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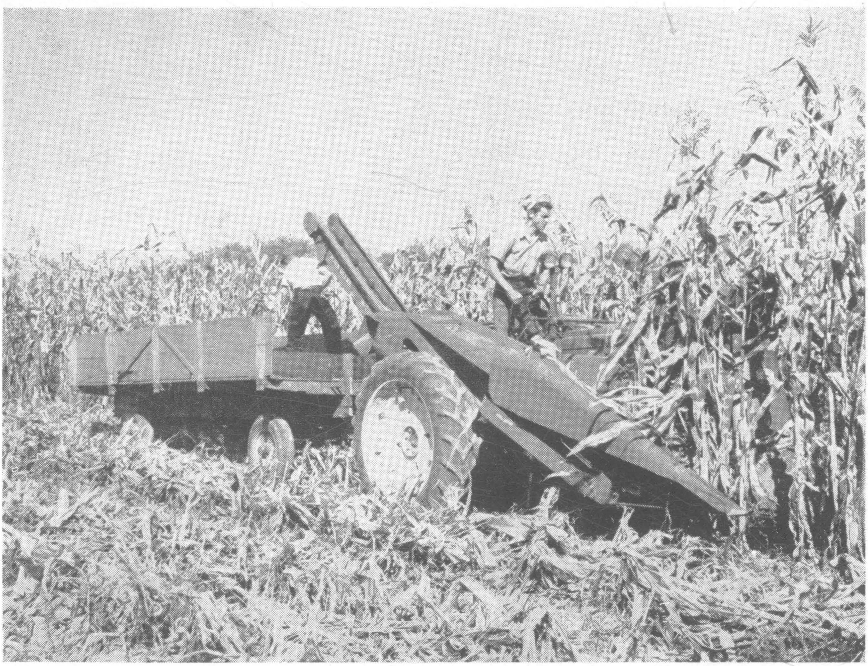

OHIO AGRICULTURAL EXPERIMENT STATION

WOOSTER, OHIO

CONTENTS

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TILLAGE PRINCIPLES IN PREPARING LAND FOR CORN

C. J. WILLARD, GEORGE S. TAYLOR, and W. H. JOHNSON[1]

Past experiments (2, 3, 4, 5, 6, 9, 11) have shown that emergence, growth, and yield of crops are affected by tillage treatments. An experiment was started at the Ohio State University in 1938 to study the principles of preparing land for corn, to discover what constituted desirable preparation of the soil for corn.[2] A progress report of this work was prepared in 1946 (10). This article summarizes the results of this experiment during its fourteen years on Range 1800, Agronomy Farm, Columbus, Ohio.

EXPERIMENTAL CONDITIONS

The experiment was located on soils of the Miami catena, with a rather uniform 2 percent slope. The soil is predominately Miami silt loam; but considerable areas of Brookston and small areas of Crosby and Pandora silt loams occur in the plots. A three-year rotation of corn, wheat, and mixed hay (alfalfa-clover-timothy) was followed. Three blocks of 12 plots each were used, so all crops appeared annually. There were two replications, treated alike except that the corn stalks were removed in one replication and disked down for wheat in the other. The plots were 22.5 × 125 feet, which permitted six 42-inch rows of corn with 1½ feet between plots. In the fall, the corn ground was disked and wheat and timothy sowed. An alfalfa-clover mixture was sowed the next spring. The wheat was harvested, at first with a binder, later with a combine. The stubble was always clipped and, after combine harvest, the straw was removed. Hay was harvested the third year, but yields were seldom taken.

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[2]This experiment was begun by C. O. Reed of the Department of Agricultural Engineering and L. D. Baver and C. J. Willard of the Department of Agronomy, The Ohio State University and Ohio Agricultural Experiment Station. During the experiment it has been worked on successively by B. T. Shaw (1942), J. B. Page (1943-49), and G. S. Taylor (1951) of the Department of Agronomy and E. A. Silver (1940-1944), C. B. Richey (1942-1944), G. W. McCuen, R. L. Erwin (1945-1948), and W. H. Johnson (1948-1951) of the Department of Agricultural Engineering.

This experiment was started as "exploratory in nature". Considerable changes were made each year until 1943, when the main outline of the final plan was adopted. The plan followed with increasing consistency since 1943 was as follows:

Treatment 1. Normal or standard soil preparation for corn on most Ohio farms: plowing followed by disking, usually several diskings.

Treatment 2. Minimum soil disturbance, with trash buried. This condition was obtained by plowing with a sod plow which was equipped with an extended wing like the old "prairie breaker", so that the furrow slice was completely inverted. A minimum of seedbed preparation, usually only once over with a smoothing harrow or disk set straight, preceded planting.

Treatment 3. Maximum fracturization of soil. This condition was obtained with a rotary tiller. To obtain a satisfactory seedbed for corn on the 1-year alfalfa-clover-timothy sod which was used in this rotation, it was found necessary to rotary till the plots two and three times.

Treatment 4. Surface treatment to kill vegetation and subsurface tillage to loosen the soil slightly without inverting the furrow slice. The subsurface tillage was at 5 to 6 inches with 22-inch sweeps which were being extensively used in Nebraska (Fig. 1). The surface treatment consisted of disking or skimming with the sweeps, or both, sufficient to kill vegetation. Residues were left on the surface and the corn was planted directly in this residue mulch.

Treatment 5. Surface tillage to kill the sod, no other tillage. This treatment had as little tillage as possible consistent with killing the sod. All residues were left on the surface. The surface treatment of 4 and 5 was always identical.

Treatment 6. Standard soil preparation, as in Treatment 1, with the addition of a straw mulch (approximately 2 tons per acre) after the first cultivation.

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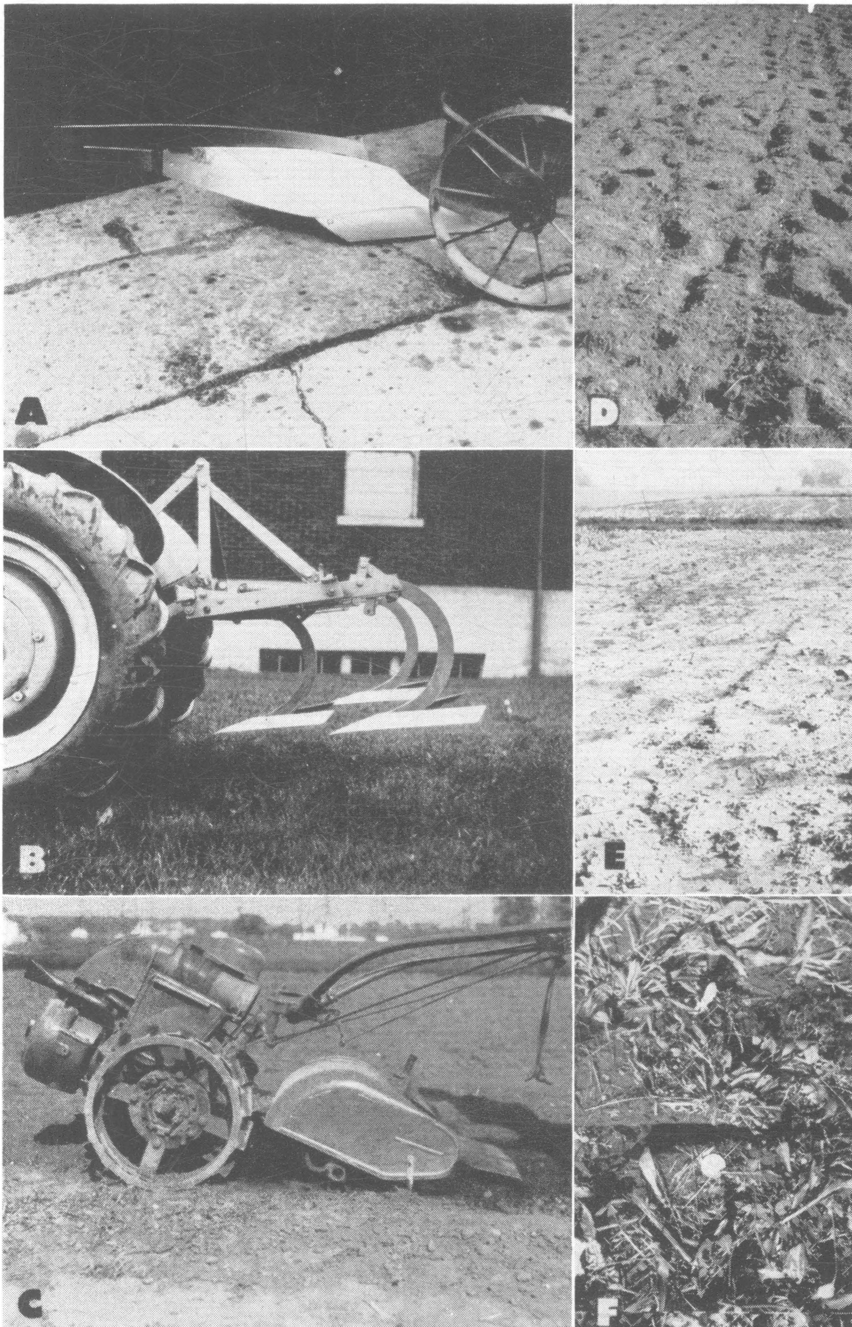
Fig. 1.—Equipment used in tillage experiment and resulting soil conditions. A, sod plow with extended moldboard or "prairie breaker"; B, subsurface sweeps mounted on tractor; C, rotary tiller used in most of these tests; D, rotary tilled plot immediately after preparation (footprints show the deeply fluffy nature of the seedbed); E, rotary tilled plot after a heavy rain; F, effect of sweeps on surface vegetation when run at 5 to 6 inches. (Close-up, 1 week after tillage, after ½ inch rain.)


A
D
B
E
C
F

Part of the evolution of these plans may be worth giving. All concerned recognized that a practical function of plowing was burying surface organic residue to kill the sod and permit operation of planting machinery. Treatment 2 was an attempt to do as little more than this as possible. The first year nothing more was done. The result was inadequate stands because of the rough seed-bed, even though the corn was hill planted by hand. In 1939, an attempt was made to prepare each hill as it was hand planted. From 1940 through 1945, one harrowing was given this plot before planting. In 1946 and thereafter a light disking was given this plot—just enough to enable a corn-planter to work.

In 1941, C. B. Richey modified a prairie breaker plow so that it would turn over flat the somewhat loose sod produced in this rotation. This plow was used for the remainder of the experiment. A problem with this plot was the time of doing the plowing. In most years it was done early to let the soil settle, which made planting without further preparation difficult. Other years this plot was the essential equivalent of "once-over" planting (6) which was more satisfactory.

Treatment 3 used a garden-sized rotary tiller most years and a field-sized rotary tiller once or twice. Aside from the problem of re-preparing the land when a rain came between preparation and seeding, which was sometimes done by the rotary tiller and sometimes by the disk, this plot was very uniformly treated through the years.

Treatments 4 and 5 were intended to prepare the land for corn and still leave the organic matter on the surface. The subsurface was disturbed less in 5 than in 4. In the first years the surface growth was macerated with the rotary tiller to a shallow depth on both plots. Special hills were prepared in which to plant the corn in Plot 4, with no preparation in Plot 5. This special preparation for planting in Plot 4 was dropped in 1941.

The use of the wide sweeps at a shallow depth to destroy the forage growth was begun in 1941. In the same year, the wide sweeps were run at 5 to 6 inches in Plot 4, but no further treatment was applied to Plot 5.

This method also failed to kill the forage satisfactorily, and in 1944 Plots 4 and 5 were disked twice in addition to skimming. That year it was noted in the field records that "It was extremely difficult to plant in the unplowed plots where residues were left on the surface. Uniform stands were not obtained." In 1945, 1946, and 1947 these plots were only disked as a means of killing the forage. In 1948 the sweeps were again used before disking, and this was done more or less thereafter.

Disking does not kill alfalfa readily. The sweeps preceding it helped, but the seedbed was never satisfactory. The failure to obtain adequate stands and yields from this method is a convincing argument against ordinary disking as a means of preparing sod land for corn. Much more time, labor and expense went into the preparation of the disked plots than any others.

In Treatment 6, the seedbed was conventionally prepared, one cultivation given, and then a straw mulch approximating 2 tons per acre was applied. In one or two years some nitrogen was applied at the same time, but in most years none was applied. Although this treatment is not related to the others, the plots demonstrated the value of a mulch, even one not calculated to give best results in growing corn.

Fertilizing. At first no fertilizer was used on corn in the experiment. Wheat always received 200-300 pounds per acre of 0-14-7, or later 0-14-14, whatever was being applied on other wheat seedings on the farm. The hay was never directly fertilized.

In 1941, the unplowed plots developed symptoms of severe potash deficiency. To study this in 1942, 400 pounds per acre of 0-14-14 fertilizer were drilled across half of all plots. In 1943 and thereafter 300 pounds per acre of 0-14-14 fertilizer were applied in the row with the corn planter, fertilizing three rows of each plot.

Planting. The plots were planted in hills by hand in 1938, 1939, and 1940. After that the corn planter was used, and the fertilizer was applied by the planter in 1943 and thereafter.

Cultivating. In the original plan there were differences in the type of cultivator used on different plots, but in 1941 and following, all plots were treated the same after planting except for the mulched plots.

Experimental measurements. Data obtained include yields of crops, stands of corn, height of corn to tip of the extended leaves, plant tissue analyses, soil aggregation, pore size distribution and volume weights.

Yields of corn were obtained by weighing the ear corn from the four inside rows. Yields were expressed in corn of 15.5% moisture. Every plant in each plot was measured to the tip of the extended leaves in July or August. This gave the number of plants per plot at the same time; hence, differences in stand reported were the result of differential emergence and of any losses in stand from rodents and cultivation.

Wheat yields were taken each year during the last eleven years of the experiment, except for 1942 and 1946, when labor difficulties interfered. Hay yields were not taken each year, since data in earlier years had indicated that tillage operations for corn did not significantly affect yields of hay.

Plant tissue analyses for potassium and nitrogen were made in 1951. Total nitrogen of corn tissues was determined by the Kjeldahl method. Potassium was determined by the use of the flame photometer.

Soil aggregation, pore-size distribution, and bulk densities were the physical soil properties evaluated. Physical measurements were taken in 1944, 1949, and 1951. Composite samples of disturbed soil were taken from the 0-6 inch depth for aggregate analyses. The soil was air-dried, and the fraction between 0.25-2.00 mm diameter was wet-sieved for 30 minutes. The percentage of soil on sieves of different sizes was determined by weighing.

Pore-size distribution and bulk densities were obtained from undisturbed soil cores by the use of an air pycnometer and tension tables. Soil porosities are expressed as percent of the soil volume, and bulk density as a ratio of dry soil weight to its volume.

RESULTS AND DISCUSSION

A. Effect of Tillage on Crop Yield

Corn. Throughout the experiment, the effect of tillage on corn yields was most striking (Tables 1 and 2). Corn yields were significantly higher on the plowed plots. The highest yield was obtained on the plowed plots receiving a straw mulch, though the yield did not differ significantly from those obtained from the other plowed plots. Lowest yields were obtained from the plots receiving only surface tillage (Treatment 5). Surface plus subsurface tillage (Treatment 4) resulted in a significant increase in yield above surface tillage alone. The yield from the rotary-tilled plots was comparable to that obtained with surface plus subsurface tillage.

One factor responsible for yield differences among the different plots was stand. In those plots which were not plowed, corn stands were significantly lower than in the plowed ones (Table 1). The lower stands on the surface-tilled plots were largely a result of poor seed coverage as a result of plant residues in the surface soil. In addition to poor germination on those plots, corn seedlings were often destroyed by birds and rodents which could easily reach the kernels of corn in the loose soil. Less difficulty was experienced on the rotary-tilled plots, although stands were lower on those plots than on those which were plowed. Since the soil in the rotary-tilled plots often crusted, it is believed that the compacted soil surface was largely responsible for reduced stand in these plots. There were no significant differences in stand among the plots which were plowed.

The effect of stand on corn yield is shown by the high correlation between these two measurements (Table 1). An analysis of covariance was made for the seven years in which stands were taken. When the effect of stand on yield was removed from the yield variance, the treatment "F-value" was reduced from 9.3 to 3.9. While this information indicates the important effect of stand, the fact that both F-values are statistically highly significant points out that factors other than stand were of considerable importance.

For example, height of corn plants and yield were highly correlated, (Table 1), and highest yield and greatest corn heights were obtained from the plowed plots.

Early in the experiment, it was noted that corn plants on certain tillage plots showed symptoms of nutrient-element deficiency. Potash deficiencies were obvious on those plots which were not plowed. Severe deficiency symptoms were seen in the unfertilized plots, but milder symptoms were also observed in the fertilized plots receiving rotary and subsurface tillage. Chemical analyses made in 1951 showed marked differences in potash content (Table 1), while nitrogen contents were nonsignificant.

TABLE 1.—Effect of tillage treatments on yield, stand, height, potassium and nitrogen content of corn, and yield gains for fertilizer

Tillage treatment	Yield/A 14-year fertilized and unfertilized	Plants/A (7-year average)	Height (10-year average)	K_2O† in leaves 1951	Nitrogen† in leaves 1951	Gain for 0-14-14 fertilizer (10-year average)
	Bu.	Hundreds	In.	Pct.	Pct.	Bu/A
1. Standard plow . . .	53.4	117	60.6	1.47	3.13	3.4
2. Prairie breaker . . .	54.5	114	57.4	1.04	3.30	4.5
3. Rotary tillage	46.9	107	56.0	0.66	3.00	10.5
4. Surface and subsurface tillage . . .	44.7	95	50.5	0.69	3.25	4.9
5. Surface tillage only	40.2	92	50.4	0.65	3.11	4.7
6. Standard plow plus mulch	54.9	129	63.2	1.35	3.25	2.5
L.S.D. (0.05 level)	4.4	20	4.0	0.20	N.S.	. . . .
Coefficient of variation (Pct.)	11.8	16.3	8.0	7.20	3.00	. . . .

Correlations: Stand with yield, $r = 0.68$*; height with yield, $r = 0.63$*

*Statistically significant at the 0.01 level.

†Potassium and total nitrogen analyses were from the three lower corn leaves of 10 plants. Unfertilized sections of plots, June, 1951.

TABLE 2.—The effect of tillage treatments on the yield of corn. University farm, Columbus. 1938-51

Tillage treatment	Corn yields per acre, bushels, average fertilized and unfertilized														
	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	Av.
1. Standard plow	50.3	58.8	17.1	47.5	47.4	61.1	48.4	50.6	58.4	50.2	37.0	70.4	92.1	58.0	53.4
2. Prairie breaker	46.6	62.8	15.3	41.5	43.4	64.9	53.3	57.2	63.0	49.0	27.6	77.6	94.1	67.0	54.5
3. Rotary tillage	43.2	55.2	24.0	36.9	38.0	58.7	51.5	42.8	58.6	38.0	15.7	67.3	79.6	46.9	46.9
4. Surface and subsurface tillage	36.4	48.9	14.7	35.9	33.4	60.2	46.8	46.8	63.2	19.6	14.2	66.8	81.7	57.8	44.7
5. Surface tillage only	25.5	49.7	11.0	37.2	29.8	53.9	46.0	41.7	55.9	13.0	14.1	65.3	68.8	51.0	40.2
6. Standard plow plus mulch .	49.6	59.1	14.9	51.0	51.8	70.4	62.6	52.5	70.5	45.5	41.6	70.4	81.8	46.7	54.9
Rainfall, May through August (inches) . . .	16.8	12.8	12.5	15.5	14.8	17.8	13.9	16.5	22.0	22.3	13.8	13.1	9.8	8.7	15.0

Despite obvious signs of potash deficiency, both visibly and as revealed by analyses, the response to potash and phosphorus fertilization was small (Table 1). The average indicated increase from fertilizer on the unplowed plots was 6.7 bushels, and on the plowed plots it was 3.5 bushels. In view of the great lack of plot uniformity and fairly frequent reversals of response, these data are either not significant or just barely significant. Potash fertilization prevented the appearance of potassium deficiency symptoms on the unplowed plots. These soils in other plots on the Agronomy farm have at no time shown a large response to phosphate-potash fertilization. The total yields were much smaller than they should have been, due basically to nitrogen deficiency and the fact that the corn was planted late. This experiment does not in any way answer questions of proper fertilization of corn on this soil.

Since rainfall is often a limiting factor in corn production in central Ohio, one might expect that a soil mulch would significantly increase corn yields. This was not true in this experiment, and it is largely explained by the lack of correlation between rainfall and corn yield in the tillage plots. Apparently other factors such as stand and small applications of nitrogen fertilizer were responsible for this lack of correlation.

Weed control was difficult in the treatments which were not plowed (Fig. 2). Furthermore vegetation from the hay crop was not effectively killed by these treatments. Rotary tillage was moderately effective in killing grasses, but from 5-15 percent of the legumes lived after tillage. A converse situation was found in the plots receiving subsurface tillage. The plowed plots have been freer of weeds and other vegetation than the unplowed ones.

Wheat. The only adverse effect on wheat yields was obtained in Treatment 6 (Table 3). The reduction in yield was from poor stands as a result of the straw mulch. Since this decrease in yield was not a result of a tillage treatment, one can conclude that the methods of preparing land for corn used in this test had no significant effect on wheat yields.

In some years where stalks were not removed, reductions in wheat stands and yields resulted. The average yield of wheat with stalks left on was 20.9 bushels and with stalks removed was 24.5 bushels. The difference was due in part, at least, to poor stands because of failure of the drill to cover the seed when stalks were left on the ground. Whether other factors, such as nitrogen deficiency, were also present is not determinable. This result is in accord with recent experiments at Wooster.

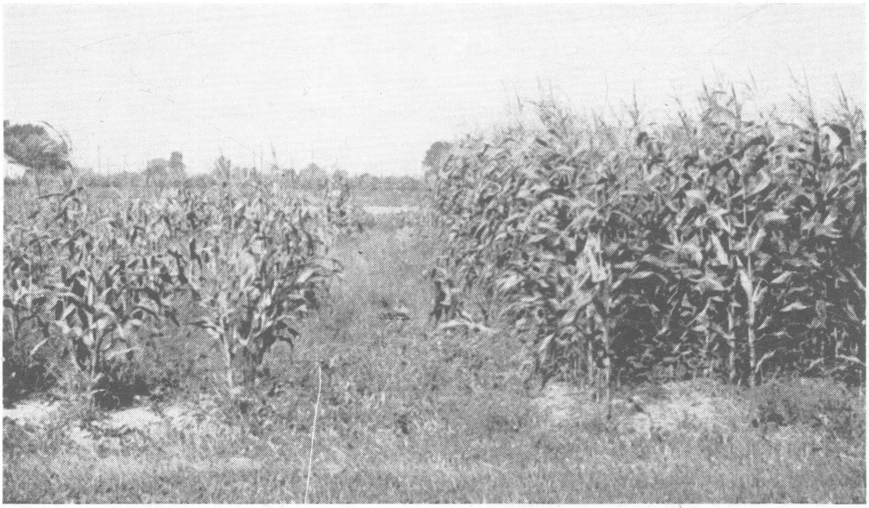


Fig. 2.—Contrast in corn growth, 1949. Left, treatment 5, subsurface sweeps to 3-inch depth, then disked; right, treatment 6, plowed, planted, straw mulch after first cultivation. Note reduced stand, lack of weed control, and reduced growth on subsurface-tilled plot.

TABLE 3.—The effect of tillage treatments on wheat and hay yields

Tillage treatment	Yields per Acre: Wheat 9-year average: Stalks removed Bu.	Stalks left Bu.	Average Bu.	Hay* 3-year average Lb.
1. Standard plow	27.2	21.6	24.4	3,870
2. Prairie breaker	28.6	22.9	25.8	3,870
3. Rotary tillage	26.7	24.6	25.7	3,890
4. Surface and subsurface tillage	23.9	23.0	23.5	4,210
5. Surface tillage only	23.8	21.7	22.8	3,840
6. Standard plow plus mulch	16.8	11.8	14.3	3,830
Average	24.5	20.9	22.8	....
L.S.D. (.05 level)	....	....	3.1	N.S.
Coefficient of variation (Pct.)	....	....	13.5	6.0

*First cutting only.

Hay. Although only a few years' data on hay yields were obtained, both observations and these data indicate that tillage had no significant effect on this crop. It was observed, however, that reductions in both stand and yield of hay occurred occasionally on the plots receiving straw mulch.

B. Effect of Tillage on Soil Physical Conditions

Since the effects of tillage on soil properties are most pronounced during the period immediately following the tillage operations, greatest emphasis was placed on taking physical measurements during the year in which corn appeared in the rotation. Measurements were taken during only three years, but sufficient data were accumulated to characterize the effect of treatments on soil physical conditions.

Pore-size distribution and volume weights. An obvious effect of tillage was that of decreasing the bulk density of soil. This is illustrated by differences between bulk density of soil in meadow and in corn (Table 4). Lowest density resulted from those treatments which include plowing. Further, plowing resulted in a rather uniform distribution of bulk densities, with plow depth. This was not the case with treatments which were not plowed, for in these plots greater densities are found at the 3-6 inch depth than in the upper 3 inches. In Treatment 5, surfaced tilled to 3 inches, the soil between 3-6 inches which essentially was untouched by the tillage tools has a high bulk density; while at the same depth, the plots receiving rotary and subsurface tillage had bulk derisities midway between the plowed and the surface tilled.

The volume of pores drained at a tension of 40 cm of water, or "aeration porosity" was determined on natural soil cores in 1944 and 1949 (Table 4). At the 0-3 inch depth, lower values of aeration porosity were found in the unplowed plots than in the plowed ones. It was only at the 3-6 inch depth, however, that these differences become statistically significant. There was some discrepancy between the 1944 and 1949 values of aeration porosities at the 3-6 inch depth in the rotary-tilled plots. This discrepancy may be due to differences in rainfall intensity during these years, for it has been observed that the soil receiving this tillage treatment compacts extensively after heavy rains (Fig. 1).

The aeration porosity values for the soils in meadow show that the effect of tillage treatments did not persist through two years. While physical data are not available for the first year after tillage, similar wheat yields suggest that differences in physical properties were minimized by that time. There was a considerable reduction in aeration porosity of all plots two years after the tillage operations.

TABLE 4.—The effect of tillage treatments on aeration porosity, bulk density, and soil resistance

Crop	Soil depth, inches	Date of sampling	Tillage Treatment 1 Standard plow	2 Prairie breaker	3 Rotary tillage	4 Surface and subsurface tillage	5 Surface tillage only	6 Standard plow plus mulch	L.S.D.* (0.05 level)	C. V.† Pct.
			Bulk density (gms/cc)							
Corn	0–3	July '49	1.19	1.22	1.27	1.28	1.32	1.25	N.S.‡	5.5
Corn	3–6	July '49	1.27	1.20	1.32	1.32	1.42	1.20	0.10	3.1
Meadow	0–3	July '49	1.36	1.33	1.33	1.36	1.35	1.46	N.S.	2.4
Meadow	3–6	July '49	1.29	1.32	1.37	1.36	1.32	1.38	N.S.	2.5
			Aeration porosity (percent)							
Corn	0–3	July '49	20.3	22.4	18.9	17.1	17.6	23.0	N.S.	9.3
Corn	3–6	July '49	17.4	22.5	12.9	16.3	13.6	24.4	3.7	8.0
Corn	3–6	Oct. '44	25.9	24.9	24.2	19.2	14.2	26.9		
Meadow	0–3	July '49	10.6	12.6	13.5	12.6	13.4	12.3	N.S.	7.0
Meadow	3–6	July '49	14.0	13.4	13.3	14.5	14.7	12.5	N.S.	7.0
			Soil resistance: (Number of times core sampler had to be dropped to penetrate 3 inches)							
Corn	3–6	Oct. '44	14.2	14.4	18.8	26.0	25.5	13.0		

*Lowest significant difference between treatment means.

†Coefficients of variation of experimental data.

‡Non-significant differences between treatment means.

Since aeration porosities were low and volume weights were high at the 3-6 inch depth in the surface-tilled plots, it is possible that root extension might be restricted in these plots. Relative differences in soil resistance were measured by counting the number of times a core sampler weight had to be dropped to penetrate three inches of soil. While these measurements are empirical and vary inversely with moisture content, the data at the bottom of Table 3 indicate a compact soil region at 3-6 inches in the plots receiving only surface tillage.

Aggregation. While soil aggregation is affected by many factors, the main effects of tillage are probably those which involve the placement of organic residues and the degree of mixing the residues with the soil. With surface tillage most of the residues remain in the upper 3 inches of soil. This factor is probably responsible for the high aggregation in these plots (Table 5). The higher values for aggregation in the rotary-tilled plots are probably due to intimate mixing of soil and residues. When a composite sample of soil was taken from the "0 to 7" inch depths, there were no significant differences in aggregation as a result of the various tillage methods.

Other physical properties. Although the surface conditions of the soil were not evaluated quantitatively, there were obvious differences as a result of the tillage treatments. Those plots receiving subsurface tillage had a considerable amount of crop residues mixed in the top two inches of soil. When the residues were not adequately mixed with the soil, difficulty was experienced in planting corn. Water infiltration rates were high on these plots, although the experimental area was level enough so that runoff and erosion were not important factors to consider in this study. Immediately after rotary tillage, the soil on the plots receiving this treatment was very loose, but the soil usually became compact after heavy rains (Figure 1).

During June and July, 1948, gaseous diffusion rates and oxygen contents were determined in these plots (1). Soil oxygen contents did not differ significantly between treatments and did not drop below 18.5% in the top foot of soil in the entire experimental area planted to corn. Gaseous diffusion rates in soil were significantly higher where the prairie breaker was used than when the standard plow was employed. Likewise, these rates were somewhat higher following the standard plow than in the non-plowed plots.

TABLE 5.—The effect of tillage treatments on soil aggregation

Crop	Soil depth, inches	Date of sampling	Soil particles retained on a 0.25 mm diameter sieve (percent)						L.S.D. (0.05 level)	C. V. Pct.
			1	2	3	4	5	6		
			Standard plow	Prairie breaker	Rotary tillage	Surface and subsurface tillage	Surface tillage only	Standard plow plus mulch		
Corn	0–7	June '49	36.8	36.1	36.5	34.3	34.6	38.2	N.S.	10.0
Corn	0–7	July '49	35.3	36.1	40.1	33.4	36.1	30.6	N.S	13.0
Corn	0–3	Aug. '49	19.3	18.3	20.0	27.0	29.1	17.3	7.0	12.4
Corn	0–7	Aug. '49	42.9	43.0	47.9	40.9	40.6	40 4	N.S.	16.5
Corn	0–5	June '51	**53.1***	55.8	70.8	62.1	66.9	60.3	7.3	4.6
Corn	0–5	Aug. '51	74.4	78.5	80.1	78.2	74.6	73.3	N.S.	
Meadow	0–7	July '49	42.0	41.1	48.9	55.7	55.1	43.8	8.2	6.7
Meadow	0–7	Aug. '49	44.9	53.7	60.3	43.9	62.9	46.1	N.S.	13.4

*In 1951 a portion of air dried soil between 2.00–4.76 mm was used for wet sieving; hence the high values for aggregation.

DISCUSSION

Initial tillage (plowing, rotary tillage, etc.) results in a large decrease in volume weights and a substantial increase in the larger sized pores. Such a soil condition is characterized by high evaporation losses as a result of exposing a large surface area, by high water-infiltration rates, and by a rapid exchange of gases between the soil and the atmosphere. Usually, these soil conditions are not optimum for seed coverage and emergence; and a more desirable seedbed is generally obtained after secondary tillage operations (disking, harrowing) or after the settling and subsidence effects of rainfall. To produce an optimum seedbed in soil receiving different tillage treatments, one must not only vary secondary tillage operations but must also plan tillage treatments with reference to climatic conditions. The latter consideration is of much importance when rotary tillage is used in humid areas. Rotary tillage produces a loose, low volume-weight soil. After a heavy rain, however, the soil generally becomes compact, resulting in low water infiltration rates.

Apparently, surface tillage treatments (Treatments 4 and 5) do not produce a rootbed of sufficient low volume weight and pore-size distribution for optimum corn growth. The settling effects of rainfall would tend to accentuate the compaction process on these plots. In this experiment, the crop yield data indicate that under the existing weather conditions, plowing produces a more desirable soil condition for corn throughout the growing period of the plant than the other tillage treatments.

The one year (1940) out of the fourteen in which rotary tillage produced a greater yield than all other methods of preparation was one in which there was no heavy rain at any time after the plot was prepared, so that the soil remained loose and "fluffed up" for the entire season. While no yields were large, because of late planting and a dry season, the rotary-prepared plots were obviously and outstandingly superior. This constitutes additional evidence of the value of high porosity on these soils for corn.

It is worth while to speculate on the reason for this response to greater pore space. We have little evidence that corn roots **per se** require more oxygen than they can readily obtain in ordinarily compact soils of this catena. However, we know that nitrification takes place much more rapidly in the better aerated soils. It would be highly instructive to see whether high nitrogen applications would produce high yields of corn on normally compact soils of this catena, that is, whether extra nitrogen could substitute for extra tillage.

In tillage, the physical properties of the upper two inches of soil are often of primary importance in plant emergence. At least one tillage requirement must be met: seed must be covered and in adequate contact with the soil to insure transfer of moisture from the soil to the seed and to prevent loss of seed by birds and rodents. The surface treatments offer some difficulty in stand establishment because of crop residues. For adequate stands, the surface soil must contain a high proportion of small-sized aggregates (<2.00 mm in diameter). To accomplish this, the soil surface is often pulverized from repeated secondary tillage operations and thereby loses some of its structural stability. This problem is important in areas where some form of residue mulch tillage is recommended to reduce soil erosion.

The effect of surface tillage on potash and nitrogen deficiencies has been reported by several workers (2, 3, 10). A nitrogen deficiency in corn can be largely explained by a wide carbon-nitrogen ratio in the crop residues mixed with the soil. There has not been an adequate explanation of the potash deficiency. Some investigators (8, 10) suggest that low oxygen percentages in mulch-tilled soil may adversely affect potash uptake by plants. Soil oxygen contents were determined on these plots during June and July 1948 (1). Oxygen contents did not differ more than 0.3% between the different tillage treatments, although gaseous diffusion rates were much higher on the plowed than on the unplowed plots. Some recent greenhouse work by Shapiro **et al.** (12) showed that potash uptake by corn was not reduced by oxygen contents as low as 12.5 percent.

A possible explanation for potash deficiency in surface-tilled plots is that potash uptake may be related to the volume of soil contacted by the corn roots. Davis (7) reported that under mulch tillage the main corn root often makes horizontal but not vertical growth at the lower depth at which the soil is tilled. He did not find this to be the case in the plowed plots. In this experiment observations by the authors indicated a rather severe potash deficiency when the corn was 5-15 inches tall but much less pronounced deficiency symptoms at later stages of growth. These observations suggest that as the root system contacts a greater volume of soil that the total potassium taken up increases to a point where it may not be deficient.

Since this experiment was initiated, Borst[3] has conducted extensive research on residue-mulch tillage for corn in relation to erosion control on Wooster and Canfield silt loams. With an adequately fine seedbed and additional potash on the mulch-tilled treatments, corn yields have been reduced only 5-8 percent below those obtained by plowing.

[3]Borst, H. L. Unpublished data, 1946-54. Ohio Agricultural Experiment Station and USDA (ARS), Wooster.

CONCLUSIONS

This experiment was exploratory and procedures were frequently changed during the course of the experiment. It was conducted on land so non-uniform that only the most outstandingly consistent results could be significant.

The following conclusions were consistent throughout the experiment:

1. Surface treatment alone was entirely unsuited to preparing sod land for corn in this area. The most important difficulty was that of operating planting machinery in the surface debris, resulting in poor stands; however the plants which became established did not grow or yield as well as those in the plowed plots. There is every evidence from this experiment, as from many others with corn on fine-textured soil, that corn responds favorably to a greater degree of porosity than is present in these soils without tillage, so that tillage to a depth of at least 6-8 inches benefits the crop.

2. The results show conclusively that there is no advantage for corn in more working of plowed land than is necessary to insure a good stand, and there are indications that such working may be detrimental. Although there were only a few seasons when this experiment included the equivalent of the once-over techniques now being recommended (5, 6), the data from this experiment indicate that such techniques lead to maximum corn yields when a satisfactory stand of corn is obtained.

3. The experience with rotary tillage as a primary means of preparing sod land for corn on these fine textured soil types was unfavorable.

4. The wide sweeps were not a satisfactory substitute for plowing on these soil types in this climate.

5. In view of the increasing tendency to leave cornstalks on the land and sow wheat, the definitely and significantly lower yields of wheat where the cornstalks were disked down, than where the cornstalks were removed, is of practical importance. Much of this loss was due to mechanical failure to get a stand of wheat because the drill did not get into the ground. Our data do not indicate whether this was the only reason for the loss.

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