REDUCED TILLAGE IN CORN PRODUCTION

B852/3.5M/66 AGRICULTURAL EXPERIMENT STATION UNIVERSITY OF MISSOURI

ABSTRACT

This bulletin reports the results of research on reducing the tillage required in producing corn. Two methods of reduced tillage were studied and compared with conventional methods of tillage. The wheel-track method of planting in plowed ground and a new method developed during these studies produced yields equal to those produced with conventional methods, but at lower costs.

The new method consists of using a special tool, called a strip plow, which, when combined with suitable attachments, plows strips 22 inches wide and a standard row width apart, fertilizes, applies herbicide and insecticide, and plants in a once-over operation. The strips left unplowed between the rows are plowed when the corn is about 8 to 10 inches high, as part of the first cultivation.

Contents

Corn Belt Branch
Soil and Water Conservation Research Division
Agricultural Research Service
U. S. Department of Agriculture
Columbia, Missouri

and the

Agricultural Engineering Department
of the
Missouri Agricultural Experiment Station
Cooperating

Reduced Tillage in Corn Production

F. D. Whitaker, J. S. McKibben, and M. M. Jones[1]

In 1956 the Department of Agricultural Engineering of the Missouri Agricultural Experiment Station began studies to evaluate reduced-tillage methods for growing corn and to develop, if possible, a method which would be faster and lower in cost, and which would produce yields equal to or higher than those produced with conventional methods or some of the other developing reduced-tillage methods.

Prior to 1956, considerable emphasis was placed on thoroughly working the soil to a depth of 7 or 8 inches by multiple tillage operations. Such methods were not only expensive in time, labor, and machinery, but they resulted in certain other disadvantages, such as: (1) sealing of the soil surface during heavy rains, resulting in high runoff and erosion losses; (2) deep crusting of the soil surface, frequently resulting in poor stands; (3) prolific weed growth; and (4) development of traffic pans in many soils, due to numerous operations with heavy equipment.

Wheel-track planting, which was coming into favor, produced good yields but had certain disadvantages. This method consists essentially of two operations. The ground is first plowed, and the planting is done soon afterward in wheel tracks. The tracks are made by the wheels of the tractor pulling the planter, or by heavy planter wheels. There is no secondary tillage such as disking or harrowing ahead of the planter. With the wheel-track method, planting needs to be done soon after plowing, and it can proceed no faster than plowing. Therefore, some planting is often delayed well beyond the desirable planting time. Another difficulty is in arranging equipment to form well-compacted, suitably-spaced wheel tracks for the rows.

Early Experiments

The early experiments on reduced tillage were conducted as a part of a larger study on intensive cropping. Small grain, usually wheat, was removed for silage about June 1. Corn was planted in the stubble. During these early experiments, the strip-tilling equipment underwent considerable change and development. The seasons were rather unfavorable for late-planted corn. Therefore, the work for the years 1956 through 1958 has been summarized and is only briefly discussed in this bulletin.

These early experiments were conducted on the Midway Farm near Columbia on a Grundy silt loam.

[1]Hydraulic Engineering Technician, USDA, Columbia, Missouri; Associate Professor of Agricultural Engineering, University of Missouri; and Professor of Agricultural Engineering, University of Missouri, respectively.

Fig. 1 The once-over strip tilling and planting equipment used in the first experiments on reduced tillage. The strip tiller equipment, mounted on the tractor cultivator frame, consists of wide sweeps to clear trash from the row areas, 9-inch deep-tilling sweeps, disk hillers, and rotary hoe units. A rear-mounted tractor planter planted in the center of the tilled strips.

Three methods of tillage were studied and compared. The conventional method consisted of plowing, tandem disking, harrowing, and planting as separate operations. This method was used as a standard or check for comparison with the other two methods.

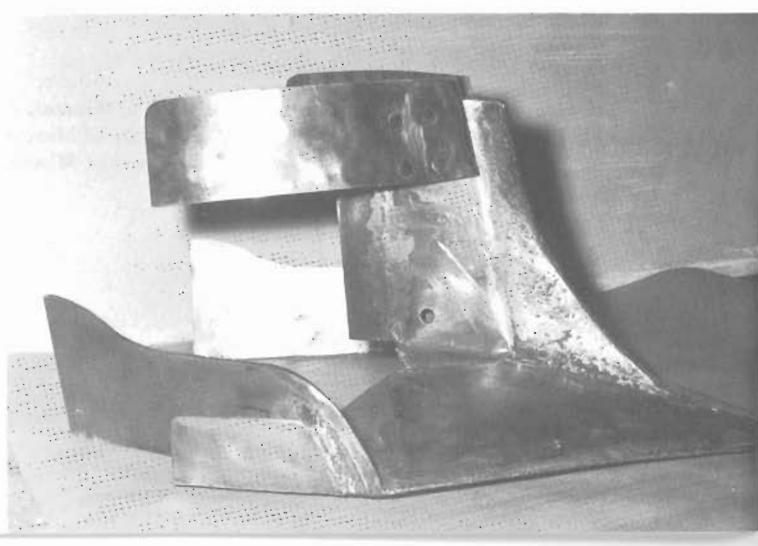
A second method, wheel-track planting, was a twice-over method and consisted of plowing and then planting with a rear-mounted tractor planter arranged to plant in the tractor-wheel tracks.

The third method, the "strip-till" method, which was later developed into the "strip-plow" method, consisted of a once-over operation with special equipment on a front-mounted tractor cultivator frame and a rear-mounted, two-row planter (Fig. 1). Wide sweeps were used in front of the tractor to clear the trash from the row areas, and immediately behind were 9-inch sweeps that tilled strips about 6 inches deep and 40 inches apart. Disk hillers were mounted behind the tilling sweeps to move soil to the centers of the rows, and rotary hoe units mounted in a reverse position were used to pack the row areas. A two-row tractor cultivator was used on all plots.

The results of the 1956-1958 experiments were encouraging and suggested that both the strip-till method and the wheel-track method would produce yields comparable to the conventional method with much lower power, labor, and machinery costs. During this period, there was considerable change and development of the equipment for strip tillage, which resulted in a basic tool, the strip plow (Fig. 2).

The strip plow consists essentially of a deep-running sweep with top wings to force the surface soil and trash outward, and lower wings to move the

Fig. 2 The basic strip plow unit which was developed from these studies. The top wings force the surface soil and trash outward, and the lower wings move moist, trash-free soil in the bottom of the furrow slice toward the center of the strip.



moist, trash-free soil in the bottom of the furrow slice inward. These basic strip plows were incorporated into a combined tilling and planting implement. This implement, with appropriate standard attachments, will plow and compact strips through the field, place heavy applications of fertilizer in the bottoms of the strips, apply starter fertilizer, apply soil insecticide and herbicide, and plant in a single operation.

The plowed strips are 22 inches wide, 8 to 10 inches deep, and a standard row width apart, leaving unplowed strips approximately 18 inches wide. Trash is tucked down in the edges of the plowed strips, and the soil ahead of the compacting wheels is well pulverized and raised about 2 to 3 inches above the undistrubed soil between the plowed strips (Fig. 3). Wheels then firm the soil ahead of the planting mechanism to achieve, essentially, wheel-track planting.

The strips between the rows are plowed when the corn is 8 to 10 inches tall. This is done with half-width, right- and left-strip plows (half plows), which were developed for use on a rear-mounted tool bar. These are preferred to full-size strip plows for this operation because the load is easily centered behind the tractor when working two or four rows. Also, they move the trash away from the rows and leave it at the low point between the rows, where it is in best position to retard erosion and aid in moisture infiltration.

Studies Expanded

In 1959 the Soil and Water Conservation Research Division of the Agricultural Research Service became a cooperator, and these studies were expanded. The experimental plots at Columbia were relocated on the University of Missouri South Farm, on a Mexico silt loam soil. This soil is representative of Midwest claypan soils characterized by gently rolling topography, a gray leached surface, low fertility, and a clay subsoil layer of low permeability. Optimum soil moisture is necessary at planting time for good tilth.

Experiments were also begun in northeast Missouri, near Elsberry, on a Sharon silt loam soil. This soil was formed by outwash from the Mississippi River hills. It has plastic "gumbo" layers at various depths. The gumbo layer is near the surface on about one-third of the experimental area, and is well below

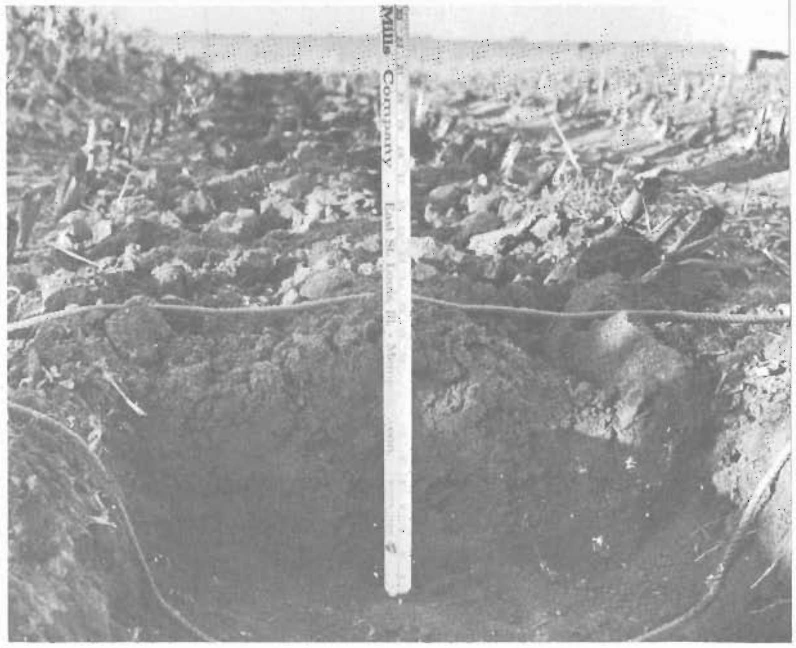


Fig. 3 The strip plow unit plows a strip about 22 inches wide and 8 to 10 inches deep, leaving a well-pulverized furrow slice about 2 to 3 inches above the adjacent unplowed ground.

plow depth on the remainder. The silt loam surface layer above the gumbo in this soil has good tilth through a wider range of moisture content than the claypan soil of the Columbia experimental area. The gumbo layer has poor tilth, especially if the moisture content is slightly high.

Design of the Experiments

Randomized block designs with three or four replications per treatment were used during the period 1959 through 1963. The plots near Elsberry were 20 feet by 800 feet and 40 feet by 400 feet; those near Columbia were 20 feet by 100 feet.

Commercial hybrid seed corn was drilled at a 9-inch spacing in 40-inch rows for an anticipated stand of 16,000 plants per acre. Although the methods of applying fertilizer could not be the same with all tillage treatments, the amounts applied were kept as nearly equal as possible for all plots in a particular location and year.

Nitrogen side dressings of 33-0-0 at rates of 350 to 400 pounds per acre were made at the time of the first cultivation on all plots. Beginning in 1962, a preemergence herbicide and a soil insecticide were

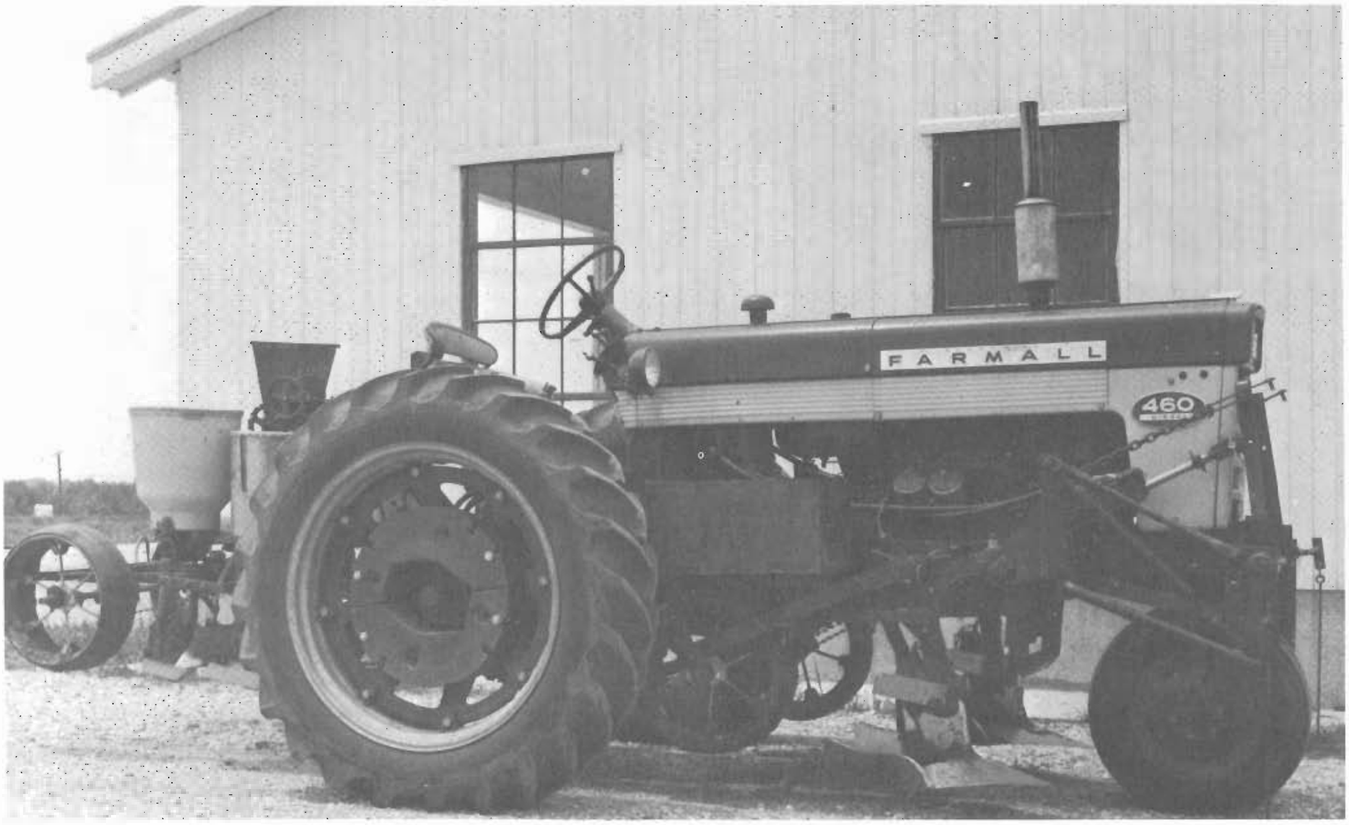


Fig. 4 The strip plow and planter used in the 1962 and 1963 experiments.

applied in the row areas at planting time to obtain better weed and insect control.

Tillage Methods and Equipment

As in the earlier studies, the experimental strip-plow method and the wheel-track method were compared with the conventional method.

In the conventional method, the stalks from the previous crops were shredded, the row ridges were disked down with a tandem disk, and the soil was plowed and then tandem disked and harrowed before planting. Corn was planted with the tractor wheels set so the rows were not in the wheel tracks.

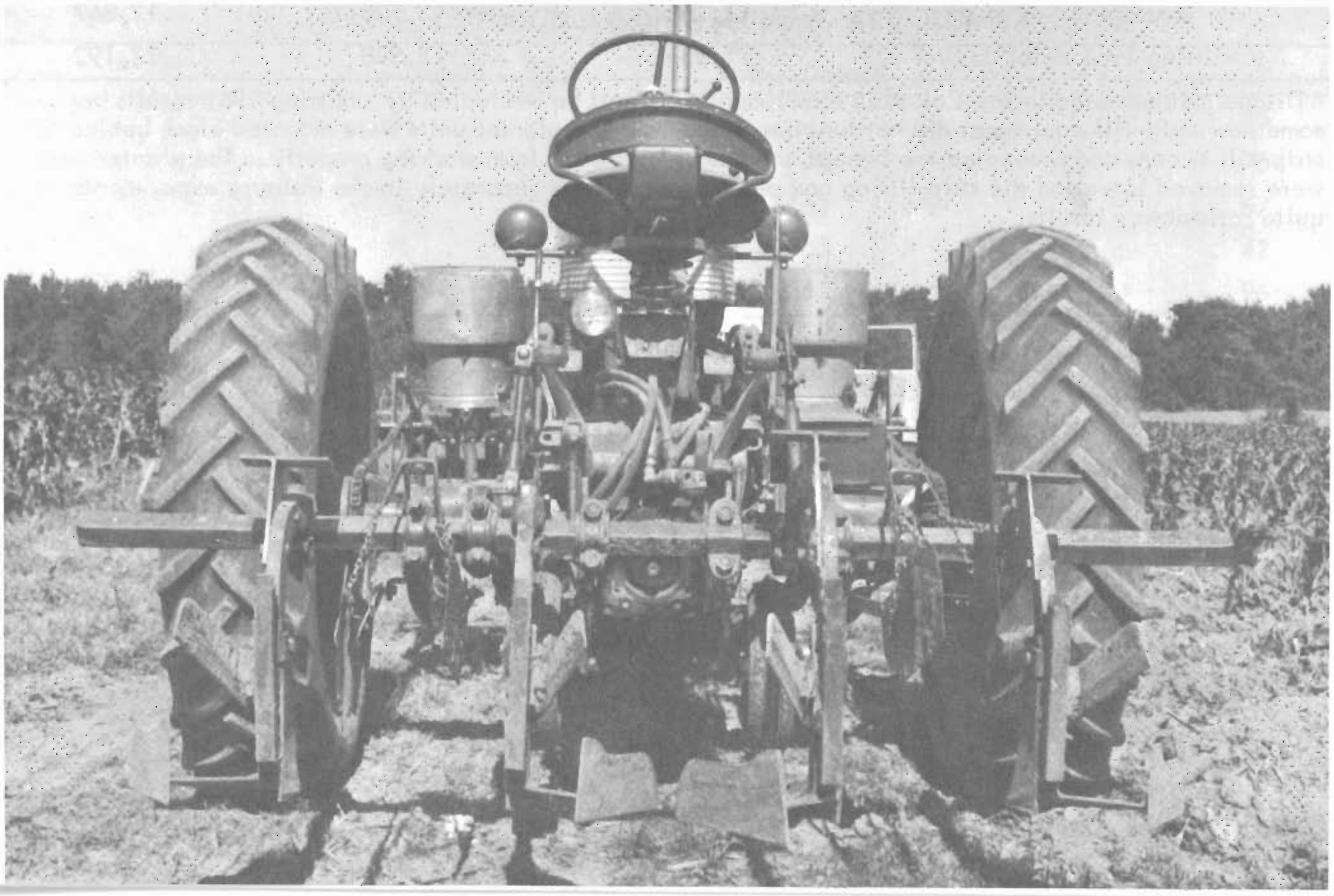
In the wheel-track method, the stalks from the previous crops were shredded, the row ridges were disked with a tandem disk, the soil was plowed, and the crop was planted without further tillage. The tractor wheels were set so crops were planted in tractor wheel tracks.

With the strip-plow method, the stalks from the previous crop were shredded, but after the 1961 season the ridges were not disked, because this was found to be unnecessary. In fact, the strip plow worked better in undisked ground. After 1961, plowing with the strip plow, planting, fertilizing, and applying of such herbicide and soil insecticide as desired, were accomplished in a once-over operation (Figs. 4 and 5). Until this time, no satisfactory combination implement had been developed. Previously, plowing was done with the strip plow, followed by a second operation in which the planting and the application of starter fertilizers, herbicides, and soil insecticides were accomplished.

With the conventional and wheel-track methods, corn was cultivated with conventional two-row equipment two or three times as needed for weed control. With the strip-plow method, the first cultivation was with the half plows mounted on a rear tool bar to plow between the rows (Fig. 6). Regular cultivator sweeps were used on the front cultivator gangs when needed for weed control in the row area. Only two sweeps were used per row, and these were set to work close to the rows. Any additional cultiva-

Fig. 5 The strip plow and planter at work. Stalks from the previous crop were shredded, but no other work was done ahead of the strip plow. The strip plow units are mid-mounted ahead of the tractor rear axle, and a tractor planter is rear mounted and equipped with attachments to apply fertilizer, soil insecticide, and a herbicide.

Fig. 6 A tractor equipped to plow the middles with rear-mounted "half plows" at the time of the first cultivation. Regular front sweeps set to work close to the row may be used for more complete weed control, if needed. Also, fertilizer may be applied as desired.



tions were the same as with the other two treatments.

Experimental Results

Plant population, early growth, and yield data are given in the following tables. Tables 1 and 2 show that corn stands were considerably higher in most cases on the Sharon silt loam near Elsberry than on the Mexico claypan soil near Columbia for all three tillage methods. Better soil tilth on the silt loam near Elsberry at planting time favored maintenance of a more nearly optimum soil moisture during dry periods and less water damage during wet periods following planting.

Plant mortality during the first cultivation was somewhat higher with the strip-plow equipment in its earlier stages of development because of poor maintenance of row spacings. There was a considerable amount of volunteer corn on all plots each year. The strip-plow method moves all surface trash away from the row area; therefore, practically all volunteer corn is killed by subsequent cultivation. The plant populations of the wheel-track and the conventional plots were increased somewhat by volunteer stalks in the rows.

Observations and measurements of the growth of the corn plants showed that during the early part of the season, corn on the conventional-method plots was usually a little taller than that on the reduced-tillage plots (Tables 3 and 4). However, the difference in early plant growth was not significant during most years and was not evident by the time the corn was tasseling.

Data in Table 5 show that yields from the strip-plow and conventional treatments on the Mexico silt loam at Columbia were about equal, while those from the wheel-track method were about 11 bushels per acre more.

The average yield on the Sharon silt loam soil at Elsberry was 126 bushels per acre from the strip-plow

TABLE 1--PLANT POPULATION AT COLUMBIA

Year	Time Counted	Strip-Plow	Wheel-track	Conventional
1959	July 23	7,033	8,950	9,050
1960	Harvest	10,513	11,643	8,220
1961	July 10*	10,133	14,133	15,566
1962	Harvest	14,200	17,000	17,500
1963	Harvest	14,400	12,800	14,000
Average		11,256	12,905	12,867
(Omitting 1961 data)		11,536	12,598	12,192

*Tillage methods used in the Columbia experiments can best be evaluated by omitting 1961 results because some new strip-till equipment did not function properly. The planter units were mounted close behind the strip-till sweeps and prevented the sweeps and the planter units from working properly. The planter units were removed later and the strip tilling and planting were done separately in the Elsberry experiments, with quite satisfactory results.

TABLE 2--PLANT POPULATION AT ELSBERRY

Year	Time Counted	Strip-Plow	Wheel-track	Conventional
1959	Harvest	13,500	13,100	15,600
1960	Harvest	14,700	16,100	16,250
1961	Harvest	15,133	15,933	14,066
1962	June 15	15,000	18,400	17,000
1963	Harvest	13,600	14,800	15,900
Average		14,387	15,667	15,763

TABLE 3--EARLY GROWTH, HEIGHT (inches), AT COLUMBIA

Year	Last Date Measured	Strip-Plow	Wheel-track	Conventional
1959	July 23	74	78	77
1960	July 23	66	70	67
1961	July 10 1/	19	31	33
1962	June 29	34	38	39
1963	Not measured			
Average		48	54	54
(Omitting 1961 data)		58	62	61

1/ See footnote, Table 1.

TABLE 4--EARLY GROWTH, HEIGHT (inches), AT ELSBERRY

Year	Last Date Measured	Strip-Plow	Wheel-track	Conventional
1959	Not recorded	22	22	31
1960	(Height not measured in the 1960 experiments)			
1961	June 28	26	24	24
1962	June 15	61	62	63
1963	June 19	65	68	70
Average		43.5	44	47

TABLE 5--CORN YIELD (bushels per acre), AT COLUMBIA

Year	Strip-Plow	Wheel-track	Conventional
1959	40	51	45
1960	62	78	70
1961	1/ 38	61	67
1962	51	55	42
1963	104	115	96
Average	59	72	64
(Omitting 1961 data)	64	75	63

1/ See footnote, Table 1.

and conventional methods of planting. Yields from the wheel-track planting method averaged 129 bushels per acre (Table 6).

The average corn yields (1959-1963) from the reduced tillage methods were about equal to those from the conventional method on both the Sharon silt loam and the Mexico silt loam soils. Average yields on the Mexico claypan soil near Columbia were about 50 percent lower, however, than those from comparable treatments on the Sharon soil near Elsberry.

The accumulated average yields in bushels per 1,000 stalks are shown in Figures 7 and 8. On the claypan soil, the yields from reduced-tillage methods were slightly lower than yields from the conventional method. On the Sharon silt loam soil, however, yields from the strip-plow method were higher than those from the wheel-track and conventional methods.

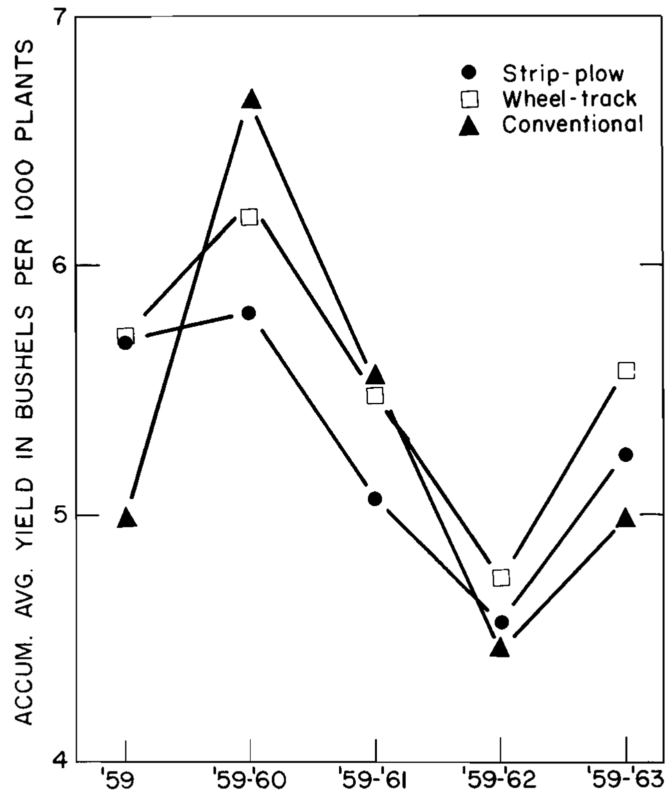


Fig. 7 Accumulated average corn yields (bushels per 1000 plants) for the period 1959-1963 on the claypan soils near Columbia.

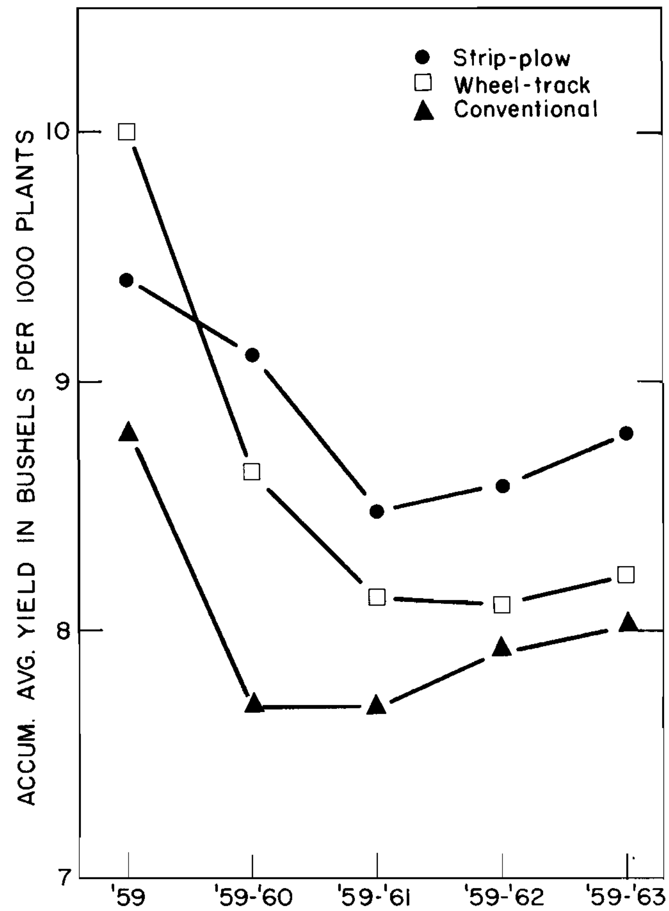


Fig. 8 Accumulated average corn yields (bushels per 1000 plants) for the period 1959-1963 on the Sharon silt loam soil near Elsberry.

TABLE 6--CORN YIELD (bushels per acre), AT ELSBERRY

Year		Strip-Plow	Wheel-track	Conventional
1959		127	131	137
1960		130	121	108
1961		110	115	108
1962		133	148	145
1963		132	129	133
	Average	126	129	126

Comparative Costs of Tillage Methods

Although yields were not significantly different between the strip-plow method and the wheel-track and conventional methods, the cost of tillage operations obviously would be considerably less. To get some definite information on the cost of tillage operations with the wheel-track and the strip-plow methods, time, fuel, and draft studies were made.

Draft Studies

Draft tests were made on the strip-plow and a moldboard plow in Mexico silt loam near Columbia in 1961. Strain gage equipment was used to measure draft. The results are shown in Figure 9.[2] The strip plow had a draft some 20 percent greater than a moldboard plow of equivalent width at 3 miles per hour. As the speed was increased to 7 miles per hour, the draft of the strip plow increased 22 percent, while the draft of the moldboard plow increased 76 percent. Also, the appearance of the strip and the quality of the work done by the strip plow changed only slightly with increased speed; whereas, the work of the moldboard plow was quite unsatisfactory at higher speeds.

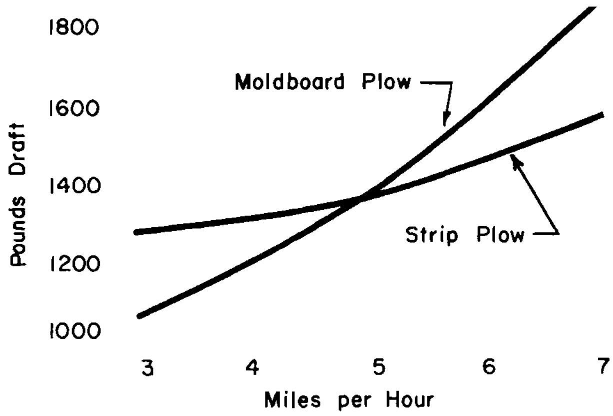


Fig. 9 Draft comparisons of the strip plow and a moldboard plow of equivalent width at different speeds of operation.

Time and Fuel Studies

Time studies were conducted in 1962 comparing strip plowing and planting with plowing and wheel-track planting. In the wheel-track method, plowing was done with a full 3-plow tractor pulling a 3-bottom plow, and the planting was done with a light farm tractor pulling a 2-row planter as a separate operation. The strip plowing and planting were accomplished as a once-over, 2-row operation with equipment mounted on the same 3-plow tractor. Time and fuel requirements are given in Table 7.

Almost exactly one-half as much time was required for a man and tractor to plow strips and plant an acre as to plow and wheel-track plant an acre. The fuel required to plow an acre in preparation for wheel-track planting was sufficient not only for the

[2]A full report of the draft tests is given in an unpublished master's thesis entitled "Draft Measurements of a Strip Tiller" (1961) by Joe P. Gentry, which is in the University of Missouri Library.

TABLE 7--TIME AND FUEL REQUIREMENTS

Wheel-track Planting		
Plowing	49.3 min/acre	1.86 gal. diesel fuel per acre
Planting	38.4 min/acre	.87 gal. gasoline per acre
First Cultivation	26.2 min/acre	.55 gal. diesel fuel per acre
Total	114.9 min/acre	3.28 gal. fuel per acre
Strip-plow Planting		
Strip Plowing and Planting	44.4 min/acre	1.20 gal. diesel fuel per acre
First Cultivation and Strip Plow Middles	27.1 min/acre	.66 gal. diesel fuel per acre
Total	71.5 min/acre	1.86 gal. diesel fuel per acre

*2.41 gallons diesel fuel, plus 0.87 gallon gasoline per acre.

strip-plow planting operation, but also for the combined operation of plowing the middles and making the first cultivation. This was unexpected, because the previously discussed draft tests indicated that about 20 percent more fuel would be needed to plow the strips and later plow the middles than would be required for moldboard plowing. The draft tests of the strip plowing were made in undisturbed soil, so the results should apply to the first plowing of the strips. Apparently a much lower draft is required to plow the middles later, along with the first cultivation, and this accounts for the lower-than-expected fuel consumption.

Conclusions

Strip plowing and planting, as finally developed into a once-over operation, and plowing followed by wheel-track planting, both give satisfactory results. Yields are comparable with those produced by conventional methods. However, the strip-plow method requires the least time and fuel, and, in addition, has the following important advantages.

Observations following heavy rains indicate that runoff and erosion losses are considerably lower with strip plowing. From planting time until first cultivation, the soil between the rows is protected by residues from the previous crop. After the middles are plowed, the soil is left rough and receptive to moisture infiltration. Also, much of the crop residue is partially mixed with the surface soil by this operation, and thus reduces erosion during later growth.

The strip-plow method is quite flexible and adaptable to various methods of weed control and fertilizer application. A heavy application of fertilizer can be placed in the bottom of the plowed strips, and starter fertilizer can be placed to one side and slightly below the seed at planting time. Soil insecticide and herbicide may also be applied at planting time, if desired. Nitrogen fertilizer may be applied at the time of the first cultivation and plowing of the middles.