TEXAS AGRICULTURAL EXPERIMENT STATION
R. D. LEWIS, Director, College Station, Texas

Bulletin 711

STUBBLE MULCH MANAGEMENT

for Water Conservation and Erosion Control on Hardlands of the Southern Great Plains

in cooperation with the
UNITED STATES DEPARTMENT OF AGRICULTURE

June 1949

The TEXAS AGRICULTURAL AND MECHANICAL COLLEGE SYSTEM
GIBB GILCHRIST, Chancellor

[Blank Page in Original Bulletin]

Preface

This bulletin contains a resume of the stubble mulch tillage studies carried on the past 7 years at the Amarillo Conservation Experiment Station.

The Amarillo station is located in the 15 to 20-inch rainfall belt in the Panhandle of Texas. Drouth years occur in which it is extremely difficult to maintain a vegetative cover adequate to protect the soil from wind and water erosion. Much of the rainfall occurs as torrential showers so that maintaining the hardland soil in as permeable a condition as possible is a matter of considerable importance.

Considerable information has been obtained in the Plains States during the past 10 years concerning the merit of stubble mulch farming. Cultivation by this method is done with sweeps which till the soil without turning it. Thus, as much plant residue as possible is kept on the surface of the ground.

Subtillage is compared with the oneway and moldboard plows in raising wheat in the studies made at the Amarillo station. Data are presented on grain yields, soil moisture, available nitrogen and organic matter.

The Southern Great Plains are generally said to comprise Eastern New Mexico, Southeastern Colorado, Southwestern Kansas and the Panhandles of Oklahoma and Texas.

CONTENTS

P52-749-3M-L180

BULLETIN 711 JUNE 1949

STUBBLE MULCH MANAGEMENT for Water Conservation and Erosion Control on Hardlands of the Southern Great Plains

CHARLES J. WHITFIELD, C. E. VAN DOREN and WENDELL JOHNSON*

LEARNING to farm the heavy soils of the Southern Great Plains successfully has been the basis of investigations at the Amarillo Conservation Experiment Station for the past 7 years.

Conservation of the soil and water resources and dependable crop production are fundamental to successful farming in this 15 to 20-inch rainfall belt, an area susceptible to both wind and water erosion. The average annual precipitation on the Amarillo station, 1939 through 1948, has been 18.2 inches. The principal crops are winter wheat, grain and forage sorghums, Sudan, and native and introduced grasses. Detailed studies, most of which were initiated in 1941, of stubble mulch tillage, cover crops, crop rotations, adapted crops, including grasses and legumes, and other conservation practices such as terracing and water spreading, have given helpful information on conservation of both soil and water. Definite progress has been made in controlling erosion and stabilizing crop production by the use of stubble mulch tillage.

This report concerns studies made of stubble mulch practices in growing winter wheat on Pullman silty clay loam, a deep, fine textured, slowly permeable hardland soil, high in fertility and moderately high in organic matter under native conditions. There are some 11,750,000 acres of these deep, heavy soils in the Southern Great Plains.

A group of 32 plots one-third acre in size were established in 1941 and 1942. Four types of implements, two plows and two subtillage machines, were used on plots planted to wheat year after year. These were the oneway plow, the moldboard plow, the Noble cultivator, and a subtillage machine developed at the Amarillo station. Two types of implements, the oneway plow and the Amarillo subtillage machine, were used on plots planted to wheat one year and fallowed the next year. Each treatment was randomized and replicated 4 times.

*Respectively, project supervisor, soil conservationist and soil scientist, Amarillo Conservation Experiment Station, Amarillo, Texas.

This study is a cooperative project between the Texas Agricultural Experiment Station and the Research Division, Soil Conservation Service, U. S. Department of Agriculture, which operate the Amarillo Conservation Experiment Station. The station is 14 miles west of Amarillo.

Specifications and Equipment for Land Preparation

Performance requirements for a subtillage implement to be used for land preparation at the Amarillo station were set forth as follows:

1. Maximum amount of residue to be left on the surface (stubble mulch), with as many as four tillage operations within a 3-months period.
2. Cultivation of land at different depths to prevent plow sole formation, to aid in the deeper penetration of moisture, and to obtain a rapid, effective weed kill.
3. Fields to be left in suitable condition for planting crops.

After considerable testing of various combinations of sweeps and other implements, it was found that to do a successful job of subsurface tillage a subtiller should:

1. Be capable of operating at fixed depths.
2. Be equipped with rolling coulters to cut residues and weeds ahead of the sweeps to prevent clogging.

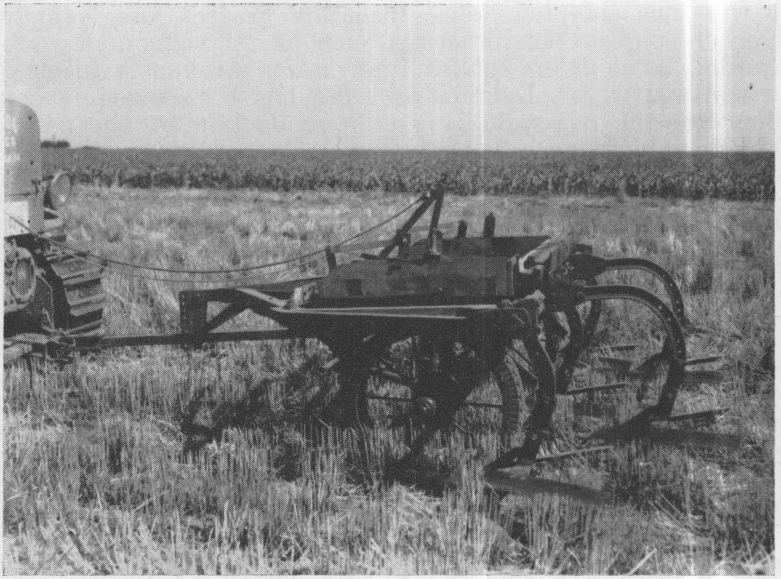

Figure 1. Subtillage machine employing five 30-inch sweeps designed for operation at controlled depths in Pullman silty clay loam soils with a minimum of clogging due to surface residues.

3. Have adequate weight and strength for penetration and operation under difficult soil conditions.

4. Cultivate the soil to kill weeds and volunteer crops, such as wheat, effectively.

A machine embodying these requirements, determined by more than 3 years of study, was constructed at the Amarillo station in the spring of 1945. It consists of five 30-inch Dempster sweeps mounted on a heavily reinforced carrier equipped with a power lift and rolling coulters. The implement has been used the past 4 years with a high degree of success under a wide range of conditions. Trashy fields, some of which were covered with a heavy growth of volunteer wheat, have been worked successfully with no more difficulty, generally, than would be encountered using the oneway.

Results in Grain Yield

Grain yields for each of the 7 years, 1942-48, are given in Table 1 for the plots in wheat year after year, along with the 7-year average.

Table 1. Grain yields from stubble mulch plots in continuous wheat, 1942-48

Tillage	Wheat yield—bushels, per acre							7-year average
	1942	1943	1944	1945	1946	1947	1948	
Moldboard plow..	20.3	4.2	19.7	4.4	1.8	31.8	5.6	12.5
Oneway plow....	20.1	6.0	24.5	6.3	2.6	28.4	4.6	13.2
Subtillage.....	19.0	7.1	26.4	6.9	6.0	34.3	6.2	15.1

An average of 2.6 bushels more wheat per acre was obtained from the continuous wheat plots which were subtilled than was produced after the moldboard plow, and 1.9 bushels more than where the oneway was used. The fact that subsurface tillage gave increased wheat yields during the period these tests were in operation is in harmony with the effectiveness of stubble mulches in controlling erosion. It is also interesting to note that the average annual wheat yield on the subtilled plots was 15.1 bushels per acre.

The grain yields for the 7-year period are shown in Table 2 where two implements, the oneway plow and the subtiller, were used on plots planted to wheat one year and fallowed the next.

An increase of 2.8 bushels per acre was recorded in favor of the subsurface tillage implement over the oneway on plots in wheat and fallow. For any single crop year, wheat after a year of fallow consistently outyielded wheat planted year after year (compare Tables 1 and 2). This effect has been pronounced

Table 2. Grain yields in wheat and fallow system, 1943-48

Tillage	Wheat yield—bushels per acre						Average yield on fallow land
	1943*	1944	1945	1946	1947	1948	
Oneway.....	11.9	28.4	16.7	8.5	33.1	13.9	18.8
Subtillage.....	14.6	28.4	20.4	13.9	36.8	15.7	21.6

*Plots fallowed in 1942.

in dry years when the moisture stored during a year of fallow has meant the difference between crop success and failure. In addition, fallowing has made possible the production and maintenance of a stubble mulch to protect the soil from blowing regardless of the occurrence of periods of subnormal precipitation (Figure 2).

Plow Sole

There has been no indication of plow sole formation during these studies. Depth of plowing for all four implements for the first operation of the season, was 4 to 5 inches, for the second 2 to 3 inches, and for subsequent operations 1 to 2 inches. This is common practice throughout the area and there is no indication that deeper plowing is necessary even at periodic intervals.

Precipitation

Four of the 7 years of this study had less than the Amarillo station average of 18.2 inches of precipitation (Table 3).

Table 3. Precipitation, annual and by crop years for wheat, 1941-48

Year	1941	1942	1943	1944	1945	1946	1947	1948
Annual	32.6	18.5	17.1	21.7	12.9	15.9	14.4	20.4
Crop year (July-June).	26.5	17.3	21.2	15.7	13.5	20.8	13.6	

Soil Moisture

Soil moisture samples taken on the continuous wheat plots have failed to show moisture to be consistently higher under subtillage than under the other cultural methods. In fact, soil samples taken in October 1948 showed that the subtilled plots in both the continuous wheat and the wheat-fallow-wheat system, after producing a crop of wheat in 1948, were somewhat lower in soil moisture than plots tilled with the oneway or moldboard plow (Table 4).

Figure 2. Subtilled land showing wheat stubble residue remaining on surface.

Since the larger yields have been obtained on the subtilled plots, it would be difficult to assess the amount of moisture actually made available to the crop under different tillage systems by a consideration of soil moisture data alone where a measure of the moisture used by the crop is not available. It is noteworthy, however, that when land has been in fallow for a year, more moisture is consistently found in subtilled than in onewayed land. This is convincing proof of the efficiency of the stubble mulch system in storing moisture. Of especial interest in this connection are the data which compare

Table 4. Average moisture content to a depth of 3 feet of stubble mulch plots, October 1948 and March 1949

Tillage method	Land in:	Moisture content, percent	
		Oct. 1948	Mar. 1949
	Continuous wheat		
Moldboard plow	Wheat	16.0	18.1
Oneway	Wheat	16.3	17.2
Subtillage	Wheat	15.1	20.1
	Wheat-fallow-wheat system		
Oneway	Fallow	16.2	19.0
Subtillage	Fallow	15.3	20.1
Oneway	Wheat	18.1	17.3
Subtillage	Wheat	21.5	18.9

moisture reserves in the stubble mulch plots in late March 1949, about 5½ months after the October sampling. It is apparent that the subtilled fallow and continuous wheat plots had been able to retain sufficient winter precipitation to more than overcome the moisture deficiencies of the previous fall, and at this season of the year were able to surpass the oneway and moldboard plow plots in moisture content.

Available Nitrogen

Samples taken in October 1948 were analyzed for available nitrogen. They reveal (Table 5) that:

1. On the continuous wheat plots, nitrates were lower on subtilled than on oneway plots.

2. Nitrates were increased by fallowing and in general were lower on continuous wheat than on wheat-fallow rotation plots. This appeared to be true where moisture was available for nitrification and where there were no crops to take up the nitrates.

Essentially the same relationships were found to exist in late March 1949, at which time the mean nitrate-nitrogen content of the top 4 feet of soil in parts per million was 4.4 on moldboard plow plots, 5.9 where the oneway plow was used, and 3.0 with subtillage. In the relatively dry area of the Southern Great Plains, moisture appears to be the limiting factor in crop production, rather than fertility.

Table 5. Nitrate nitrogen determinations (p.p.m.) on stubble mulch plots, October 1948

Cultural practice			Depth of sample	
			0–3 inches	3–6 inches
Continuous wheat				
	Oneway		22.6	7.4
	Subtillage		8.6	3.3
Wheat and 1 year of fallow				
	Oneway	(wheat 1947-48)	21.5	14.6
		(fallow 1947-48)	30.9	11.8
	Subtillage	(wheat 1947-48)	12.8	4.7
		(fallow 1947-48)	40.0	11.7

Organic Matter

Organic matter determinations made in October 1948 showed slightly higher percentages in stubble mulch tillage when compared with the conventional oneway method of tillage (Table 6). Also, wheat-after-wheat plots were slightly higher in organic matter than were the plots in wheat-fallow rotation.

Table 6. Percent of organic matter in stubble mulch plots, October 1948

Cultural practice			Depth of sample	
			0–3 inches	3–6 inches
Continuous wheat	Oneway		2.05	1.46
	Subtillage		2.09	1.58
Wheat and 1 year of fallow	Oneway	(wheat 1947-48)	1.90	1.53
		(fallow 1947-48)	1.96	1.52
	Subtillage	(wheat 1947-48)	2.03	1.66
		(fallow 1947-48)	2.08	1.54

Straw-grain Ratio

Ratios of the weight of grain and the weight of straw produced on continuous wheat and on wheat-fallow-wheat plots are given in Table 7.

Straw to grain ratios on continuous wheat plots were consistently highest where the moldboard plow was used as the tillage implement and lowest where subtillage was practiced. The highest ratio, 7.64, was obtained on the moldboard plow plots in 1946, the year of least precipitation in this study. In a given year, lower ratios were observed on fallow plots than where continuous wheat had been grown using the same tillage treatment. This is an indication that the yield advantage gained by subtillage over other methods of seedbed preparation may also be due to an improved moisture-fertility balance. This could be the case if the lower nitrification rate often observed under subtillage has the effect of avoiding overstimulation. In this connection, on the subtilled continuous wheat plots the light-green color of foliage associated with a meager supply of available nitrogen was distinctly in evidence on May 1, 1949. This was in marked contrast with the darker-green color of wheat on the oneway and moldboard plow plots. Conditions for nitrification and non-symbiotic nitrogen fixation are regarded

as being very favorable on the soils of the Southern Great Plains and more than the optimum amount of nitrates may at times be present in the soil. Support for this theory is found in the data presented in the discussion of soil moisture and available nitrogen.

In late March 1949, the greatest amount of available nitrogen and the least amount of soil moisture were found in the one-wayed continuous wheat plots, and the largest amount of soil moisture combined with the smallest amount of available nitrogen occurred in the subtilled plots. It is likely that subtillage through the agency of lower temperature and higher surface moisture content, inhibits nitrification in early spring and thereby retards vegetative growth to a point more compatible with climatic conditions. As a result, more efficient use as far as grain production is concerned is made of the rather scanty rainfall of the region.

Table 7. Ratios of weight of straw to weight of grain on stubble mulch plots in continuous wheat and in wheat-fallow-wheat. Precipitation received during corresponding crop or crop and fallow seasons, 1943-47

Tillage practice	1943	1944	1945	1946	1947	1943–46 average
	Ratio of straw to grain—continuous wheat					
Moldboard plow.....	5.26	2.98	2.74	7.64	2.02	4.66
Oneway.....	4.03	1.84	1.59	4.49	2.15	2.99
Subtillage.....	3.55	1.32	1.06	2.89	1.73	2.20
	Precipitation, inches per crop year					
	17.3	21.2	15.7	13.5	20.8	16.9
	Ratio of straw to grain—wheat-fallow-wheat					
Oneway.....	3.18	1.84	0.92	2.89	....	2.21
Subtillage.....	2.81	1.85	0.84	2.01	....	1.88
	Precipitation, inches per crop and fallow 2 years					
	43.8	38.5	36.9	29.2	34.3	37.1

Significance of Data

Analysis of variance of grain yields on the continuous wheat plots (Table 2) showed that:

1. The differences in grain yields between implements are highly significant.

2. The yield differences between the subtilled and the plowed plots for 1942 and 1943 during the first 2 years of treatment are not significant. There is a significant difference in yields favoring subtillage during the next three years, 1944, 1945 and 1946; and a highly significant difference for 1947 and 1948. In other words, the effects of stubble mulch tillage were accumulative through the 7-year period of study. This favorable effect of subtillage appears to be due at least in part, to an improvement in the physical condition of the soil. Tables 4 and 5 do not show the accumulative beneficial effect of the stubble mulch to be due to stored moisture or enhanced conditions for nitrification. However, data on the ratio of weight

Table 8. Analysis of variance; stubble mulch plots; continuous wheat, by years and for 7-year period‡

Source variation	Degrees freedom	Mean square						
		1942	1943	1944	1945	1946	1947	1948
Total	15							
Treatment	3	1.89	14.30	*40.75	*5.32	†18.93	†31.14	†4.84
Replication	3	36.00	3.65	14.66	2.29	5.07	12.06	.30
Error	9	2.99	3.88	10.19	.91	3.24	.97	.54

Source variation	Degrees freedom	Sum squares	Mean square
Total	111	12,955.91	
Treatment	3	149.54	†49.85
Years	6	12,177.89	
Interaction	18	201.97	†1.22
Replication	21	222.10	
Exp. error	63	204.41	3.24
Treatment total	3	149.54	†49.85
Noble blade vs. sweep machine	1	5.16	5.16
Noble blade & sweep machine vs. oneway & moldboard plows	1	138.40	†138.40
Oneway vs. moldboard plow	1	5.94	5.94

*Data significant at the 5% level.
†Data highly significant at the 1% level.
‡Analyses were made by K. B. Porter, Agronomist, Amarillo Experiment Station.

of straw to weight of grain produced on continuous wheat and on wheat-fallow-wheat plots indicate an improved moisture-fertility balance (Table 7).

3. There was no significant difference in grain yields between the two subtillage sweep machines, the Noble cultivator and the station machine. The subtiller that works best under the conditions encountered may be used without loss of yield.

4. Differences in the grain yields between the oneway and the moldboard plow were not significant.

5. Analysis of variance of plots in wheat and fallow indicates that differences recorded between onewayed and subtilled plots have a high degree of significance (Table 9).

Table 9. Analysis of variance of yields of stubble mulch fallow plots, by years and for 6-year period

Source variation	Degrees freedom	Mean square					
		1943	1944	1945	1946	1947	1948
Total	11						
Treatment	2	*7.60	4.88	*42.80	*52.55	*16.17	4.10
Replication	3	10.44	5.25	2.61	2.39	9.33	2.81
Error	6	1.68	4.94	5.06	1.53	1.81	1.53

Source variation	Degrees freedom	Sum squares	Mean square
Total	71	5,729.74	
Treatment	2	170.77	†85.39
Years	5	5,275.72	
Interaction	10	85.43	*8.54
Replication	18	78.47	
Exp. error	36	99.36	2.76
Treatment total	2	170.77	†85.39
Noble blade & sweep machine vs oneway plow	1	165.77	†165.77
Noble blade vs sweep machine	1	5.00	5.00

*Data significant at the 5% level.
†Data highly significant at the 1% level.

Summary and Recommendations

1. A subtiller constructed on the Amarillo station has been used with a high degree of success. It consists of five 30-inch Dempster sweeps mounted on a heavily reinforced carrier and is equipped with a power lift and rolling coulters.

2. An average of 2.6 bushels, or 21 percent more wheat per acre was obtained from the continuous wheat plots which were subtilled than was produced using the moldboard plow, and 1.9 bushels, or 14 percent more than when the oneway was used.

3. An increase of 2.8 bushels, or 15 percent, was recorded in favor of the subsurface sweep machine over the oneway in a wheat and fallow system.

4. Analysis of variance showed these differences on grain yields to be highly significant in favor of the subtilled plots.

5. The effects of stubble mulch tillage have been accumulative through the 7-year period of study, the improvement being due in part at least to an improved physical condition and a better moisture-fertility balance in the soil.

6. Data have been presented which would indicate that the stubble mulch system of tillage for winter wheat production on the silty clay loam soils of the Southern Great Plains can be used to accomplish its intended purpose of moisture conservation and erosion control without financial sacrifice by the farmer in reduced returns from the land.