Bulletin B-535

A 17-Year Comparison of Four Methods of Tillage for Winter Wheat in a Rotation

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January 1960

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THIS PUBLICATION REPORTS a 17-year comparison of four methods of primary tillage for winter wheat.[1] Methods compared were moldboard plowing, basin listing, one-waying, and use of subsurface blades (sweeps).

The wheat was grown in a five-year rotation with spring oats and sweet clover on Series 1600 of the Oklahoma Agricultural Experiment Station's Perkins Farm nine miles south of Stillwater.

Method of Comparison

Test Plot Soils

The experimental plots were on Norge loam, a medium textured soil with moderately permeable subsoil. When the experiment started, this soil contained sufficient organic matter to produce average wheat yields of 16 bushels per acre when 150 pounds of superphosphate was drilled with the seed at planting time. The average organic matter content of composite samples of surface soil collected from all plots in 1950 was 1.60 percent. The average climatic possibility from wheat production on this land was about 20 bushels per acre during the period 1932-57. This experiment covered the years 1941 through 1957.

Oats were planted on all plots in the spring of 1940 to obtain information on soil variability. Average yields on the areas[2] to be given

[1] By primary tillage is meant the first tillage following removal of the preceding crop, wheat or otherwise.

[2] The term "area" is used herein to designate all plots given the same kind of primary tillage. "Plot" is used to designate the rotation plots within each area. Each tillage area and its included plots was replicated three times.

Research reported herein was initiated under Oklahoma Station Project 55-A.

different types of primary tillage were: Moldboard plow, 55.4 bushels per acre; basin lister, 54.9 bushels; one-way disk, 54.0 bushels, and subsurface sweeps, 55.2 bushels. Thus the average productivity of the areas appeared to be similar.

All plots were limed at the beginning of the experiment at the rate of 2 tons per acre.

The average mechanical composition of the soil in percent, was:

	Sand	Silt	Clay
0-1 foot depth	52.7	28.6	18.7
1-2 feet depth	47.9	27.0	25.1
2-3 feet depth	55.6	21.6	22.8

Rotation and Cultural Methods

The rotation followed on each area was one year of spring oats with biennial sweet clover planted as a companion crop, sweet clover harvested for seed the second year, followed by three years of wheat.

On each area, the same implement used for primary tillage following the wheat was also used following the oats and the sweet clover.

The oats were drilled in February in 14-inch rows and fertilized with 150 pounds of 20 percent superphosphate per acre applied in the drill rows. The sweet clover seed was usually broadcast from a grass seed box on the oat drill, but in a few seasons was drilled across the oat rows immediately after the oats were planted. In either case the surface soil was packed with a corrugated roller after the sweet clover was planted, to provide a more favorable condition for the early germination of the sweet clover. This crop occupied the land until July of the following year, when a seed crop was harvested. All sweet clover residue except the seed remained on the land.

The wheat was drilled in 14-inch rows at the rate of 50 pounds of seed per acre. Twenty percent superphosphate was applied in the row at planting time at the rate of 150 pounds per acre.

The wheat was harvested with a binder. This left only about one-third as much straw on the land as would have been left by a combine.

Tillage Methods Used

The moldboard plow was of conventional type. The basin lister had 8-inch shovels spaced 21 inches apart, and the one-way had 26-inch discs. The sweeps used during the first five years had 42-inch blades set at a 90-degree angle. Thereafter 30-inch blades set at a 60-degree angle were used. Three ½-inch steel rods about 8 inches long were welded to the underside of each blade to assist in pulverizing the soil. These sweeps operated much better than the 42-inch blades in loose, trashy soil.

All areas were usually tilled during the same week, soon after the wheat or the sweet clover seed was harvested. All tillage was parallel with terrace ridges.

On the plowed, basin-listed and one-wayed areas, a tandem disk was used during the summer months to kill volunteer wheat plants, small weeds, and grass. A tandem disk also was used on the sweep-tilled area during seasons when abundant summer rainfall produced so much summer vegetation that it could not be effectively controlled with sweeps.

All areas usually were disked immediately before planting.

Crop Varieties Grown

Turkey wheat was grown the first two years. The high susceptibility of this variety to leaf rust resulted in low yields in 1941, therefore Tenmarq was planted in the fall of 1942. In 1943 and following years, the Pawnee variety was planted.

The sweet clover was Madrid yellow, and the oats Neosho.

Seasonal Conditions During Tests

The 1951 wheat crop was severely injured by greenbugs and yields were very low. The 1955 yields also were very low due to severe fall and early spring drought. Above-average rainfall occurred during the 1956-57 growing season.

About 90 percent of the sweet clover seedlings disappeared from the sweep-tilled areas in the spring of 1949. It was assumed that they were killed by disease, since sweet clover leaf weevils were not observed in the field. Alfalfa planted the following fall on this area and plowed under in the summer of 1950 provided a quantity of legume residue comparable to that on other areas. No sweet clover forage yields were obtained from 1954 through 1957.

Table I.—Annual Average Wheat Grain and Straw Yields in Relation to Different Methods of Primary Tillage; Perkins Farm, 1941-1957.*

Year	Moldboard Plow		Basin Lister		One-way Disk		Sweeps	
	Grain (bu./A.)	Straw (lbs./A.)	Grain (bu./A.)	Straw (lbs./A.)	Grain (bu./A.)	Straw (lbs./A.)	Grain (bu./A.)	Straw (lbs./A.)
1941	6.2	1277	6.6	1251	6.9	1429	8.5	1503
1942	18.1	1867	16.7	1762	16.2	1724	19.1	2105
1943	8.9	1055	8.3	943	10.6	1303	12.6	1489
1944	34.8	2792	29.2	2218	33.0	2409	32.9	2487
1945	16.4	2951	15.5	2552	17.1	2886	16.7	2584
1946	19.0	1929	19.5	2124	18.1	1769	21.0	2088
1947	37.6	3625	36.7	3332	35.6	3318	36.3	3426
1948	22.0	1658	19.9	1578	23.3	1683	22.2	1740
1949	37.4	2990	36.3	2989	34.1	2830	34.1	2793
1950	24.0	1953	24.0	1947	23.0	1856	23.5	1982
1951	7.5	1561	11.0	1350	11.1	1441	13.0	1901
1952	27.2	2188	20.4	1523	23.2	1610	22.2	1775
1953	20.3	2256	16.4	1534	15.8	1642	15.6	1733
1954	15.9	1350	8.4	708	9.9	768	9.1	701
1955	4.0	769	3.1	607	3.4	689	4.0	708
1956	19.6	1681	15.5	1292	12.1	1298	14.5	1182
1957	17.5	----	17.6	----	18.3	----	18.5	----
Average	19.8	1994	17.9	1732	18.3	1791	19.0	1887

* All data are the average of eight or nine plots. The higher yield obtained on the plowed plots was significant at the 5% level over the yields obtained from other methods of tillage. The higher yield obtained on plots tilled with sweeps was significant at the 5% level over yields obtained where the plots were basin listed or tilled with a one way disk.

Results and Discussion

Wheat Yields

Table I shows annual wheat grain and straw yields by tillage areas. Each yield shown in this table is the average of either eight or nine plots.

The 17-year average yields of grain and straw on the plowed areas were significantly higher at the five percent level than those on the other three areas. Grain production on the sweep-tilled areas was significantly higher at the five percent level than on the basin-listed or one-wayed areas. Straw production on the basin-listed land was significantly lower than on the land tilled with a one-way disk or sweeps.

During favorable seasons, plowing usually produced the highest grain yields. However, grain yields on plowed land were usually lower than on the other tillage areas when a vigorous vegetative growth occurred on plowed areas in late fall or early spring and rainfall was below average in March and April.

Figures 1 and 2 show trends in yields on the different tillage areas. Averages for the four methods were very similar for the first 11 years,

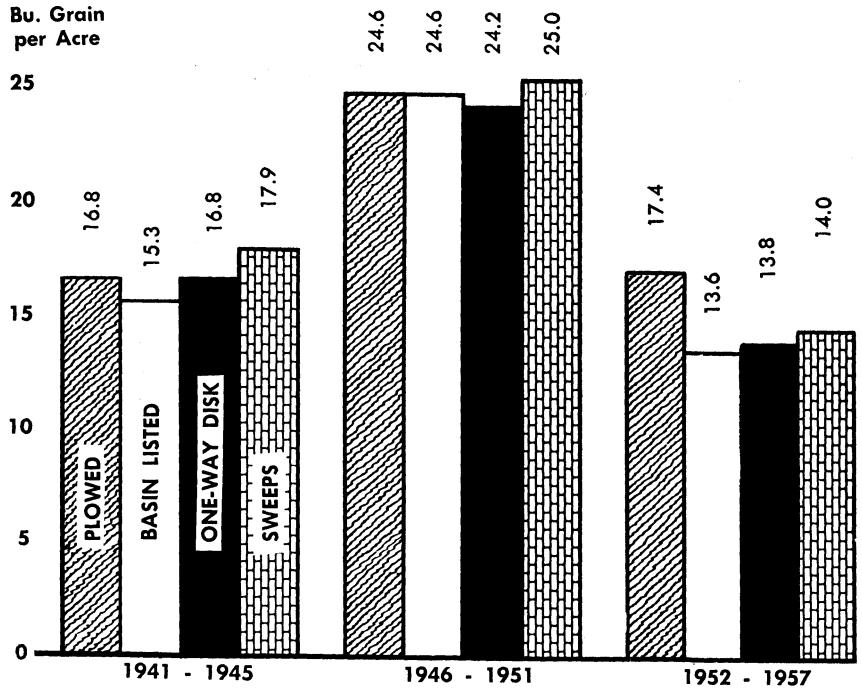

Figure 1. Average yield of wheat under different methods of tillage in a rotation with sweet clover at Perkins Farm, 1941-1957.

Table II.—Annual Average Spring Oat Grain and Straw Yields in Relation to Different Methods of Primary Tillage; Perkins Farm, 1941-1956.*

Year	Moldboard Plow		Basin Lister		One-way Disk		Sweeps	
	Grain (bu./A.)	Straw (lbs./A.)	Grain (bu./A.)	Straw (lbs./A.)	Grain (bu./A.)	Straw (lbs./A.)	Grain (bu./A.)	Straw (lbs./A.)
1941	54.9	2430	39.6	1440	49.9	2483	49.8	1780
1942	22.5	915	18.7	625	24.8	726	11.4	446
1943	10.2	1139	9.1	823	4.7	873	4.8	573
1944	27.6	992	18.5	663	19.1	434	27.0	914
1945	33.6	1427	30.4	1348	34.6	1446	35.7	1430
1946	47.9	2182	51.4	2077	55.3	2209	48.4	1885
1947	63.6	2230	53.5	1828	55.1	1687	54.1	1760
1948	32.5	1451	31.9	1464	32.0	1355	35.7	1578
1949	36.3	2072	40.1	1789	39.1	1575	42.5	1520
1950	37.8	2364	21.6	1897	24.5	1836	23.3	1760
1951	29.1	2688	25.7	2145	28.2	2012	27.5	1830
1952	43.4	1593	33.5	1229	34.8	1115	35.8	1160
1953	17.3	1276	16.2	1093	15.1	975	16.2	1125
1954	46.7	1299	37.2	1372	30.4	1109	33.6	1235
1955	29.0	2078	30.6	1962	34.2	1790	36.1	1739
1956	23.9	1233	23.0	1100	24.7	1348	22.1	1461
Average	32.7	1609	28.4	1344	29.8	1351	29.6	1305

* All data are the average of three plots.

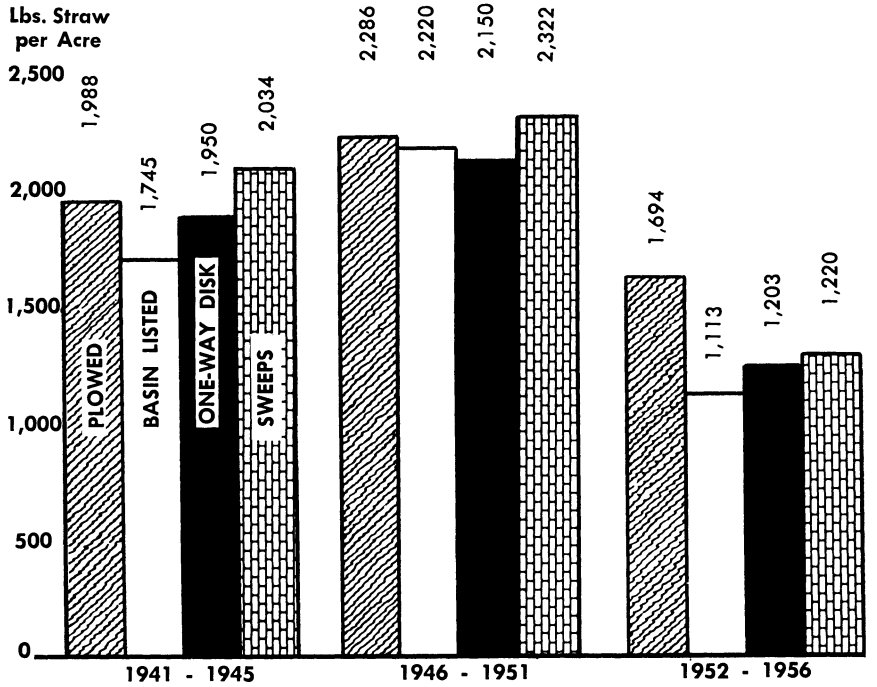

Figure 2. Average yields of wheat straw under different methods of tillage in a rotation with sweet clover at Perkins Farm, 1941-1956.

but in the following six years the average grain yields on the plowed areas were about 25 percent above those on the other 3 tillage areas. The higher yields on the plowed areas in 1953, 1954 and 1956 may be related to a more thorough stirring of the soil by the moldboard plow and consequent liberation of more nitrogen from the decay of soil organic matter.

Yields of Oats

Average oat yields for the four tillage areas are shown in Table II. Yields of grain and straw were significantly higher on the plowed plots, apparently due to the more favorable effect of this method of tillage upon the available nitrogen supply.

Sweet Clover Forage Yields

Table III shows the yields of air-dry sweet clover forage on the basis of samplings taken in late May or early June the second year after planting, for the years 1942 to 1953, inclusive. Yields were similar on all four tillage areas, and a statistical analysis showed no significant differences. Sweet clover seedlings did not survive the severe summer droughts during the three seasons 1954 through 1956.

Table III.—Average Yields of Dry Sweet Clover Forage in Relation to Methods of Primary Tillage; Perkins Farm, 1942-1953.*

Year	Moldboard Plow	Basin Lister	One-way Disk	Sweeps
1942	6,780	6,540	7,750	7,020
1943	3,390	3,630	3,890	3,890
1944	5,570	5,810	5,080	6,540
1945	5,810	6,770	5,090	5,810
1946	4,920	5,040	5,765	5,040
1947	7,260	7,018	6,897	7,018
1948	7,015	6,540	6,900	7,015
1949	6,410	5,560	6,770	6,290
1950	5,687	6,534	5,324	4,356**
1951	3,972	4,114	4,961	3,972
1952	4,840	4,356	4,356	5,082
1953	2,782	2,180	1,935	2,060
Average***	5,370	5,340	5,390	5,340

* No sweet clover yields were obtained from 1954 to 1957, due to severe drought.
** A mixture of alfalfa and sweet clover.
***No statistical significance between the yield on different plots.

Effectiveness of Weed Control

Summer vegetation was not as well controlled on the sweep-tilled areas, where sweeps were used for both primary tillage and summer weed control, as on the other three areas where a tandem disk was used for summer tillage. Several days of dry weather was required to kill vegetation on land stirred with the sweeps, whereas small plants covered completely with soil were killed even though rain fell within a few hours after the plots were disked.

Effects of Tests on the Soil

Nitrogen Content

Nitrates in the soil at wheat planting time after the first two years of the rotation are shown in Table IV. It is clear that on this soil the accumulation of nitrates was influenced to a greater extent by sweet clover residue than by method of tillage.

Table IV.—Nitrate Content of Soil Samples From Plowed, One-Wayed and Sweep-Tilled Plots After First Two Years of Rotation.
(Nitrogen as Nitrates in Parts per Million)

	0 to 2 inches deep	2 to 4 inches deep	4 to 6 inches deep
Plots containing sweet clover residue			
Plowed	9.3	7.5	6.9
One-wayed	8.7	6.9	6.9
Tilled with sweeps	9.3	7.2	6.6
Plots containing wheat stubble; first year after sweet clover			
Plowed	6.6	5.9	5.1
One-wayed	8.7	6.9	7.5
Tilled with sweeps	6.3	4.5	4.5
Plots containing wheat stubble, where no sweet clover had been grown			
Plowed	3.4	3.6	3.3
One-wayed	3.9	2.8	2.2
Tilled with sweeps	4.0	3.0	3.7

In general, a soil nitrogen deficiency was not an important limiting factor on plant development in this experiment where sweet clover was grown in the rotation. The beneficial effect of nitrogen supplied by sweet clover was evident in the individual plot yields in 1942. On plots where sweet clover had been grown the previous year, average grain yield for the four tillage treatments was 21.1 bushels per acre as compared to 15.7 bushels on plots where there had been no sweet clover. The corresponding straw yields were 2,375 and 1,559 pounds per acre.

Lack of available soil nitrogen probably was the cause of the lower

grain and straw yields on all plots where the moldboard plow was not used from 1953 to 1957. These differences can be observed in Figures 1 and 2.

Minerals in Surface Layers

Soil samples from the plowed and sweep-tilled areas after completion of the seventh year of the experiment were compared in a greenhouse and laboratory study by W. L. Garman, at that time a member of the Oklahoma Station agronomy staff. Samples were taken from the surface three inches of soil and from the 3-to 6-inch layer. All coarse organic matter was removed by screening before the soil was placed in pots. The results, presented in Table V, show a tendency for more available plant nutrients to accumulate in the surface three inches of the sweep-tilled area as compared with the plowed land.

Table V.—Greenhouse Yields of Oats, and Easily Soluble Phosphorus and Exchangeable Potassium Content of Soils Collected From Moldboard Plowed and Sweep-Tilled Plots; Perkins Farm, 1946.

Tillage Method	Depth of Sampling (inches)	Oat Grain Yield (grams)	Phosphorus* (ppm)**	Potassium (ppm)**
Moldboard Plow	0-3	19.5	19	165
	3-6	17.4	17	170
Sweeps	0-3	21.6	21	224
	3-6	14.8	14	176

* Determined by leaching with 0.1 normal acetic acid.
** Parts per million.

Soil Moisture at Planting Time

Soil moisture was determined at wheat planting time during the first three years of the experiment. The data are shown in Table 6. There were no significant differences between tillage methods at the 5 percent level.

The total rainfall for July, August and September for these three years was: 1940, 11.8 inches; 1941, 11.3 inches; and 1942, 16.2 inches. The average for these months from 1931 through 1957 was 9.19 inches.

Table VI.—Average Soil Moisture in Early October in Relation to Different Methods of Primary Tillage; Perkins Farm, 1940-1942.
(Moisture in Percent, by Years)

	Depth of Sample (feet)	1940*	1941*	1942*	Average
Moldboard Plow	0-1	13.2	16.3	18.5	16.0
	1-2	14.7	17.2	17.9	16.6
	2-3	12.8	14.6	15.1	14.2
Basin Lister	0-1	11.8	16.2	16.3	14.8
	1-2	15.3	17.7	16.8	16.6
	2-3	12.6	15.3	15.1	14.3
One-way Disk	0-1	12.5	16.0	18.3	15.6
	1-2	14.6	17.4	17.0	16.3
	2-3	10.0	14.7	14.3	13.0
Sweeps	0-1	12.7	15.5	17.2	15.1
	1-2	14.7	17.0	17.6	16.4
	2-3	11.9	15.2	15.1	14.1

No significant difference, at the 5% level, in moisture content of the soil layers from the different tillage areas.
* Averages of three composite samples. To prevent mixing soil from the different layers as the auger was removed from the hole, the top samples were taken with a 1½-inch auger, those from the second foot with a 1¼-inch auger, and those from the third foot with a 1 1/8-inch auger.

Effects of Surface Cover

During many seasons the presence of wheat straw or sweet clover residue on land tilled with sweeps prevented the soil surface from being flattened by rain. On plowed plots, rain often packed the surface of the plots and caused some rill erosion. Wind erosion was not a problem in this area.

Figure 3 shows the protective effect of straw left on the surface of land tilled with sweeps as compared with plowing.

Little or no straw was left on the surface of the plowed land, whereas on sweep-tilled land the crop residue covered about 20 percent of the surface. Surface cover was determined by dropping a 7-foot rule at various places on each plot and measuring the total inches of straw appearing along one edge of the rule, then computing the percentage cover.

The one-way disk left a high percentage of straw on or near the surface, as illustrated in Figure 4.

The basin-listed land held a 3-inch summer rain that fell in 3 hours when considerable soil and water was lost from the other tillage areas. However, a greater surface exposure permitted a more rapid loss

Figure 3. Sweep-tilled plot (foreground) has protective cover. Plowed plot (background) has none. Rills developed on plowed area. Wheat planted in October and photographed in early spring.

Figure 4. Straw cover on a plot tilled with one-way disk.

of surface moisture by evaporation before the land was levelled by disking to prepare a seedbed for the wheat or oats. The water conserving effect of basins made by the lister disappeared as a result of summer tillage required to control weeds and grass or to prepare a seed bed for the wheat.

Summary

Four methods of primary tillage—the first tillage after harvesting the preceding crop—used in preparing a seedbed for winter wheat were compared over a 17-year period. The wheat was grown in a five-year rotation with spring oats and sweet clover on a medium textured soil with moderately permeable subsoil. Tillage implements were moldboard plow, basin lister, one-way disk, and sweeps. All tillage and planting operations were on the contour.

Average wheat yields were: On plowed land, 19.8 bushels per acre; subtilled with sweeps, 19.0 bushels; one-way disked, 18.3 bushels; and basin listed, 17.9 bushels. Method of tillage had little influence on wheat production during the first 12 years of this experiment, in which a good crop of sweet clover was grown every fifth year on a medium textured soil. Higher yields of wheat were obtained on the plowed areas in 1953, 1954 and 1956 than on plots where other methods of primary tillage were used.

A preliminary study indicated that there was a greater tendency for plant nutrients to accumulate in the 0 to three inch layer of subtilled plots than in the 0 to three inch layer of plowed land.

Average oat yields obtained the following year after wheat land was tilled in July by various methods were as follows: plowed plots, 32.7 bushels per acre; one-way disked, 29.8 bushels; subtilled with sweeps, 29.6 bushels; and basin listed, 28.4 bushels.

During three seasons of above average summer and early fall rainfall, there was no appreciable difference in the quantity of moisture at planting time in the first, second or third foot of soil on the different tillage areas.

The average yield of sweet clover was very similar on the variously tilled areas. The average yield of dry sweet clover produced the second year after planting during the 12-year period from 1942 to 1953 was as follows: Plowed plots 5,370 pounds; basin listed plots, 5,340 pounds; one-way disked plots, 5,390 pounds; and subtilled plots, 5,340 pounds per acre. Sweet clover seedlings were killed by severe summer drought from 1954 to 1956.

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