Compaction Caused by Tractor Wheels in the Cultivation of Sugar Beets

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The cultivation of sugar beets, five or six times during the season, has a cumulative compacting effect on the soil, the results of which have not yet been fully or definitely determined. That considerable compaction occurs is readily admitted since on all of the seeding and cultivating operations, the equipment used is so designed that the tractor wheels travel in the same row or path each time. For four-row equipment this means that every other row becomes a path for a tractor wheel. The intervening rows, on the other hand, receive the full benefit of the cultivation because no compaction occurs.

The compacting force will, of course, depend on the total weight of the tractor and the weight distribution on the wheels of the tractor. For example, a Model A International Tractor[2], a size ordinarily used for cultivating sugar beets, weighs about 2,850 pounds with the driver. The weight distribution is as follows:

Front wheel 950 pounds or 475 each wheel
Rear wheels 1,900 pounds or 905 each wheel

With the beet cultivator mounted on the tractor, the total weight, with driver, is increased to 3,470 pounds; 1,160 on the front and 2,310 on the rear.

This tractor is equipped with 5-inch tires on the front wheels and 9-inch on the rear. The normal or prescribed inflation for these tires is 24 pounds of pressure in the front and 12 pounds in the rear. Such a tractor weighing 2,850 pounds with driver at Huntley Field Station, Montana, was used in connection with a study to measure the compaction which occurs when cultivating sugar beets.

The bearing surface of the tires on the ground was measured with the tractor standing still. The method used was to jack the wheel off the floor, paint the lower section of the tire with black paint, then lower the wheel onto a large sheet of paper. This left a clear impression of the bearing surface of the tire. Only the lugs left an impression on the paper. However, on loose soil the grooves between the lugs would also carry some of the load.

The area, in square inches, of the impression made by each tire was carefully measured with a planimeter. From these measurements, and the weight carried by each wheel, the pounds per square inch bearing pressure of the tractor wheel on the ground was calculated. The procedure described above was repeated for both front and rear tires while inflated four pounds above normal and four pounds below normal. The bearing surface and bearing pressure and pounds per square inch between wheel and ground are given in Table 1.

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[2]A Model "A" tractor equipped as above was weighed at Huntley Field Station.

Table 1.—Compacting Force of Tractor Wheels with Tires Inflated Four Pounds Above Normal, Normal, and Four Pounds Below Normal.

Front Wheels	TIRE INFLATION		
	4 Pounds Above Normal 28 p.s.i.	Normal Pressure 24 p.s.i	4 Pounds Below Normal 20 p.s.i
Weight carried on each wheel	475 lbs.	475 lbs.	475 lbs.
Area of bearing surface of lugs	10.16 sq. in.	10.09 sq. in.	12.07 sq. in
Average weight per square inch bearing surface	46.8 lbs.	47.0 lbs.	39.4 lbs.

Rear Wheels	TIRE INFLATION		
	4 Pounds Above Normal	Normal Pressure	4 Pounds Below Normal
Weight carried on each wheel	950 lbs.	950 lbs.	950 lbs.
Area of bearing surface of lugs square inches	10.44 sq. in.	12.23 sq. in.	15.15 sq. in.
Average weight per square inch	91.0 lbs.	77.5 lbs.	62.6 lbs.

Note that the pounds per square inch bearing pressure of the front wheels when under inflated was nearly 20 percent less than with normal inflation. The pounds per square inch bearing pressure when inflated above normal was practically the same as normal. For the rear wheels the pounds per square inch bearing pressure was nearly 19 percent less when under inflated and 12 percent more when over inflated than with normal pressure. It is believed that the vibration of the tractor also affects the amount of compaction.

Compared to the above, the pressure from the hoof of an average work horse, weight 1,600 pounds, is about 21 pounds per square inch, and of a 160 pound man, 5.7 pounds per square inch. It should, of course, be remembered that the area compacted by a horse's hoof is comparatively small and that there is also little possibility that the horse would step in the same place each time during succeeding cultivations, whereas, the compaction from a tractor wheel is a continuous strip along the entire row. Thus, the cumulative compaction from horse's hoofs would not be so pronounced as from the tractor wheel.

Some idea of the amount of compaction which takes place in the beet row where the tractor wheel travels may be obtained by measuring the force required to drive a stake or bar into the soil. Such a test was made at the Huntley Field Station during the summer of 1955. A small pile driver was made which was used to drive a round bar into the ground by striking it with a hammer dropped from a given distance.

In the test described, a 10-pound weight was used for a hammer. It was dropped a distance of two feet for each blow. The bar driven into the ground was 1⅛ inches in diameter. Twenty-five blows were used for each test. The tests were made before and after irrigation and in each case were made in the row traveled by the tractor wheel and in the adjacent middle row.

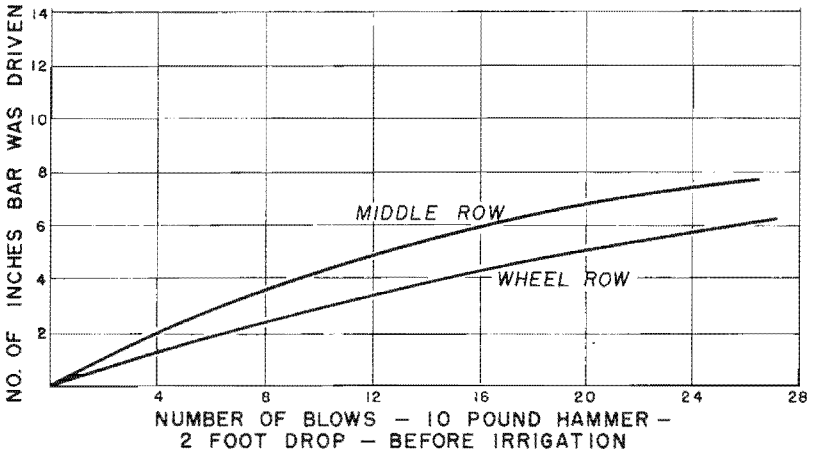

Figure 1.—Compaction tests, Field "K," Huntley Field Station.

The results of these tests can best be shown graphically. Figure 1, which is the average of five tests, shows a comparison between the resistance of the soil in the wheel row compared to the soil resistance in the middle row before irrigation. The data taken before irrigation show that the bar was driven 7.6 inches in the middle row and 5.9 inches in the wheel row which was 1.7 inches or 28 percent farther with 25 blows in the middle row than it was in the row compacted by the tractor wheel. After irrigation the test showed a difference of 2.3 inches or 20 percent in favor of the middle row (See Figure 2).

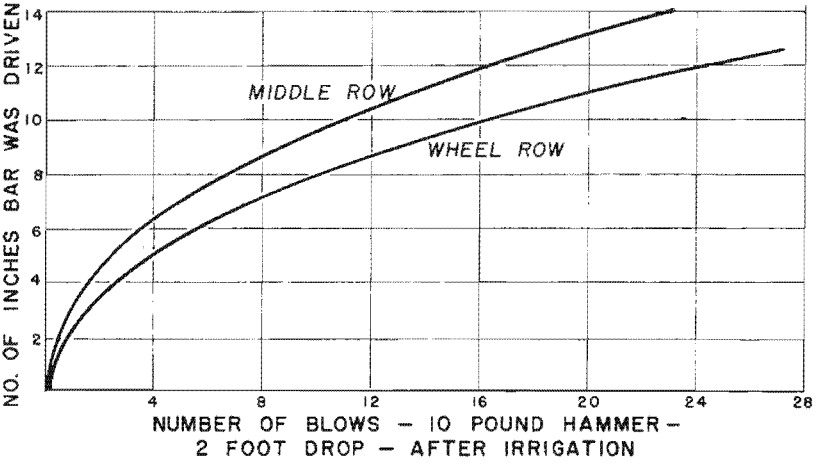

Figure 2.—Compaction tests, Field "O," Huntley Field Station.

Before irrigation, the effect of compaction appeared at a depth of one inch in the wheel row when the distance driven became less than one-fourth inch for each blow. In the middle row the bar was driven 5.4 inches before the resistance was great enough to reduce the distance driven per blow to less than one-fourth inch.

One day after irrigation a similar test was made. The results are shown in Figure 2. In this test the bar was driven 14.5 inches by 25 blows in the middle row compared to 12.1 inches in the wheel row. The bar was driven over three inches by the first blow of the hammer in the middle row as compared with 2.2 inches in the wheel row or nearly an inch farther. After 20 blows, the distance driven by one blow of the hammer dropped to less than one-fourth inch per blow in both cases, but the distance driven by 20 blows was nearly 13.2 inches in the middle row as compared to 10.9 inches in the wheel row.

These tests clearly show that tractor wheels cause considerable compaction. They also give a measure of the amount of compaction in the soil at the end of the season.

Irrigators recognize this condition and make allowance for the difference in rate of absorption of water. The general practice is to turn a smaller stream into the wheel rows because of the low intake rate, and a larger amount into the middle rows since the intake rate is greater. Where the plastic tubes are used, 2 one-inch tubes are set in the middle row and one in the wheel row. When the same size stream is turned into all rows, the wheel rows usually reach across the field in about one-half the time required for the others.

Infiltration readings were taken in both wheel rows and middle rows by the ring method. Six rings were used for this test; three in the wheel rows and three in adjacent middle rows. The results are shown in Figure 3.

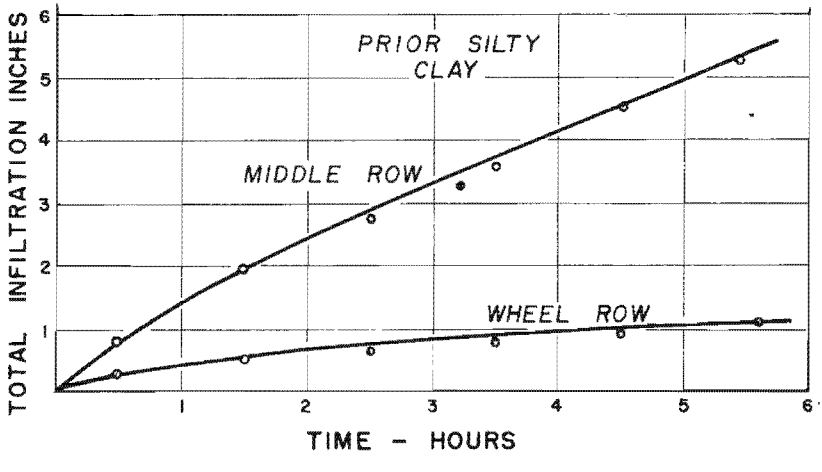

Figure 3.—Effect of compaction by tractor wheels on infiltration, Huntley Field Station.

These data show that a total of 5 5/16 inches of water were absorbed in the middle row in 5⅓ hours, almost an inch per hour. During the same time, 5½ hours, only 1⅛ inch was absorbed in the wheel row. This test was made at the end of the irrigation season after six cultivations. The tractor wheel had, therefore traveled seven times along the same path—once for seeding, six times during cultivating operations.

The last irrigation of the season was applied during the second week in September. The difference in time for the water to reach the end of the row between the middle furrows and those compacted by the tractor wheels was not as obvious because of the large shrinkage cracks in the soil. Many of these extended all the way across the row so that the water from adjacent rows intermingled to such an extent that all rows reached the end at the same time.

There was, however, a difference between rows in the amount of water stored in the soil. Soil samples taken before and after irrigation showed that with the moisture content approximately the same in all rows before irrigation, comparatively little absorption of water took place in the wheel row while the middle row absorbed the full field capacity. The soil where the tests were taken is a heavy silty clay.

It is not known to what extent compaction interferes with the root development but it is thought that compaction of the soil may affect the beet in two ways: (a) Through reduced aeration, and (b) through adverse change in structure. There is also the possibility that the soil fertility may be affected indirectly by the reduced aeration. Two dozen beets were carefully lifted so as not to damage the roots. The soil was then washed away by means of a fine spray of water. Before lifting, each beet was marked on the side next to the wheel row with a colored pencil.

After the soil had been washed away from the roots, the beets were carefully studied and photographed to determine if any significant differences in the root development existed. As far as could be observed, there were no differences in the root development on the two opposite sides of he beet, either in the total number of rootlets or their length. The fine oots of the beet occur in two grooves or bands. The band of roots sometimes urves half way around the beet. In some cases these bands of roots are on the sides of the beet next to the furrows. In other cases they are on opposite sides longitudinally in the rows. Their position appears to result from the accidental way the seed comes to rest when dropped from the drill.

The conclusions reached from this short study are as follows:

1. Considerable compaction occurs in the rows traveled by the tractor. This compaction is apparent from the driven bar test, both before and after irrigation.

2. The compaction causes a marked reduction in the rate of infiltration of irrigation water and also in the total amount of water stored in the soil from one irrigation. Whether or not this affects the yield of the sugar beets adversely is not known.

It is believed that the amount of compaction can be reduced by under inflation of the tractor tires. The amount of infiltration of water could, no doubt, be increased by widening the wheel row so a wide shallow furrow could be made. This would increase the area covered with water and also the amount of water entering the soil.

If wider equipment were designed, such as six or eight rows, the relative number of wheel rows in proportion to the total would be greatly reduced. Further studies are needed to determine to what extent compaction interferes with the growth and yield of sugar beets. Then measures to overcome the compacting effect of the tractor wheels can be devised as far as the expected benefits will justify.