreased resulting in fewer wheels. But the load on the wheels remained unchanged. Hence higher stresses were exerted on the soil. This meant that there were higher densities along the path of the wheels over a lesser area of the soil. Since the recorded densities were the average densities across the entire

TABLE III. AVERAGE DRY BULK DENSITIES AT VARIOUS DEPTHS BEFORE PACKING

Wheel Diameter (inches)	Depth inches	133.5 lb/ft width Wheel width, inches 1/2	1	1 1/2	94.8 lb/ft width Wheel width, inches 1/2	1	1 1/2
8	1 1/2	0.92	0.90	0.89	0.93	0.88	0.91
	2 1/2	0.93	0.92	0.90	0.94	0.92	0.92
	3 1/2	0.92	0.92	0.90	0.93	0.93	0.93
24	1 1/2	0.91	0.91	0.93	0.91	0.90	0.95
	2 1/2	0.94	0.92	0.93	0.92	0.90	0.94
	3 1/2	0.94	0.90	0.92	0.90	0.91	0.94

Bulk density in gm/cc.
One inch spacing

TABLE IV. AVERAGE DRY BULK DENSITIES AT VARIOUS DEPTHS AFTER PACKING

Wheel Diameter (inches)	Depth inches	133.5 lb/ft width Wheel width, inches 1/2	1	1 1/2	94.8 lb/ft width Wheel width, inches 1/2	1	1 1/2
8	1 1/2	0.96	0.95	0.93	0.97	0.96	0.97
	2 1/2	1.03	1.03	1.02	1.01	1.04	1.04
	3 1/2	1.04	1.05	1.04	1.02	1.03	1.04
24	1 1/2	0.93	0.97	0.99	0.92	0.98	0.99
	2 1/2	1.03	1.02	1.03	1.01	0.99	1.02
	3 1/2	1.05	1.02	1.05	1.01	1.00	1.03

Bulk density in gm/cc
One inch spacing.

width of the soil, the density concentrations were evened out giving the same density for all the wheel widths or for all the wheel spacings.

Land Packer Tests

The result of the analysis of variance indicated that there was no significant effect from the type of packer, packer weight, or the depth of cultivation on the dry bulk density (this is valid for the range of values used in the tests). The only significant variation in dry bulk density occurred with changes in depth down to the depth of cultivation just as in the model tests (Figures 7 and 8). Because relatively few data were available, the least significant difference in dry bulk density at 95% and 99% probability levels was 0.05 gm/cc and 0.007 gm/cc respectively for any set of means of variables.

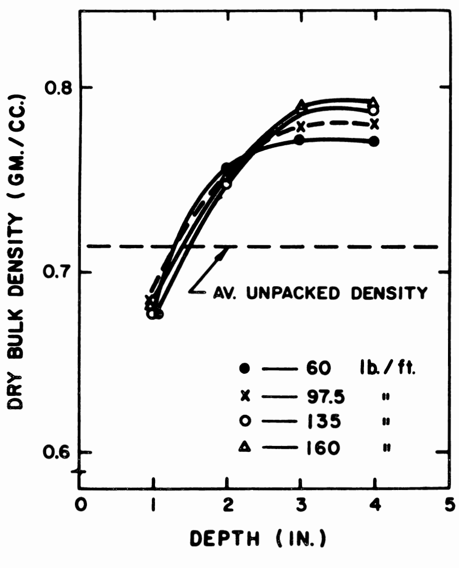

Figure 7 Crowfoot packer.

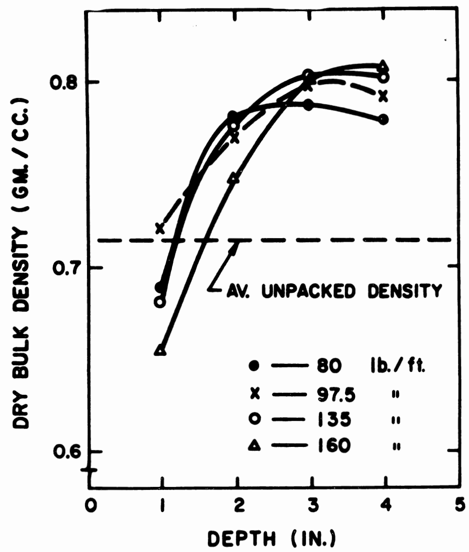

Figure 8 Coil packer.

CONCLUSIONS

From the studies undertaken the following conclusions were drawn:

1. An increase of 41% in the packer model weight (94.8 to 133.5 lb/ft. width) resulted in less than 1% increase in the packed density.
2. For each packer model arrangement the resulting packed density was immaterial to the unpacked (cultivated) density.
3. No significant difference in density was obtained by varying the following parameters of the model.
   (i) wheel diameter from 8 inches (19.2 cm) to 24 inches (61.0 cm),
   (ii) wheel width from ½ inch (1.3 cm) to 1½ inches (3.8 cm) and
   (iii) spacing between wheels from 1 inch (2.5 cm) to 5 inches (12.7 cm).
4. For the conventional land packers there was no statistically significant difference in the packed densities obtained from various weights of packers. The type of packer (coil or crow-foot) and the depth of cultivation did not have any appreciable effect on the packed density.

SUMMARY

A laboratory study was undertaken to determine the effect of packer models made of flat wooden discs stacked on a shaft and the conventional types on the soil bulk density at several depths. The *in situ* bulk density was measured before and after

packing by gamma ray density unit. The values of the dry bulk density of the soil after cultivation increased after packing but the resulting density was not related to the unpacked density. However, the packed density was less at the surface. In the model tests an increase of 41% in the packer weight resulted in an average increase of less than 1% in the dry bulk density. Wheel diameter, width and spacing considered produced about the same packed densities. In the case of the coil and crowfoot packers there was no statistically significant difference in the packed densities obtained from different weights, and type of packers used.

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