

The Effect of Tillage Method on Soil and Moisture Conservation in the Plains Area of Northern Montana

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MONTANA STATE COLLEGE
AGRICULTURAL EXPERIMENT STATION
BOZEMAN, MONTANA

The Effect of Tillage Method on Soil and Moisture Conservation and on Yield and Quality of Spring Wheat in the Plains Area of Northern Montana

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INTRODUCTION

During the relatively short span of years that an appreciable part of Montana has been cultivated, soil erosion by wind and water has become a serious problem. Wind erosion on cultivated land became especially serious in the thirties over most of the dry land areas of the state. During this decade large acreages of seeded crops were completely destroyed by soil drifting, fence rows were covered, highway travel became hazardous, and in some areas soil was removed to a depth of several inches.

Strip cropping and cloddy mulches were among the earliest practices recommended for wind erosion control by the Montana Agricultural Experiment Station and the Montana Extension Service. During the thirties the Soil Conservation Service assisted in carrying out intensive conservation practices on demonstration projects and demonstration farms throughout the state. In 1939 a Soil Conservation Districts Law was passed by the Montana legislature. Districts created since that time are being assisted by State and Federal agencies in applying conservation practices to the land.

In 1939 the Montana Agricultural Experiment Station and the Soil Conservation Service entered into cooperative research on problems of crop production as related to soil and water conservation. Since fallowed lands presented the greatest erosion problem, it was determined that there was the greatest need for research relative to erosion control on these lands. In 1940 a study of tillage methods and methods of handling crop residues was started near Froid, and in 1941 a similar project was started at the North Montana Branch Station near Havre.

This bulletin is a summary of the information and data obtained on erosion control, moisture conservation, and crop production on these two projects. Also included is a discussion on methods and equipment used most satisfactorily in carrying out a system of stubble mulch summer fallow.

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TILLAGE INVESTIGATIONS AT FROID, MONTANA

This work was started in 1940 on 320 acres of land located 4 miles south and 1½ miles east of Froid, Montana.

Both wind and water erosion were severe problems in this vicinity. In the area selected, soil drifting has been greatly reduced through strip cropping. On fields where contour strip cropping has been established, water erosion has also been reduced. Wind erosion is still common on block fallow and fallow strips running east and west. Strips running north and south are more effective in localizing soil blowing, because westerly winds prevail.

SOIL AND CLIMATIC CONDITIONS

The land in this area is slightly rolling, and the soil type is chiefly a Lihen sandy loam. These soils are very susceptible to wind and water erosion because of the sandy surface soil. The subsoil is heavier than that found on the surface, and in general the soil type is capable of producing good yields when precipitation is adequate and favorably distributed.

The average annual precipitation for this locality is close to 13 inches.² At least half of this precipitation normally occurs during the months of May, June, and July.

The period from 1941 to 1947 was a favorable one for crop production in this area. Annual precipitation averaged only 12.63 inches, but 29 percent of this amount fell in June and 57 percent during the months of May, June, and July. No so-called "dry years" occurred during the years covered by this report.

Heavy rains, locally referred to as "cloudbursts", are not uncommon. These rains often cause a tremendous amount of soil-washing. Figures 4, 5, 6, and 7 on pages 8 and 9 show what happened on plots in this project on July 17, 1945, when 1.65 inches of rain fell in 15 minutes. Similar erosion occurred on July 17, 1946, when 2.4 inches of rain was recorded in an hour's time.

EXPERIMENTAL METHODS

Size and Arrangement of Plots

The plots used in this study were 3 acres in size, 10 rods wide, and 48 rods long. The plots were arranged with crop and fallow in alternating strips. Strips were laid out east and west in order to expose the plots to the greatest amount of wind erosion possible. Prevailing winds in the area are from the west and northwest.

²Martin, R. J., and Corbin, E., 1930 Climatic Summary of the United States, Section 10—Northeastern Montana, U. S. Department of Agriculture, Weather Bureau.

Treatments

Nine methods of fallow were compared in this project in an alternate crop fallow system. Treatments were run in duplicate and were as follows:

1. Continuous use of oneway	T
2. Moldboard plow followed by duck foot and waffle*	B
3. Moldboard plow followed by duck foot and waffle*	T
4. Moldboard plow followed by duck foot	T
5. Moldboard plow followed by rod weeder	T
6. Moldboard plow followed by basin lister	T
7. Continuous use of blade sub-surface cultivator	T
8. Continuous use of sweep sub-surface cultivator	T
9. Continuous use of sweep sub-surface cultivator	B

B=Stubble burned before first fallow operation

T=Stubble not burned

*The waffle machine leaves the surface in a pitted condition.

Three treatments involving two years of crop and one year of fallow were included in the study. During the fallow year all plots were tilled with a oneway disc, but three different procedures were followed in preparing the land for the second-year crop. One treatment consisted of sub-surface tilling immediately after combining, sub-surface tilling again in the spring, and then seeding in this sub-surface tilled stubble. The other two treatments consisted of spring plowing before seeding. In one case the stubble was plowed under, and in the other stubble was burned before plowing.

In order to compare the value of practices which have been used to some extent as a substitute for clean cultivated fallow, three cropping systems were studied in which there was no clean cultivated fallow. These cropping systems were alternate corn and wheat, alternate idle land and wheat, and alternate mowed idle land and wheat.

Collection of Data

Observations were made to determine which plots most effectively resisted wind and water erosion. Soil moisture determinations were made by sampling the soil to a depth of 5 feet at four locations on each plot. Samples were taken from the first 6 inches of soil and from the second 6 inches; the last 4 feet were sampled by foot depths. All samples were dried for 24 hours at 100 degrees C., and soil moisture was calculated on the basis of the dry soil weight. The yield per acre was determined by harvesting 12 (meter square) quadrats from each plot. The test weight and protein content of wheat produced has been determined each year for each treatment.

EXPERIMENTAL RESULTS

Effect of Tillage Method on Erosion Control

Wind erosion has not been particularly severe in the Froid area since the work reported in this bulletin was started. There has been a little soil movement due to wind nearly every year, and in some years there has been considerable soil blowing on some of the experimental plots. Land under all methods of fallow except sub-surface tillage has drifted some at one time or another. Not one of the sub-surface tilled plots, where the stubble was retained on the surface, has shown any evidence of wind erosion. The greatest amount of wind erosion occurred during the spring of 1948. Figures 1, 2, and 3 illustrate how effective stubble mulch fallow was in controlling soil drifting during that period.

Moldboard plowed fallow has shown the greatest tendency to drift. One-wayed fallow has been equally bad at times, but on the average it has been a little more resistant. If used too often and at excessive speeds, the one-way can set up conditions which are very favorable for wind erosion. The soils on the experimental farm are very easily pulverized, and clods are almost impossible to maintain during the fallow period. Where a "waffle"



FIGURE 1.—Stubble adjacent to fallow which was sub-surface tilled during 1947. No place was there evidence of soil drifting adjacent to stubble mulch. Photo taken May 21, 1948.



FIGURE 2.—Dust accumulation in stubble adjacent to fallow which was moldboard plowed during 1947 fallow season. Photo taken May 21, 1948.

Basins overtopped, causing dams between basins to break, and some were completely washed out. In many places soil was washed away to a depth considerably below the original depth of the basins. Figure 7 shows what happened to basin listing on a very slight slope during the storm of July 17,



FIGURE 3.—Dust accumulation in stubble adjacent to fallow which was onewayed during 1947 fallow season. Photo taken May 21, 1948.

pitting machine was used, following the duckfoot on ground previously plowed, wind erosion appeared to be increased due to the additional pulverization.

Torrential rains are not uncommon in northeastern Montana. Several heavy downpours have occurred during the past 8 years. On July 17, 1945, 1.65 inches of precipitation was recorded in 15 minutes, and on July 17, 1946, 2.4 inches of rain fell in an hour's time. Gullying and sheet erosion were severe. During both storms the greatest damage occurred on basin-listed fallow.



FIGURE 4.—Erosion caused by runoff from cropped land during rain of July 17, 1945, when 1.65 inches of rain fell in 15 minutes.



FIGURE 5.—Erosion caused by runoff from moldboard plowed fallow during same rain described in figure 4.



FIGURE 6.—Erosion caused by runoff from stubble mulch fallow during rain described in figure 4. While stubble mulch fallow did not prevent erosion under these conditions, it was less severe on this type of fallow than on any other type included in this project.



FIGURE 7.—Erosion caused by runoff from basin listed fallow during rain described in figure 4. This illustrates the danger of basin listing unless it is done on the contour or relatively level land. Overtopping of one basin causes basins on down the slope to break.

1945. Figures 4, 5, and 6 show erosion which resulted from this same storm on crop land and on fallow which was moldboard plowed and sub-surface tilled.

It is not unusual in this area to have soil extensively gullied to the depth of cultivation. Onewayed fallow and sub-surface tilled fallow have developed shallower gullies than moldboard plowed fallow, because cultivation is not as deep. This type of fallow has also shown more resistance to sheet erosion. Soil removal has been the least from sub-surface tilled plots, but no method of fallow has completely resisted some of the downpours which have occurred.

Effect of Tillage Method on Moisture Conservation

Soil moisture in fallow at seeding time has not varied a great deal because of tillage method, as is shown by the data in table 1. No one fallow method has been consistently high, and none has been consistently low. All plots were kept about equally clean and were cultivated whenever necessary for weed control. Sub-surface tilled fallow with stubble left on the surface has averaged 13.6 percent of soil moisture per foot to a depth of 5 feet; sub-surface tilled fallow on which stubble was burned prior to cultivation has averaged 13.1 percent. Moldboard plowed fallow on which stubble was plowed under has averaged 13.1 percent, and moldboard plowed fallow on which stubble was burned prior to plowing has averaged 14.1 percent. Onewayed fallow has had an

TABLE 1.—Average percent of moisture to a depth of 5 feet of soil in summer fallow at seeding time during years 1941 through 1947 and an average of the 7 years at Froid, Montana; samples taken from 4 locations on each plot, plots run in duplicate

Fallow method	Percent soil moisture by years								Avg.
	1941	1942	1943	1944	1945	1946	1947		
Sweep S. S. tiller	B	12.4	12.0	13.7	12.9	14.4	13.5	12.5	13.1
Sweep S. S. tiller	T	13.3	11.9	15.5	13.3	13.4	15.1	13.0	13.6
Blade S. S. tiller	T	12.3	12.5	14.8	11.6	14.8	14.4	15.0	13.6
M. B. plow, D.F., & W.	B	11.6	13.3	16.3	13.9	15.1	14.8	13.9	14.1
M. B. plow, D.F. & W.	T	12.3	11.3	14.9	12.4	14.1	11.7	13.7	12.9
M. B. plow, D.F.	T	11.9	11.3	15.6	12.8	12.9	12.2	13.8	12.9
M. B. plow, R.W.	T	12.3	10.2	15.1	11.4	16.0	12.5	14.2	13.1
M. B. plow, B.L.	T	12.2	11.7	14.8	14.1	13.1	13.7	13.7	13.3
Oneway	T	11.4	12.1	14.1	11.9	13.2	13.9	14.1	13.0
								Average	13.3

S.S. = Sub-surface
 D.F. = Duckfoot
 W. = Waffle
 R.W. = Rod weeder
 B.L. = Basin lister

B = Stubble burned
 T = Stubble not burned

average of 13.0 percent soil moisture for the same period. These figures indicate that plowing under large amounts of stubble may result in a little more moisture being lost because of evaporation. There is also an indication that with sub-surface tillage there is an advantage in leaving the stubble on the surface rather than burning it. These differences in soil moisture have apparently not been too important, because they have not been reflected in the yields of wheat.

There has been some question as to whether or not soil moisture is more favorable in the first foot of soil in stubble mulch fallow than in summer fallow which was plowed. Samplings have indicated a slight difference in favor of stubble mulch fallow. During the period 1942 through 1947, stubble mulch fallow averaged 12.2 percent moisture in the first foot, and fallow with stubble plowed under averaged 11.6 percent.

The average percent of soil moisture in all cultivated fallow for the seven-year period was 13.3 percent. Soil moisture samples taken from stubble land for the same period have averaged 11.9 percent moisture per foot.

Data in table 2 indicate that stubble land which was sub-surface tilled immediately after harvest has had no more soil moisture the following spring than undisturbed stubble.

TABLE 2.—Average percent of soil moisture to a depth of 5 feet in stubble land which was sub-surface tilled immediately after harvest and stubble which was not tilled; moisture samples taken in the spring of the year at seeding time during the period 1941 through 1947 at Froid, Montana

	Percent soil moisture by years							Average
	1941	1942	1943	1944	1945	1946	1947	
Stubble (fall tilled)	8.9	12.4	12.3	10.7	13.8	11.5	13.7	11.9
Stubble (not tilled)	9.6	13.1	11.9	10.6	13.4	12.9	12.1	11.9

Stubble from which the samples in the above table were taken was generally fairly clean. During years when a heavy weed growth is present at harvest time, there might be more advantage to fall tillage than these results indicate, particularly if there was considerable fall precipitation. Sub-surface tilling of stubble disturbs the stubble less than any other tillage method, but observations have been that stubble which is sub-surface tilled in the fall holds less snow than untilled stubble. The fact that fall worked stubble may hold less snow should be considered a disadvantage of fall cultivation.

The gain in soil moisture from the fall of the year to the following spring under different field conditions is shown in table 3. It has been quite generally assumed that moisture from

melting snow contributes very little to soil moisture. Data in table 3 offer good evidence that snow accumulations have been important in this respect on this project. Short corn stubble has gained only 0.5 percent in soil moisture to a depth of 5 feet, whereas idle land with tall weeds standing over winter has gained 3.6 percent in soil moisture from fall to spring.

TABLE 3.—Average percent soil moisture in cultivated fallow, wheat stubble, corn ground, and idle land in the fall and succeeding spring; fall samples taken during years 1940-1946 inclusive, spring samples taken during years 1941-1947 inclusive at Froid, Montana

Treatment	Average percent moisture per foot, fall	Average percent moisture per foot, spring	Percent gain per foot fall to spring
All cultivated fallow	13.3	13.3	0.0
Corn ground	10.6	11.1	0.5
Idle land	7.9	11.5	3.6
Idle (weeds mowed)	9.0	11.0	2.0
Stubble (fall tilled)	9.8	11.9	2.1
Stubble (not tilled)	9.3	11.9	2.6

The soil moisture percentages given in table 3 are averages of soil samples taken to a depth of 5 feet. Fall samples were taken around October 1, and spring samples were taken at seeding time.

It is apparent that the mowing of weeds on idle fallow resulted in less moisture being consumed by weeds during the growing season than if the weeds were not mowed. At seeding time, however, the unmowed idle fallow contained more moisture than the idle fallow which was mowed. The stubble on the corn plots was generally short, the result being that little snow was held on the plots, and the gain in soil moisture from fall to spring was correspondingly low.

Effect of Tillage Method on Yield of Spring Wheat

The yearly and average yields of spring wheat grown on land prepared by the different methods of fallow and fallow substitutes are given in table 4. Yields of spring wheat on fallow were not greatly affected by tillage method used. All moldboard plowed fallow averaged 29.2 bushels per acre. All sub-surface tilled fallow averaged 28.4 bushels and oneway fallow 27.9 bushels per acre. Clean cultivated fallow has consistently outyielded idle fallow and corn ground. Wheat after idle fallow has averaged 20.9 bushels and wheat after corn 21.5 bushels. More favorable results might have been obtained with wheat after corn had the corn been cut green as fodder. Corn in this project was not harvested until after growth had stopped because of frost. The corn was

not hoed but was cultivated on the average of three times each summer. Considerable weed competition was present in some years, but generally the corn was as free of weeds as the average corn grown in the area.

TABLE 4.—Yield of spring wheat in bushels per acre following various methods of fallow and cropping practices at Froid, Montana

Treatment	Yields in bushels per acre by years						
	1941	1942	1943	1944	*1946	1947	Average
	Fallow substitutes						
Idle	B 25.8	23.9	24.2	17.0	15.1	18.0	20.7
Idle (weeds mowed)	T 23.4	22.2	24.3	21.7	17.2	17.0	21.0
Average all idle	24.6	23.1	24.3	19.4	16.2	17.5	20.9
Corn ground	25.6	22.8	23.5	23.6	16.9	16.4	21.5
	Methods of fallow						
Oneway	T 31.9	33.1	26.3	29.2	22.9	24.0	27.9
M.B. plow, D.F., & waffle	B 31.7	30.1	33.0	27.7	21.8	26.8	28.5
M.B. plow, D.F., & waffle	T 33.5	31.1	32.7	24.2	24.3	27.3	28.9
M.B. plow, D.F.	T 33.2	32.3	31.2	27.2	24.0	28.4	29.4
M.B. plow, R.W.	T 36.6	32.5	31.0	32.0	25.1	27.0	30.7
M.B. plow, B.L.	T 33.5	30.3	29.6	27.6	22.8	26.0	28.3
Average all moldboard	33.7	31.3	31.5	27.7	23.6	27.1	29.2
Blade S. S. cultivator	T 35.6	28.3	28.9	25.5	20.8	27.1	27.7
Sweep S. S. cultivator	T 33.6	31.4	30.4	27.6	23.4	28.7	29.2
Sweep S. S. cultivator	B 33.9	30.3	31.7	27.3	21.1	25.9	28.4
Average all sub-surface	34.4	30.0	30.3	26.8	21.8	27.2	28.4
Average all fallow							28.8

*1945 data not used due to damage from wind, hail, and sawfly.

M.B. = Moldboard
 S.S. = Sub-surface
 D.F. = Duckfoot
 R.W. = Rod weeder
 B.L. = Basin lister

B = Stubble burned
 T = Stubble not burned

Some question exists among farmers as to how long sub-surface tillage can be continued on a particular field without plowing or doing some deep tillage. Yields obtained from sub-surface tilled fallow in 1947 were fully as high as from other types of fallow, as shown in table 4. This land had not been plowed since 1939, sub-surface tillers being used exclusively every fallow season. These results indicate that on a Lihen sandy loam no reduction in yield is apt to result from shallow cultivation over a period of 8 years. The plots which had been continuously sub-surface tilled

since 1939 revealed no so-called hard pan or plow sole. When plots were observed in a dry condition, the soil was harder close to the surface on the sub-surface tilled plots than on the plots which were plowed; this hardness disappeared as soon as the soil became wet.

Fallow in a two-year crop, one-year fallow rotation has produced as much wheat per acre as fallow in an alternate crop fallow system. Onewayed fallow after two years of crop has averaged 28.8 bushels per acre, and all fallow in an alternate crop fallow system has also averaged 28.8 bushels (see tables 4 and 5). Data presented in table 5 show that spring plowing for the second year crop after fallow has out-yielded sub-surface tillage as a preparation for the second year crop. Poorer stands and weedier grain resulted on the sub-surface tilled stubble than where the stubble was plowed under. The drill used for seeding in the sub-surface tilled stubble was not suitable for this purpose in that much of the time it did not get the seed into a satisfactory seed bed. This added to the advantage of spring plowing.

Burning of stubble prior to spring plowing where wheat followed wheat resulted in an average yield of 25.4 bushels per acre as compared with 24.1 bushels where the stubble was plowed under. Stubble was quite heavy during the period of years included in this study and no doubt caused some drying



FIGURE 8.—Trash guard attached in front of colter. This attachment is helpful when working in heavy stubble or trash.

of the soil and a poorer seed bed when plowed under. The detrimental effects of destroying organic matter by burning stubble has not had an opportunity to become fully evident during this short period of time.

When plowing in heavy stubble, a plow often becomes clogged. In order to avoid this difficulty, farmers often resort to burning their stubble. The trouble from clogging can be greatly reduced by attaching a trash guard in front of the plow colters as shown in figure 8.

TABLE 5.—Yield of spring wheat in bushels per acre in a two year crop, one year fallow system for the period 1941 through 1947* at Froid, Montana

Treatment	Yield of spring wheat by years						Average
	1941	1942	1943	1944	* 1946	1947	
**1st crop R-1	T 32.0	30.1	33.0	35.5	19.9	24.9	29.2
**1st crop R-2	T 30.7	30.0	30.7	35.4	22.3	23.6	28.8
**1st crop R-3	T 32.6	25.6	34.4	33.9	20.8	23.5	28.5
Average 1st year crop	31.8	28.6	32.7	34.9	21.0	24.0	28.8
***2nd crop R-1	T 23.4	30.0	28.0	28.5	15.6	19.1	24.1
***2nd crop R-2	B 25.5	33.7	30.4	26.3	16.4	20.2	25.4
***2nd crop R-3	T 17.1	26.2	25.7	24.7	11.8	18.0	20.6
Average 2nd year crop	22.0	30.0	28.0	26.5	14.6	19.1	23.4

* 1945 data not used due to crop damage from wind, hail, and sawfly.

** All first year crop after fallow was grown on fallow which was worked with a oneway.

***Second year crop after fallow.

R-1 = Stubble plowed under in spring before seeding.

R-2 = Stubble burned, then spring plowed before seeding.

R-3 = Sub-tilled immediately after removal of first year crop after fallow, then sub-tilled again in spring before seeding.

During the rather favorable seven-year period in which these data were gathered, the average yield of all second-year crop after fallow on spring plowing was 24.8 bushels per acre (table 5, R-1 and R-2). The average yield per acre on fallow in a crop fallow system was 28.8 bushels (table 4). This may raise the question as to whether or not the alternate crop fallow system is the most profitable in this area. It must be remembered that this differential relationship will not always hold true: soil type and climatic conditions will vary. It should also be remembered that these results were obtained over a relatively short period of time and that no dry years occurred during the period. It is true, however, that the soils in this area are relatively light and are consequently not as well suited to the alternate crop fallow system

as are the heavier soil types. The soil type, coupled with favorable seasonal precipitation during the experimental period, probably accounts for the fact that wheat after fallow has not shown a greater advantage.

On the basis of yields obtained during this period, the two-year crop, one-year fallow system has produced more grain than the alternate crop fallow system. Over a period of six years the alternate crop fallow system has produced three crops and the two-year crop, one-year fallow system has produced four crops. In the alternate crop fallow system, all crops were after fallow, and in the two-year crop, one-year fallow system, two crops were after fallow and two were on land in second-year crop. Three crops on fallow (in an alternate crop fallow system) have produced 86.4 bushels on six acres of land. Two crops on fallow plus two crops following wheat (in a two-year crop, one-year fallow system) have produced 107.2 bushels on six acres. This is an advantage of 20.8 bushels for the two-year crop, one-year fallow system.

There are of course other factors to consider besides the total bushels of wheat produced. Cost, labor distribution, timely operation, percentage of crop failures, and weed control are other important considerations. The cost involved with the two systems will vary with operators but will generally be less with the alternate crop fallow system. The alternate crop fallow system also favors seeding at the most opportune time. Second-year crop is generally put in on spring plowing or onewaying. In cases where the land preparation for second-year crop extends the seeding operation considerably, this is a disadvantage. Investigations at the North Montana Branch Station near Havre suggest that the proper time to seed spring wheat on fallow is during the last two weeks in April.³ Seeding after the first week in May has resulted in reduced yields because of lateness of seeding, and heavier weed infestations have been present in the grain crop when seeding was done early in April. The use of selective sprays for weed control may overcome the weed problem which has been encountered in connection with early seeding during years past. When the two-year crop, one-year fallow system is used, there is a greater tendency for wild oats and other weeds to build up than there is with the alternate crop fallow system. The two-year crop, one-year fallow system has the advantage of reducing the amount of fallow. This is desirable from an erosion control standpoint, because fallow land presents the greatest erosion problem in Montana.

³Bell, M. A., *The Effect of Tillage Method, Crop Sequence, etc.*, Montana Agricultural Experiment Station Bulletin 336, 1937.

A corn-wheat rotation has the advantage of leaving the ground bare for a relatively short period of time. This helps minimize the dangers from wind erosion and also helps control water erosion if the crops are grown on the contour.

Corn grown up and down hill has a tendency to lead the water off the land in a hurry because of the concentration of water in furrows between corn rows.

Wheat after corn has averaged 21.5 bushels per acre (see table 4). This is approximately 75 percent of wheat grown after fallow. In calculating production from a corn-wheat rotation, however, the corn produced must also be taken into consideration. Falconer is the variety of corn which has been grown, and the average yield of shelled corn has been 24.8 bushels per acre. The total weight of stover and ear corn produced per acre has averaged 4094 pounds. The corn has not generally been well matured and would as a rule cause a storage problem if it were cribbed. However, if it were hogged off, grazed off, or cut for fodder, it would furnish a lot of feed. The value of the corn crop would vary with the method of utilization.

Under conditions which have existed during the time these data were collected, the corn-wheat rotation has produced more pounds of corn and wheat combined than has been produced by wheat alone either in a crop fallow or in a two-year crop, one-year fallow system. The alternate crop fallow system has the advantage of reducing the percentage of years of crop failure, and the introduction of corn into the cropping system has the disadvantage of requiring additional machinery and labor to take care of that crop.

Effect of Tillage Method on Straw-Grain Ratio

The ratio of grain to straw has been approximately the same from all methods of fallow in the crop fallow system (see table 6). More straw was produced per pound of grain in the fallow following two years of crop than in any other treatment. Fallow consistently produced more straw per pound of grain than idle land, corn land, or land where wheat followed wheat.

Table 6 is a short summary of the relationship between straw and grain produced following different cropping sequences and methods of fallow.

The fact that fallow produces relatively more straw than it does wheat is important from the standpoint of dry land production of small grains for hay. It is generally true that farmers grow small grains for hay on land which was not in fallow the previous year. When the alternate crop fallow system is deviated from, and grain hays such as oats, barley, and rye enter the

cropping program, then the largest returns will usually result if the small grain hays are grown on fallow and wheat is seeded on cropped land normally seeded to grain hay.

TABLE 6.—Pounds of straw per 100 pounds of spring wheat produced by various methods of fallow and cropping practices during the period 1941 through 1947* at Froid, Montana

Treatment	Pounds of straw	Pounds of grain
Methods of fallow		
Alternate wheat and fallow system		
Oneway	181	100
Moldboard plow	182	100
Sub-tillage	178	100
Two-year wheat, one-year fallow system		
1st year crop	195	100
2nd year crop	154	100
Idle wheat and corn-wheat rotation		
Idle	156	100
Corn	161	100

*1945 data not included due to wind, hail, and sawfly damage.

Effect of Tillage Method on Quality of Spring Wheat

Table 7 gives detailed information on test weight and protein content of wheat produced by various tillage and cropping practices. The protein content of wheat produced on black top fallow has been higher than that produced on fallow where the crop residues were left on the surface. Wheat grown on sub-surface tilled fallow on which the stubble was burned before tillage operations were started has averaged 1.3 percent more protein than wheat grown on sub-surface tilled fallow where the stubble was not burned. Moldboard plowed fallow produced wheat having an average of 14.9 percent protein and wheat produced on fallow with a stubble mulch has averaged 14.0 percent. This difference in protein content of wheat under the two methods of residue utilization is probably due to the nitrogen requirement of organisms while breaking down the organic matter.

Wheat after corn has averaged 12.2 percent protein, wheat after idle land 12.4 percent, and wheat after wheat in a two-year crop, one-year fallow system 13.7 percent. The average protein content of wheat grown on all fallow is 14.9 percent.

Test weight of wheat has been very nearly the same on all types of fallow in the alternate crop fallow system. Wheat on fallow in the two-year crop, one-year fallow system has averaged slightly lighter in weight than wheat produced in the crop fallow system. Wheat after corn and after idle land has had the highest average test weight. Wheat after corn or after idle land matured several days earlier than wheat on fallow.

TABLE 7.—Yields of grain and straw, test weight per bushel, percent protein of spring wheat produced, and percent moisture per foot of soil at seeding time; averages of various tillage and cropping practices conducted at Froid, Montana, during the years 1941 through 1947*

Treatment	Bushels grain per acre	Pounds straw per acre	Test weight per bu.	Percent protein **	Percent moisture per foot ***
Methods of fallow					
Alternate crop and fallow system					
Oneway	B 27.9	3023	58.9	14.9	13.0
M.B. plow, D.F., & W.	B 28.5	3085	59.5	15.0	14.1
M.B. plow, D.F., & W.	T 28.9	3186	59.1	15.1	12.9
M.B. plow, D.F.	T 29.4	3223	59.3	14.8	12.9
M.B. plow, R.W.	T 30.7	3227	58.9	14.9	13.2
M.B. plow, B.L.	T 28.3	3222	59.2	14.8	13.3
Average all moldboard	29.2	3189	59.2	14.9	13.3
Noble cultivator	T 27.7	2987	59.5	14.1	13.6
Chase cultivator	T 29.2	3023	59.4	13.9	13.6
Chase cultivator	B 28.4	3104	59.1	15.3	13.1
Average all sub-surface	28.4	3038	59.3	14.4	13.4
Average all methods of fallow	28.8	3120	59.2	14.8	13.3
Two-year crop, one-year fallow system					
1st crop R-1	T 29.2	3315	58.0	15.1	
1st crop R-2	T 28.8	3432	57.8	15.4	
1st crop R-3	T 28.5	3381	58.0	15.3	
Average 1st year crop	28.8	3376	57.9	15.3	
2nd crop R-1	T 24.1	2116	59.3	13.6	11.9
2nd crop R-2	B 25.4	2272	58.6	13.9	
2nd crop R-3	T 20.6	2101	59.3	13.7	11.9
Average 2nd year crop	23.4	2163	59.1	13.7	11.9
Idle-wheat and corn-wheat rotation					
Idle	B 20.7	1882	60.1	12.2	11.5
Idle (weeds mowed)	T 21.0	2017	59.8	12.6	11.0
Average all idle	20.9	1950	60.0	12.4	11.3
Corn ground	21.5	2081	59.9	12.2	11.1

* Grain and straw yields for 1945 not included due to damage from wind, hail, and sawfly.

**Protein N x 5.7 on a basis 13.5 percent moisture in the grain.

***Soil moisture average of five-foot depths.

B = Stubble burned.

T = Stubble not burned.

R-1 = Stubble plowed under in the spring in preparation for second year crop after fallow.

R-2 = Stubble burned and then spring plowed in preparation for second year crop after fallow.

R-3 = Stubble sub-surface tilled immediately after harvest and again in spring in preparation for second year crop after fallow.

Effect of Tillage and Cropping Method on Weed Control

More difficulty has been experienced in controlling shallow-rooted weeds on sub-surface tilled fallow than on fallow worked with a oneway or moldboard plow. Tap rooted weeds were quite easily killed with certain sub-surface tillers, but the surface feeders and small weeds were more difficult to kill. The weeds which have been the hardest to control with sub-surface tillage are green foxtail (*Setaria viridis*), wild buckwheat (*Polygonum convulvulus*), and small Russian thistle (*Salsola pestifer*). A straight shearing sweep has not done a good job of killing these weeds. A blunt sweep or a sweep with considerable pitch has done a much better job because of the greater stirring of the soil. A rod weeder has been used quite satisfactorily in working sub-surface tilled fallow; this implement stirs the surface soil more than most sweep type cultivators. Most effective weed kills have been obtained with sub-surface tillers when they were pulled at a fair rate of speed. A speed of five miles per hour seems to be satisfactory under most conditions.

During some years weeds have been a little more prevalent in grain grown on sub-surface tilled and onewayed fallow than on fallow which was moldboard plowed, but this has not always been the case. During one year, plowed fallow was heavily infested with lamb's quarters, while sub-surface tilled and onewayed fallow was relatively clean.

The practice of allowing land to lie idle during the fallow season has resulted in wild oats (*Avena fatua*) appearing in increasing numbers in the grain. Where idle land was mowed, however, wild oats were kept under control. Blue lettuce (*Lactuca pulchella*) has increased on land in a wheat idle rotation but has been effectively controlled in the fallow wheat system.

Green foxtail has been difficult to control in corn. This has resulted in a considerable infestation of this weed in grain grown on disked corn ground.

SUMMARY OF WORK AT FROID

Erosion Control

1. Leaving crop residues on the surface has reduced wind and water erosion.
2. Basin listing when not on the level has resulted in severe washing during heavy rains.

Moisture Conservation

1. There has been very little difference in the amount of moisture conserved in the soil by different methods of fallow.

2. Sub-surface tilled fallow where stubble was left on the surface has contained more moisture than sub-surface tilled fallow where the stubble was burned.
3. Plowed fallow where stubble was burned has contained more moisture than fallow where stubble was plowed under.
4. Mowing of weeds on idle land has conserved more moisture during the growing season than allowing weeds to grow. The unmowed idle land, however, has held more snow over winter and has contained more moisture at the time of seeding spring wheat than the mowed land.
5. Soil moisture in fallow has changed very little from fall to spring.
6. Snow has added considerably to soil moisture in idle and stubble land.
7. Corn ground has averaged considerably and consistently less soil moisture at seeding time than fallow.
8. Sub-surface tillage of stubble immediately after harvest has not resulted in an increase in soil moisture the following spring.

Crop Yield

1. Yields of spring wheat have been about the same on all methods of fallow.
2. Burning of stubble has not affected crop yield in either plowed or sub-surface tilled fallow.
3. Spring plowing of land which was allowed to lie idle the previous year has averaged 73 percent of the yield of wheat on fallow.
4. Spring plowing with wheat as a previous crop, in a two-year crop, one-year fallow system has averaged 86 percent of the yield of wheat on fallow.
5. In a corn wheat rotation wheat on disked corn ground has averaged 75 percent of the yield of wheat on fallow.
6. Fallow when compared with continuous cropping has produced relatively more straw than grain.
7. Two crops of wheat and one year of fallow has produced more wheat over the period of this study than alternate crop and fallow.
8. Alternate corn and wheat has produced more total grain of wheat and corn combined than alternate crop and fallow has produced of wheat alone.

Quality of Grain

1. Protein content of spring wheat has averaged higher on black top fallow than it has on stubble mulch fallow.
2. Test weight of wheat has been about the same on all methods of fallow in a crop fallow system.
3. Protein content of wheat grown after corn or after idle land has been considerably lower than that of wheat grown on fallow.

Weed Control

1. More difficulty has been experienced in killing shallow-rooted weeds with a sub-surface tiller than with a oneway disk or moldboard plow.
2. Sub-surface tillers which stir the soil as they move along have been more effective in killing weeds than tillers with flat sweeps which cause very little soil disturbance.

TILLAGE INVESTIGATIONS AT THE NORTH MONTANA BRANCH STATION, HAVRE, MONTANA

The work at the North Montana Branch Station started in 1941. The objectives of this project were to determine the desirability of various tillage practices and the best means of handling crop residues for soil and water conservation.

Wind erosion on fallow has been severe at times in this area and, as a result, strip cropping has become a popular practice. A good deal of block farming, however, is still being carried on. The danger involved in block fallow was clearly demonstrated again in the spring of 1948 when several days of high wind caused considerable soil drifting (see figure 10). The strip cropped fields did not always prevent soil movement, but where fallow in strips did blow it was very much more localized than on block fallow. As usual, strips running north and south were more effective than strips running east and west, because the prevailing winds are from the southwest.*

SOIL AND CLIMATIC CONDITIONS

The area used in this project slopes slightly toward the north. The soil type is classified as a Joplin loam and has a water holding capacity which makes it well suited to the summer fallow system. Clods are generally easily formed and are helpful in erosion control. However, unless care is used in the selection of tillage implements these clods may not be formed or may be broken up.

*Martin, R. J., and Corbin, E., 1930 Climatic Summary of the United States, Section 8—North Central Montana, U. S. Department of Agriculture Weather Bureau.



FIGURE 9.—Aerial view of buildings at North Montana Branch Station, Havre, Montana. Plots used in this work are in the background.

According to weather records kept at the North Montana Branch Station, the average annual precipitation for the past 32 years is 11.59 inches. The period covered in this report, 1941 through 1947, had an average annual precipitation of 11.29 inches. The precipitation during 1941 and 1942 was above the 32-year average, but each year since 1942 has been below the 32-year average. June is normally the month of highest rainfall. The average precipitation for the month of June for the period 1941 through 1947 was 3.33 inches; this was 29.5 percent of the average annual precipitation for the seven-year period. The average total precipitation for the months of May, June, and July for this period was 5.64 inches, which was 50 percent of the average annual precipitation.

Torrential rains are not common in this locality, and none occurred during the 1941-1947 period.

EXPERIMENTAL METHODS

All work in this project was on a crop fallow basis. Seventy-two plots, each forty-four hundredths of an acre in size, were used. These plots were 173 feet long, 111 feet wide, and were arranged in six strips running north and south with crop and fallow in alternate strips. All treatments were run in triplicate, one complete replication being included in each strip with treatments completely randomized. Three types of tillage implements were used. One type completely buried crop residues, one mixed them

with the surface soil, and the other left them on the surface. Two methods were used for each type of tillage, and all treatments were run on both burned and unburned stubble. Table 8 lists the treatments which were used.

TABLE 8.—*Methods of fallow included in the cooperative tillage and crop residue management project at the North Montana Branch Station, Havre, Montana*

Treatments	Stubble burned or unburned
Crop residues left on surface	
1. Blade S.S. tiller	T
2. Blade S.S. tiller	B
3. Sweep S.S. tiller	T
4. Sweep S.S. tiller	B
Crop residues incorporated with surface soil	
1. Oneway	T
2. Oneway	B
3. Moldboardless plow	T
4. Moldboardless plow	B
Crop residues turned under	
1. Moldboard plow and duckfoot	T
2. Moldboard plow and duckfoot	B
3. Moldboard plow and rod weeder	T
4. Moldboard plow and rod weeder	B

S.S. = Sub-surface tiller
 T = Stubble not burned
 B = Stubble burned

Soil moisture determinations were made in the fall and spring at four locations on each plot. These samples were taken to a depth of five feet. Samples were taken from the first six inches of soil and from the second six inches; the last four feet were sampled by foot depths. All samples were dried for 24 hours at 100° C., and soil moisture was calculated on a percentage basis of the dry soil weight.

The yield per acre was determined by harvesting 12 (meter square) quadrats per acre. During two years the plots were combined individually after the quadrats had been harvested and the yields obtained by the quadrat method were checked against the total plot yields.

Test weight and protein content of wheat produced on each soil treatment were determined each year.

Whenever possible the stubble burning was done with a running fire. During years when the stubble was too light to be burned in this way, it was bunched and burned.

EXPERIMENTAL RESULTS

Effect of Tillage Method on Erosion Control

There has not been enough runoff from the area in this project to be of any value in determining the resistance of various methods of fallow to water erosion. About the only runoff has been from melting snow, and this has been in quantities too small to cause damage.

Soil drifting has not had much opportunity to occur. The fallow strips are only slightly over 10 rods in width, and they run in a north-south direction. In addition to this, a fair cloddy mulch has been present on most of the plots during periods of high wind velocity.



FIGURE 10.—Accumulation of drifted soil in fence row and borrow pit adjacent to fallow field. Photo taken 12 miles northwest of Havre, Montana, after high winds which occurred during the spring of 1948.

EFFECT OF TILLAGE METHOD ON MOISTURE CONSERVATION

The amount of soil moisture in the different methods of fallow at the time of seeding spring wheat is given in table 9. The amount of moisture present in fallow land at seeding time has been the greatest on fallow cultivated with a blade type sub-surface tiller. The fallow cultivated with a sweep-type, sub-surface tiller has contained about the same amount of moisture as fallow which was plowed or worked with a oneway. Better weed control was generally maintained with the blade-type, sub-surface tiller than with the sweep machine, and this is probably the chief reason for the difference in soil moisture between these two treatments.

Plots on which stubble was burned have a slightly higher average soil moisture content than plots on which the stubble

was not burned. This is probably due to several reasons. First of all, there has been practically no runoff on any of the plots, so there has been no chance for more water to be absorbed on one type of fallow than on another. Better weed control was maintained on some methods of fallow where the stubble was burned, and no doubt this was a factor on treatments cultivated with the moldboardless plow and sweep type sub-surface tiller. Where stubble is plowed under, it encourages drying of the soil because of the increased aeration. Stubble on the surface absorbs a certain amount of moisture during every rain, and this is lost through evaporation and has no chance to add to the moisture in the soil.

TABLE 9.—Average percent of moisture to a depth of five feet in different methods of fallow for the period 1943 through 1947 at the North Montana Branch Station, Havre, Montana; determinations were made during the spring of the year at seeding time

Tillage method	Stubble not burned	Stubble burned
	%	%
Blade S. S. tiller	13.3	13.5
Sweep S. S. tiller	12.2	12.8
Oneway	12.6	12.9
Moldboardless plow	11.9	12.9
Moldboard plow — D.F.	12.3	12.7
Moldboard plow — R.W.	11.8	12.4

D.F. = Duckfoot
R.W. = Rod weeder

When the soil moisture in all methods of fallow was averaged, the second 6 inches of soil averaged the highest in percentage of moisture; samples taken at this depth have averaged about 2 percent higher than the first 6 inches and approximately 1 percent higher than the second foot. The third, fourth, and fifth foot have averaged about the same in soil moisture content; at these depths soil moisture has averaged 2.5 percent below that of the second foot (see table 10).

TABLE 10.—Average percent of soil moisture in all fallow at various depths during period 1943 through 1947, North Montana Branch Station, Havre, Montana; samplings were made in the spring of the year at seeding time

Depth of sample	Stubble burned	Stubble not burned
	%	%
1st 6 inches	13.3	12.7
2nd 6 inches	15.2	14.8
2nd foot	14.3	13.9
3rd foot	11.9	11.5
4th foot	12.0	11.2
5th foot	11.8	11.3

Effect of Tillage Method on Yield of Spring Wheat

Yield data summarized in table 11 show that yields have been very similar on all methods of fallow used.

TABLE 11.—Yield of spring wheat in bushels per acre produced by various methods of fallow during period 1943 through 1947 at the North Montana Branch Station, Havre, Montana

Method of fallow	Yield of spring wheat by years					Average
	1943	1944	1945	1946	1947	
	Stubble not burned					
Blade S.S. tiller	28.8	27.2	15.6	15.2	15.8	20.5
Sweep S.S. tiller	29.2	25.7	14.7	13.9	14.1	19.5
Average	29.0	26.5	15.2	14.6	15.0	20.0
Oneway	25.1	26.7	13.1	18.0	14.0	19.4
Moldboardless plow	26.4	25.5	11.9	13.0	14.3	18.2
Average	25.8	26.1	12.5	15.5	14.2	18.8
Moldboard plow, D.F.	27.5	26.6	13.0	13.8	14.6	19.1
Moldboard plow, R.W.	26.3	24.6	13.5	14.8	15.9	19.0
Average	26.9	25.6	13.3	14.3	15.3	19.1
Average all unburned plots						19.3
	Stubble burned					
Blade S.S. tiller	26.0	26.4	13.7	16.3	13.8	19.2
Sweep S.S. tiller	27.2	25.5	14.8	15.5	14.4	19.5
Average	26.6	26.0	14.3	15.9	14.1	19.4
Oneway	25.4	26.3	14.2	17.1	14.8	19.6
Moldboardless plow	24.1	30.0	11.8	15.6	14.0	19.1
Average	24.8	28.2	13.0	16.4	14.4	19.4
Moldboard plow, D.F.	27.7	24.5	13.5	15.0	16.1	19.4
Moldboard plow, R.W.	28.3	24.2	13.5	15.0	15.4	19.3
Average	28.0	24.4	13.5	15.0	15.8	19.4
Average all burned plots						19.4

D.F. = Duckfoot
 R.W. = Rod weeder
 S.S. = Sub-surface

The trend toward more soil moisture in the plots where the stubble was burned has not always been reflected in higher yields. The average yield of all burned plots is practically the same as for plots on which the stubble was not burned.

Effect of Tillage Method on Quality of Spring Wheat

Test weight and protein content of wheat produced on the various methods of fallow are given in table 12. Protein content of wheat has averaged the highest on moldboard plowed fallow. The burning of stubble has generally resulted in an increase in

protein content also, but the difference due to burning has not been as great as that due to tillage. This is contrary to data obtained at Froid. At Froid the wheat with the highest protein content in a crop fallow system was obtained from sub-surface tilled fallow where the stubble had been burned, while the lowest protein wheat was obtained on sub-surface tilled fallow with the stubble on the surface. The presence of stubble on the surface affected protein more than the tillage method at that location. Because of lower yields at Havre, the drain on nitrates in the soil has not been as great and differences in protein content of wheat are not as great as they have been at Froid. More straw has also been present at Froid which would tend to create larger differences.

The test weight of wheat has been about the same on all fallow methods.

TABLE 12.—Yield of grain and straw per acre, test weight and protein content of wheat produced, and percent of soil moisture at seeding time; average for period 1943 through 1947—North Montana Branch Station, Havre, Montana

Method of fallow	Grain yield (Bu.)	Straw yield (Lbs.)	Test weight (Lbs.)	Percent protein	Percent moisture per foot
	Stubble not burned				
Blade S.S. tiller	20.5	2524	58.1	15.4	13.3
Sweep S.S. tiller	19.5	2386	57.8	15.5	12.2
Average	20.0	2455	58.0	15.5	12.8
Oneway	19.4	2471	57.1	15.8	12.6
Moldboardless plow	18.2	2355	57.9	15.1	11.9
Average	18.8	2413	57.5	15.5	12.3
Moldboard plow, D.F.	19.1	2426	57.7	16.1	12.3
Moldboard plow, R.W.	19.0	2485	57.8	15.6	11.8
Average	19.1	2456	57.8	15.9	12.1
	Stubble burned				
Blade S.S. tiller	19.2	2485	57.6	15.3	13.5
Sweep S.S. tiller	19.5	2537	57.5	15.9	12.8
Average	19.4	2511	57.6	15.6	13.2
Oneway	19.6	2574	57.6	16.0	12.9
Moldboardless plow	19.1	2473	57.8	15.6	12.9
Average	19.4	2524	57.7	15.8	12.9
Moldboard plow, D.F.	19.4	2536	57.7	16.3	12.7
Moldboard plow, R.W.	19.3	2517	57.9	15.9	12.4
Average	19.4	2527	57.8	16.1	12.6

D.F. = Duckfoot

R.W. = Rod weeder

S.S. = Sub-surface

The data included in table 12 emphasize that there have been no great differences in soil moisture, wheat yields, or quality of wheat produced on any of the fallow methods.

Effect of Tillage Method on Weed Control

Weeds have been the easiest to control on fallow where the moldboard plow or oneway disk was used. The sub-surface tilled plots have required one additional cultivation during two of the five years that data have been recorded. Small weeds have been the most difficult to control with sub-surface tillage; this has been especially true with the flat-sweep type machine and the moldboardless plow. The flat sweeps did not stir the soil enough, and the tendency was to go too deep with the moldboardless plow. The blade-type machine, which had more pitch to its cutting blades, did a better job of controlling weeds, because it stirred the surface soil a good deal more. A rod weeder with shovel attachments has been used very successfully for cultivating sub-surface tilled fallow. On stubble mulch fallow the rod weeder has worked most satisfactorily when used following some other sub-surface tillage implement. Where straw has been mixed into the soil, there is a tendency for the straw to clog the rod weeder because it gets caught on the rod and shovels. The rod weeder with shovel attachments will penetrate light soils without previous cultivation with other equipment, but on heavier soil types some other type of tillage implement works more satisfactorily for the first operation. The rod weeder causes a good deal of soil stirring and is effective in getting good weed kills. The rod weeder has also been very satisfactory for use as a tillage implement on moldboard plowed fallow.

All grain has been about equally free from weeds during the crop season. There has been no indication that crops on one type of fallow were more inclined to be weed infested than on another.

**Yields Determined by the Quadrat Method Compared With
Total Plot Yields**

In 1946 and 1947 each plot was harvested separately with a self-propelled combine so as to get the total yield from each plot. This was done in order to get a check on the yields obtained by the quadrat sampling method. Each year 12 (meter square) quadrats were harvested from each plot and yield per acre was calculated from these samples. The plots in this project are .44 acre in size. As shown in table 13 the yields per acre calculated from the quadrat samples have been very close to the yields obtained when the whole plot was harvested.

In 1946, yields determined on a total plot basis were, with one exception, equal to or higher than yields determined on a quadrat basis. In 1947, the yields determined by each method of sampling were high approximately the same number of times; the average for all treatments was 14.7 bushels per acre by the total plot method and 14.8 bushels when determined by the quadrat method.

TABLE 13.—Comparison of yields of spring wheat obtained from quadrat sampling and total plot yield; plots .44 of an acre in size, 12 (meter square) quadrats harvested from each plot, yields shown are averages of the three plots from each treatment at the North Montana Branch Station, Havre, Montana

Method of fallow	1946		1947	
	Bu. per acre total plot yield	Bu. per acre quadrat yield	Bu. per acre total plot yield	Bu. per acre quadrat yield
Sweep S.S. tiller	B 16.6	15.5	15.1	14.4
Sweep S.S. tiller	T 14.3	13.9	13.9	14.1
Blade S.S. tiller	B 16.5	16.3	14.4	13.8
Blade S.S. tiller	T 16.1	15.2	15.1	15.8
Moldboardless plow	B 15.6	15.6	13.6	14.1
Moldboardless plow	T 13.6	13.0	13.9	14.3
Moldboard plow, D.F.	B 16.0	15.0	15.2	16.1
Moldboard plow, D.F.	T 14.8	13.8	14.7	14.6
Moldboard plow, R.W.	B 16.2	15.0	15.6	15.4
Moldboard plow, R.W.	T 15.3	14.8	15.1	15.9
Oneway	B 18.3	17.1	15.3	14.8
Oneway	T 17.2	18.0	14.0	14.0
Average	15.9	15.3	14.7	14.8

T = Stubble not burned
 B = Stubble burned
 D.F. = Duckfoot
 R.W. = Rod weeder
 S.S. = Sub-surface

SUMMARY OF WORK AT THE NORTH MONTANA BRANCH STATION HAVRE, MONTANA

Erosion Control

1. Very little wind or water erosion has occurred on any of the treatments in this study.
2. Observations made on farms in the surrounding area indicate that north-south stripping plus a stubble mulch or cloddy mulch are necessary for effective control of wind erosion on fallow.

Moisture Conservation

1. Sub-surface tilled fallow worked with a blade-type tiller has contained the most soil moisture at seeding time.

Crop Yield

1. Yield of spring wheat has been about the same on all methods of fallow.

Quality of Wheat

1. Protein content of spring wheat has averaged highest on moldboard plowed fallow.
2. Test weight of spring wheat has been about the same on all methods of fallow.

Weed Control

1. Weeds have been a little more difficult to control on sub-surface tilled fallow than on fallow worked with a oneway disk or moldboard plow.
2. Some sub-surface tillers are more effective than others in killing weeds.
3. Grain has been about equally clean during the crop season on all types of fallow.

OBSERVATIONS AND RECOMMENDATIONS REGARDING SUB-SURFACE TILLAGE ON FALLOW LAND IN MONTANA

Sub-surface tillage is a method of tillage which is accomplished by cultivating beneath the surface of the soil. When stubble and other crop residues are present, they are left on the surface to form a stubble mulch. When this type of tillage is used on fallow land, it is referred to as stubble mulch fallow.

A stubble mulch on the surface of fallow land is helpful in controlling wind and water erosion. It helps control wind erosion by reducing surface wind velocity and helps control water erosion by reducing splash and runoff. Wheat yields under a system of stubble mulch fallow have been about the same as on fallow cultivated by other methods, but the protein content of wheat has been slightly lower under the stubble mulch system. There appears to be little difference in yield of spring wheat on fallow regardless of tillage method used, provided operations are timely and erosion is kept under control.

All methods of fallow in general use have advantages and disadvantages. The two chief problems which arise in a stubble mulch system of fallow are in connection with the tillage operations and the seeding of the crop. With large quantities of crop residue on the land, some difficulties are encountered in cultivating through the trash. It is also more difficult to control certain weeds with a sub-surface tiller than it is with some other types of tillage equipment. If a lot of residue is present on the surface at seeding time, some difficulty may be experienced in doing a satisfactory job of drilling.

Since past experience has indicated that a farmer is apt to run into some difficulties with the stubble mulch system of fal-

low, it is recommended that he start out with a small acreage and familiarize himself with the operation of stubble mulch equipment and with the limitations of the system before trying it on a large acreage. If an operator starts out with too large an acreage before he has learned how to do the job, he may get discouraged with his results and revert to some other tillage method.

While it is true that some difficulties may be encountered when first attempting a system of stubble mulch farming, it is also true that when suitable equipment is properly used and adjusted the operator will have little difficulty. The desirability and practicability of the system has been demonstrated through research and through the results obtained by many farm operators.

From the standpoint of erosion control it is desirable to leave as much residue on the surface as possible. The amount that an operator should leave on the surface, however, should be governed by the amount of trash that his drill will go through satisfactorily.

When an abundance of stubble is present, it may be advisable to use a disk type tillage implement for one or more of the tillage operations. The number of times that a disk is used will depend on the amount of residue the farmer can handle on the surface. The disk used may be any one of several types on the market; the important thing is the depth of operation.

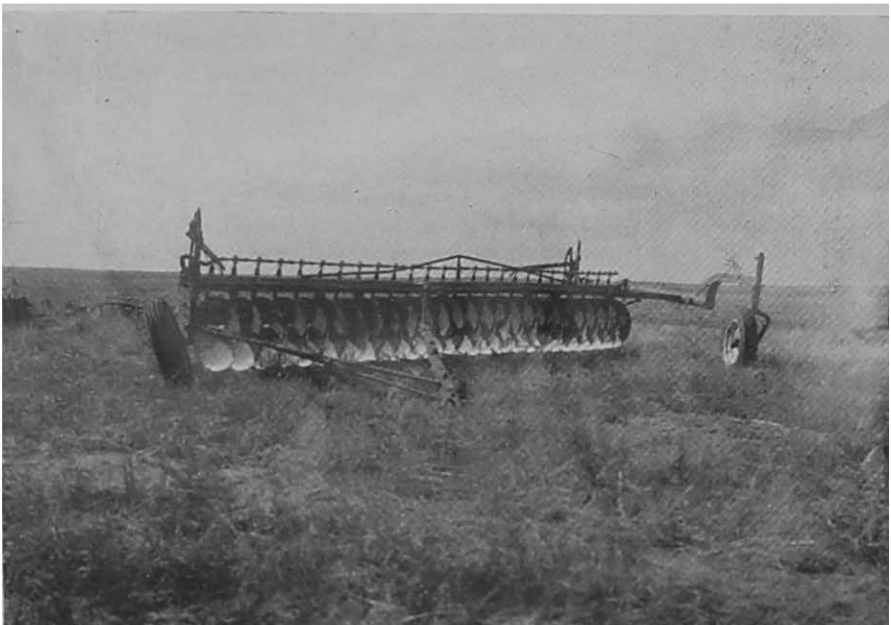


FIGURE 11.—A disk type tiller suitable for shallow disking in heavy stubble prior to sub-surface tillage.

Disking should be shallow if it is to be followed with some type of sub-surface tiller. Sub-surface tillers operate much more satisfactorily when they work below the depth of disking, and they are more effective in killing weeds if not operated too deep. If a sub-surface tiller is worked at a shallower depth than the land was disked, the stubble will catch on the sweeps or blades, and the machine will tend to push soil ahead of it and will often become clogged. Disking should not be over three inches in depth, because sub-surface tillage done much deeper than that is not very effective in killing weeds.

The Use of Straw Spreaders

If the crop is harvested with a combine, a straw spreader should be used to prevent an excessive accumulation of straw in windrows. Heavy windrows of straw are apt to cause difficulty during fallow operations and at seeding time.



FIGURE 12.—The use of straw spreaders on combines prevents excessive accumulation of straw in windrows.

Types of Sub-Surface Tillers

There are several types of sub-surface tillers on the market—the straight blade, wide sweep, narrow sweep, and rotary rod weeder. In selecting a sub-surface tiller it is important to consider such things as size, clearance, weed killing ability, and sturdiness of construction.

If a machine is too wide, difficulties will be encountered on irregular ground. If a wide piece of machinery is needed, it is

advisable to have it in sections so that it has flexibility. A wide machine built in sections will follow the contour of the land better than a machine of similar width built on one rigid frame. A wide, rigid sub-surface tiller results in a lack of uniformity in depth of cultivation; this in turn causes variation in draft and a poor weed kill.

It is very important to select a sub-surface tiller which has *sufficient clearance* to go through large amounts of stubble. Stubble in which large Russian thistles are present is especially difficult to get through, and unless the machine has a lot of clearance it will not operate without clogging.

There is a good deal of difference in the ability of various sub-surface tillers to *kill weeds*. The sub-surface tillers which tend to stir the surface soil are more effective in controlling shallow-rooted weeds than the machines which depend on a shearing action alone. Shallow rooted weeds are the most difficult to control with sub-surface tillers, and special consideration should be given to this problem when selecting a machine.

Sturdiness of construction is also important in a sub-surface tiller. If the machine is not well built, breakage and bending will result. With the large sweeps generally present on sub-surface tillers it is especially important that these sweeps be kept running as true as possible. It is difficult to get a sub-surface tiller to operate satisfactorily if the sweeps or beams are bent.



FIGURE 13.—Rod weeder with shovel attachments.

Often the rod weeder is not thought of as a sub-surface tiller, but actually it fits into a stubble mulch system very well in some localities. Under most conditions the rod weeder operates most satisfactorily when some other sub-surface tiller has been used for the first operation. In light soils which are free from rocks, the rod weeder with shovel attachments can be used for the first and succeeding operations, if crop residues are not too heavy.

Operation of Sub-Surface Tillers

In order to get good weed kills with sub-surface tillers, a *uniform shallow cultivation* is necessary. A uniform depth can best be maintained if the machine is weighted enough to hold it in the ground at all times. The weight of the machine should hold the sweeps in the ground, and the wheels should keep the sweeps from going too deep. Failure to properly weight sub-surface tillers may also result in the sweeps or blades coming out of the ground. If the sweeps come out of the ground, the machine will generally clog. The variation in depth of cultivation which results from lack of weight also causes a draft problem. Without enough weight a machine set so as to penetrate the hard spots will go deeper in soft areas and the load may be greatly increased.

Better weed kills and more satisfactory operation can be expected if a sub-surface tiller is pulled at a *fair rate of speed*. The slower the rate of speed the less soil-stirring results and the greater the tendency for the machine to become clogged. About five miles per hour seems to be a desirable speed.

Sub-surface tillage done on *warm dry days* will result in better weed kills than if the weather is cool and damp. Sub-surface cultivators also operate better if the *soil is not too wet*. Since weeds as a rule are more difficult to control with sub-surface tillers than they are with some other methods of cultivation, it is advisable to do the cultivating under optimum conditions whenever possible.

The Use of Treaders

A treader may be used to advantage following a sub-surface tiller under some conditions. A satisfactory treader can be made by reversing the prongs on a certain type of rotary hoe. If the proper type of treader is used, it will help break up the straw into shorter lengths and anchor it in the soil so it will not be blown away as easily. The treader will also help in controlling weeds by breaking up clods in which weeds might otherwise continue to grow; in going over larger weeds it tends to roll them over and pull the roots out of the ground. The use of the treader will generally result in a seed bed which is more easily seeded. When the stubble is light, a treader generally should

not be used because it will pulverize the soil and create conditions which favor soil drifting.



FIGURE 14.—A treader being pulled in tandem with a sub-surface tiller. The sub-surface tiller is weighted so a uniform depth of operation can be maintained.

Seeding in Stubble Mulch

Some difficulty may be experienced in seeding in stubble mulch when residues are heavy. The operator should keep in mind the amount of residue his drill will go through when he is cultivating his fallow. As previously mentioned, a disk may be used for one or more of the tillage operations; this will cut up the stubble and facilitate seeding operations.

A drill with wide spacings between rows will go through more residue than one with narrower spacings. The single disc drill also has some advantages in that it tends to push the straw aside instead of going directly over it as a double disc drill does. The shoe type drill with staggered shoes and wide spacings will go through a lot of trash, and it is also desirable in that the seed is placed in a good seedbed.

Fall Tillage

The use of sub-surface tillers for working stubble immediately after harvest has been tried to a limited extent. Results obtained to date have shown no advantage in soil moisture the following spring from the fall sub-surface tillage operation.

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