Tillage Practices and Sugar Beet Yields[1]

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Sugar beets produce the highest yields on the dark-colored soils which have been brought under cultivation recently. Over a period of years, growers have learned this through experience and gradually the areas of production have centered in those portions of the state where such soils prevail.

After many years of cropping, the soils in some areas have deteriorated until maximum yields are no longer possible. Even after the installation of dredge ditches and tile drains, and with the use of more and better fertilizers, yields continued to decline. Observations *in* some localities have indicated that the decline in yield may be due to poor aeration. Instances of better growth on ditch banks and poor growth where soils were puddled by excessive rains and improper handling were common.

These observations led to certain greenhouse studies which have shown that sugar beets are very sensitive to excessive soil packing and conditions of poor aeration.

In the meantime, an entirely new system of farming has been developed on sugar beet producing farms. Horses have been replaced by heavy tractors and heavier tillage implements have been designed to follow the tractor. Recently the heavy harvesting machinery has entered the picture. These changes have taken place during a period when the trend has been toward increased cropping and soil depletion, with consequent losses in organic matter, the ingredient which keeps heavy soils in a granulated condition.

Sugar beet growers have long been in the habit of working their soil into a fine, well-packed seed bed. It seemed that perhaps they were working their soils too much. Questions were being asked about rotary tillage with machines recently placed on the market. Accordingly, it seemed advisable to conduct some experiments with different types of tillage machines, particularly with the idea of finding out how much or how little tillage was necessary for sugar beets.

The results of some of the greenhouse experiments on aeration and three years of tillage work in the field are briefly reviewed in this paper.

EXPERIMENTAL METHODS

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Sugar beets, corn, soybeans, tomatoes, oats and wheat were grown in 4-gallon pots of normally and excessively packed soil. The cultures which were considered as normal were set up by simply pouring the air dry soil

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(Brookston clay loam) into the pots. In the packed cultures, the soil was moistened with an amount of water considerably less than moisture equivalent and was then tamped firmly into the jars. The moisture content was not sufficient to cause puddling. The degree of compaction was sufficient to increase the volume weight from 1.0 to 1.43. All of the cultures received 0-20-20 fertilizer and some of those excessively packed were given an application of ammonium nitrate when the plants first showed symptoms of nitrogen starvation. A picture of the effect of compaction on the biological activity within the soil was obtained by determining nitrate nitrogen and the degree of oxidation of the iron in the soil.

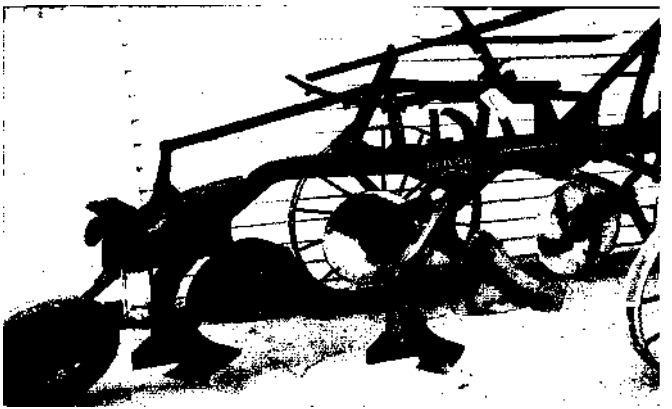

Figure 1. Plow with sub-bases.

Field

Tillage experiments were conducted on a Brookston clay loam in Tuscola county during 1947 and 1948, and on a Brookston loam in Gratiot county in 1949. Beets followed corn the first two years and grain in 1949. The different methods of tillage and the equipment used in the tests are described below. Except where noted, all plowing was to a depth of 6 inches.

Methods and Machines

Conventional plow: A two-bottom plow, followed twice over with a double-disk harrow and twice with a spring-tooth harrow.

Plow with sub-bases: A two-bottom plow with two sub-bases set to cut an additional 3-inch depth in the furrow turned by the upper bottoms (Fig. 1). The subsequent disking and harrowing was the same as for the conventional plow.

Conventional plow with plow-packer attached: In this treatment, the packer shown in Fig. 2 was attached to the conventional plow. Planting followed immediately.

Conventional plow xvith mulcher attached: The mulcher consists of a group of spring teeth between single cultipacker units. It was attached to the conventional plow as shown in Fig. 3. Again, planting followed immediately.

TABLE 1. The effect of excessive packing, with and without additional nitrogen fertilizer, on the yield of several crops in 4-gallon pot cultures.

Crop	Yield* per pot (av. of 3 replicates)		
	Normal soil (gms)	Packed soil (gms)	Packed soil + nitrogen (gms)
Sugar beets	37.5	5.8	15.5
Tomatoes	30.6	8.7	23.9
Corn	77.0	43.6	81.0
Soybeans	45.2	23.2	32.0
Wheat	22.2	18.4	39.6
Oats	34.3	23.2	37.1

*Sugar beet yields were of fresh roots. The other weights were of dry tissue, corn just tasseled, tomatoes and soybeans at the early fruiting stage, and the grains at the blossom stage.

Rotary-type tiller: The machine used was a two-wheel walking type with flexible tines. The seedbed was prepared in 1947 and 1948 by going over the ground once with hook tines to a depth of 6 inches. In 1949, when beets followed grain, it was necessary to go over the plots twice, once with knife tines, then finally with the hook tines. The knife tines would not penetrate to the 6-inch depth. The soil was cultipacked before the beets were planted.

Vertical disk plow: This machine consists of five disks which turn as a unit. It was set to cut 44 inches wide to a depth of 6 inches. The subsequent soil preparation was the same as for the conventional plow method.

Auger type plow: The plowing mechanism consists of a spiral auger mounted horizontally and driven from the tractor power-take-off. The machine was designed to cut 28 inches but it was impossible to cut more than 20 inches without overloading a two-plow tractor. It was necessary to cover the plots twice with the machine and penetration was only to $4\frac{1}{2}$ inches. A cultipacker was run over the plots before the beets were planted. As in the case of the rotary-type tiller, this was because the soil was too loose for immediate planting.

RESULTS

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Row crops were found to be more sensitive to excessive packing than were the grain crops, and of the row crops studied, sugar beets were the most sensitive. The sensitivity of sugar beets to excessive packing and poor aeration was shown strikingly in a recent publication by Smith and Cook.[3] Beets followed sweet clover in greenhouse jars. Soil compaction slowed up the growth greatly. Forced aeration was beneficial in both the normal and packed cultures.

Organisms play an important role in the effect of soil compaction on

[3] A detailed account of this experiment was published in the Soil Science Society of America Proceedings. 11:402-406. 1946.

the growth of crops. The normally packed soil contained, just after the beets were planted, 42 ppm of nitrate nitrogen, while the excessively packed soil contained only 2 ppm. In both cases, forced aeration increased the nitrate content. Compaction had so completely excluded the air that the

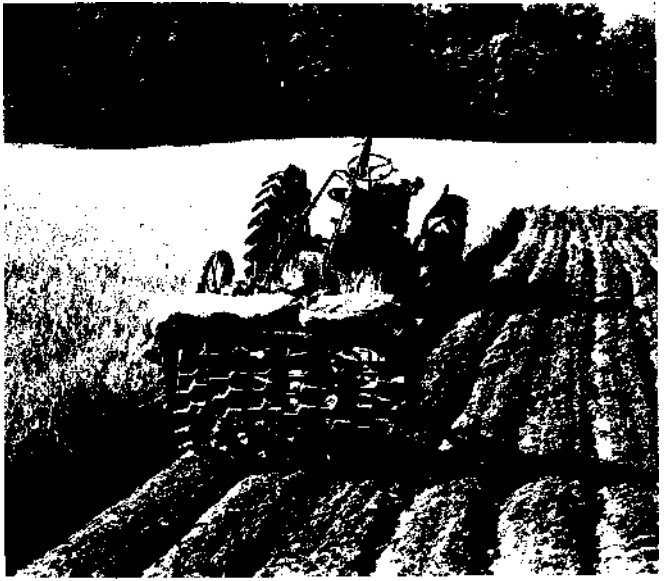

Figure 2. Two-bottom conventional moldboard plow with plow packer attached, pulled by two-plow tractor.

nitrifying organisms were unable to function.

Another proof of poor aeration in the packed soil was the presence of ferrous iron, whereas, in the normal soil, all of the iron existed in the oxidized state. Over-watering of the packed soil caused further increases in its content of ferrous iron.

In another experiment, sugar beets were compared with 5 other crops. According to the data reported in Table 1, excessive soil packing was more injurious to beets than to any other crop. Tomatoes ranked close to the beets, however, and corn and soybeans seemed considerably more resistant to the injuries from excessive packing. Grains were not badly injured.

It was thought that additions of nitrogen to the packed soil might compensate for the lack of microbiological activity and stimulate the growth enough to make up for the injury caused by packing. As shown by the data, this proved to be true with corn, wheat and oats. With the other three crops the yields had apparently been depressed for reasons other than

TABLE 2. The effect of methods of tillage on sugar beet yields

Tillage method	Yield per acre—tons Brookston clay loam 1947	1948	Brookston loam 1949
Conventional plow	**9.4**	13.0	13.8
Plow with sub bases	9.7	13.1	12.4
Conventional plow with packer	8.6	12.9	14.6
Conventional plow with inulchcr			15.9
Rotary-type tiller	8.4	12.1	13.4
Vertical disk plow	9.0	12.9	13.6
Auger-type plow	6.7	12.1	

simply slow nitrogen availability. The sugar beets are shown in Fig. 4. Where normal soil produced yields of 37.5 grams per pot, the packed soil produced only 5.8 grams per pot. With plenty of nitrogen supplied, the yield on the packed soil rose to 15.5 grams per pot, less than one-half the yield obtained on normally packed soil without an additional nitrogen application.

The evidence obtained from pot tests that beets are very seriously depressed by excessive soil compaction agrees well with observations often made in the field where yields have been low during seasons of extra-heavy rainfall and where fields have been worked while the soil was too wet.

Field

The data reported in Table 2 show that no method of tillage was significantly superior to those which included the use of the conventional plow. This is particularly interesting since during the past few years so much has been said and written against the use of the old-fashioned moldboard plow and in favor of those methods of tillage which mix the vegetation with the surface soil.

There was some slight indication that, on the clay loam soils, the subbase plow was slightly superior to the conventional plow, but this trend did not continue on the Brookston loam in 1949.

The vertical disk plow did a fairly good job in fitting the soil for beets, as the yields indicate. However, weeds were more plentiful where the soil was fitted in this manner.

In general, rotary tillage methods have not been satisfactory. In 1947 the yield obtained from plots where the auger-type plow was used was very low and that from the rotary-type tiller plots was a full ton per acre less than the yield from the plots which were plowed and tilled in the conventional manner. In 1948 the yields which resulted from these two methods of tillage were equal and about a ton smaller than those from any of the other treatment plots.

In 1949 the auger-type plow was not used in the sugar beet experiments. The yield obtained where the rotary-type tiller had been employed was not significantly smaller than that from the conventional plots but more labor was necessary to eradicate weeds. This, of course, is a serious disadvantage.

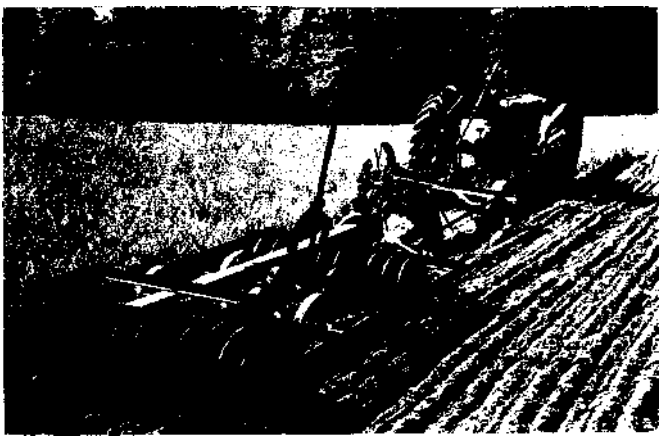

Figure 3. Two-bottom conventional moldboard plow with mulcher attached, pulled by two-plow tractor.

Of most interest in these results are the data obtained from the plots where the soil was plowed and fitted in one operation. In 1947 and 1948 this was accomplished with a conventional mold-board plow and the packer shown in Fig. 2. Planting followed immediately. The wheel width on the planter tractor was so adjusted that the tracks were left between the beet rows. Thus the beet seeds were placed in soil where the entire furrow slice was relatively loose. In 1947 the cultivating was done with a heavy tractor which so depressed the soil between the rows that some of the plants were destroyed. Thus the stand was injured and the yield somewhat decreased.

Mechanical injuries were avoided in 1948 by cultivating with a light tractor. A good stand resulted and the yield was just one-tenth of a ton under that obtained from the plots which had been disked and harrowed before planting.

The plots which received the two "once-over" tillage treatments produced, in 1949, higher yields than did any of the other plots. In fact, the mulcher plot yield was 2.1 tons per acre higher than that obtained where

the soil was fitted in the conventional manner. Close observations throughout the season correlated with the yield data. At all times the crop looked the best on those plots which had received the least pre-planting tillage.

With sugar beets, as well as with corn, beans, and oats, weed control has been easier on plots where the "once-over" tillage methods were employed. This was because weeds and grass were not pulled back to the surface where they could grow, and planting was done immediately, before weed seeds had time to germinate.

Figure 4. Sugar beets are injured seriously by excessive soil compaction. In pot 1 the soil was packed normally, while in pots 2 and 3 it was packed excessively. The beets in pot 2 received extra nitrogen fertilizer.

Weed seeds seem always to be present and every tillage operation or cultivation brings a new batch to the surface where they can obtain the air necessary for germination. When planting follows plowing immediately the crop seeds have at least an even chance of competing with the weed seeds. Observations made during these three years of tillage experiments have led to this conclusion.

SUMMARY AND CONCLUSIONS

Sugar beets, and several other crops, were grown in the greenhouse in normally and excessively packed clay loam soil. With all crops, yields were depressed by the excessive soil packing. Sugar beet yields were depressed more than were yields of other crops. Ferrous and ferric iron tests showed that aeration was poor in the packed soil. Nitrate nitrogen tests indicated slow nitrification in the packed soil.

The excessively packed soil cultures which had received additional nitrate fertilizer yielded as much corn, wheat, and oats as did the normally packed cultures. This was not true, however, with sugar beets, tomatoes, and soybeans.

During a three-year period, seven tillage methods were compared. The experimental results did not reveal any tillage method to be superior to those which included the use of the conventional plow. Weed control was more difficult after soil was fitted by those methods which mixed the vegetation with the surface soil. Rotary tillage methods were, in general, not satisfactory. Good results were obtained from plots where the soil had been plowed and fitted in one operation. Those methods of tillage left the soil loose, saved a lot of time and resulted in good yields of sugar beets.

The greenhouse experiments reported in this paper showed there is danger in excessively packing soil and the field experiments have shown that maximum beet yields may be obtained on relatively loose soils.