Influence of Tillage Interval of Fallow on Soil Water Storage

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Fallowing is practiced to increase soil water supply for the crop after fallow. But water must penetrate at least a foot below the soil surface of moldboard-plowed fallow to be "safe" from evaporation loss. Time interval between tillage of fallow to control weeds did not alter the amount of evaporation loss. When available water to 48-inch depth exceeded 4 inches the first spring of the 21-month fallow period, precipitation storage efficiency thereafter was essentially zero.

Summerfallowing has been practiced in North Dakota for several decades. How many acres are fallowed annually depends not only on agronomic factors but also on government programs, price of grain commodities, and the weather. Proponents of the practice emphasize the water-conserving, weed-controlling, and crop-yield-stabilizing virtues, while critics point to inefficiency in soil-water storage and the wind-and-water-erosion problems associated with fallow (Haas, Willis and Bond, 1974).

From an agronomic standpoint, one purpose of fallowing is to increase the soil water supply for the crop after fallow. For the first tillage operation, usually about mid-May, an implement is frequently used that incorporates all or most of the residues into the soil. Later tillage to control weeds during the summer and fall is done with implements that stir only the soil surface.

Frequency of tillage for weed control, or interval between tillage operations, varies among operators. Little information has been developed in North Dakota that can be used as a guideline to determine the frequency or interval of tillage needed for weed control, but researchers in western Canada have conducted such experiments. Molberg et al. (1967), in studies at seven semiarid region locations, found that usually three or four tillage operations were required for satisfactory weed control, but the number varied from two to six, depending on year and location. They found little difference in soil water storage regardless of number of operations. Dew (1968) reported that three operations with a field cultivator, following the initial one-way disk operation, timed for best weed control, usually controlled weeds on Ponoka loam in the subhumid region of central Alberta. Eight operations between May 20 and October 5, or 12 operations between May 5 and October 5 (oneway disk for the first and field cultivator for the others) did not result in differences in amount of water stored.

This study was conducted to determine the effect of tillage interval of moldboard-plowed fallow on soil water storage in the semiarid region of North Dakota.

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Table 1. Dates of field cultivator tillage of fallow.

Tillage[1] interval	Year					
	1967	1968	1969	1970	1971	1972
weeks	month-day					
4	6-15	6-17	6-16	6-19	6-14	6-16
	7-15	7-15	7-14	7-13	7-15	7-17
	8-12	8-15	8-15	8-17	8-16	8-14
	9-15	9-17	9-15	9-14	9-15	9-15
	10-14	10-16	10-15	10-15	10-15	10-16
5	6-22	6-21	6-23	6-26	6-28	6-22
	7-27	8-2	8-4	8-3	8-2	8-1
	8-31	9-9	9-8	9-7	9-13	9-4
	10-5	10-21	10-20	10-19	10-22	10-20
6	6-29	7-1	7-1	7-1	7-1	7-3
	8-10	8-15	8-15	8-14	8-16	8-14
	9-21	10-1	10-1	10-2	10-1	10-2
7	7-6	7-5	7-11	7-6	7-5	7-7
	8-24	9-3	9-1	9-1	9-1	9-4
	10-12	10-21	10-20	10-21	10-22	10-20

[1]*Moldboard plowed on 5-18-67, 5-17-68, 5-12-69, 5-18-70, 5-17-71, and 5-15-72.*

Procedure

Field trials were conducted from 1967 through 1972 at the Dickinson Experiment Station on an association of Morton-Arnegard loam. The plots, four replications each of four tillage intervals, were moldboard plowed about mid-May (Table 1). Fallow tillage was done with a field cultivator at intervals of four, five, six, and seven weeks, following the date of moldboard plowing. Alternate, contiguous blocks of a wheat-fallow sequence were used during the six-year period; when one set of plots was fallowed the other was cropped to wheat (Bauer and Conlon, 1974). The same tillage interval was used on the same plot of each block during each fallow year.

In 1967, soil samples were taken in the spring and fall to 60 inches and water content was determined gravimetrically. In other years, water content was determined with a neutron meter (Stone, Kirkham and Read, 1955) at least twice annually. One access tube was installed in each plot to a depth of 96 inches (16 tubes). Bulk density and water content at 15 atmosphere percentage were determined on all samples taken in 1967 and on samples taken at the access tube sites (Bauer and Conlon, 1974). The estimated available water capacity is about 2.2 inches per foot depth of soil.

This study included measurements of nitrate-nitrogen concentration at several soil depths, some soil physical properties, and wheat yields. These data have been reported (Bauer and Conlon, 1974).

For this report, statistical analysis was performed on water content difference between spring and autumn at specific soil depths to 60 inches. (Data to 84 inches, however, are included in this report). The statistical analysis was limited to the upper 60 inches because rooting of spring wheat, the most frequent crop following fallow in this area of North Dakota, is generally limited to this depth (Bauer and Young, 1969; Haas and Willis, 1962). The data were analyzed as a split plot (LeClerg, Leonard and Clark, 1962).

Results and Discussion

Table 2 shows a summary of variance sources and their significance for difference in soil water storage from spring to autumn of the fallow period. In only one of six years (1969) were the odds at the 95% probability level that tillage interval affected water storage. But water content changed with soil depth in five of the six years. In 1972, the odds were at the 99% probability level that tillage interval affected water content change with soil depth (interval x depth interaction).

Table 2. Summary of significance of variance sources and their significance for difference in water storage on fallow from spring to autumn, 1967 to 1972.

Year	Variance source		
	Interval (I)	Depth (D)	I x D
1967	ns[1]	ns	ns
1968	ns	**[3]	ns
1969	*[2]	**	ns
1970	ns	**	ns
1971	ns	**	ns
1972	ns	**	**

[1]Indicates the odds are less than 95 out of 100 that differences were due to treatment rather than chance.

[2]Indicates the odds are at least 95 out of 100 that differences were due to treatment rather than chance.

[3]Indicates the odds are at least 99 out of 100 that differences were due to treatment rather than chance.

In 1969, about 0.25 inch more water was stored to the 60-inch depth in the four and seven-week tillage interval treatments than in the five and six-week treatments. However, wheat grain yields did not differ between treatments the next year (Table

Table 3. Difference in available soil water content with soil depth from spring to autumn of fallow season.

Year	Soil depth (inches)					
	0-6	6-12	12-24	24-36	36-48	48-60
			inches water[1]			
1967	-.10 a[2]	.05 a	- .04 a	.03 a	.11 a	.06 a
1968	-.51 a	-.55 a	1.08 d	.96 d	.45 c	-.04 b
1969	-.19 b	-.96 a	.27 c	1.05 d	1.30 e	.93 d
1970	[3]	-.07 b	- .48 a	- .29 ab	- .09 b	.50 c
1971	[3]	-.53 a	.06 b	.47 bc	.90 d	.66 cd
1972	[3]	-.72 a[4]	- .34 a	- .15 b	.87 d	.54 c

[1]Each value is an average of 16 holes.

[2]Numbers followed by the same letter within any year do not differ at the 95% probability level.

[3]Not measured.

[4]The 0- to 12-inch depth.

5). In 1972, the water storage difference at the 6 to 12-inch depth for the six-week interval treatment was at least an inch higher than in the other treatments, accounting for the significant tillage interval x soil depth interaction (Table 2). The reason for the large difference is unknown.

Table 3 shows the difference in available soil water content with soil depth from spring to autumn averaged over all tillage intervals. The amounts of available water in the spring and autumn at the various soil depths are depicted in Figure 1. Date of spring and autumn measurements are shown in Table 4.

The change in water content from spring to autumn (Table 3) at any soil depth varied with years, as expected, because of yearly differences in precipitation frequency and amount. Water content at the 6 to 12-inch depth decreased from spring to autumn in five of the six years by as much as 0.96 inches. These data suggest that on moldboard plowed-fallow water must penetrate at least below the 12-inch depth in order to be safe from evaporation. Staple (1964) suggested that penetration to a depth of at least 4 to 5 inches was necessary. Water was lost by evaporation to the 12-inch depth even though seasonal precipitation was above average (Table 4). Greb, Smika and Black (1967) showed an increase in net water storage of about 0.5 to 1.6 inches during fallow from straw mulch ranging from 1500 to 9000 pounds per acre. More than 70 per cent of this gain was below the 24-inch soil depth, but the amount in the upper foot of soil was greater with than without straw mulch.

Water content decreased 0.34 and 0.48 inches at the 12 to 24-inch depth from spring to autumn of 1970 and 1972, respectively, and 0.29 inches at the 24 to 36-inch depth in 1970 (Table 3). The soil profile had been recharged with water at the 12 to 48-inch depth by the spring of 1970, and at the 12 to 36-inch depth in 1972 (Figure 1). The 1.80 to 2.04 inches of available water present in the 12 to 24-inch depth were less than the upper limit of the available water capacity at this and lower depths for soil similar to those on which these trials were conducted (Cassel and Sweeney, 1974). Therefore, loss over the spring-to-autumn period likely was caused by evaporation rather than by drainage. These plots were on south and west-facing slopes, and these have higher afternoon surface temperatures than north and east-facing slopes, and higher evaporation potentials.

The largest increase in available water from spring to autumn was 1.30 inches and this was at the 36 to 48-inch depth in 1969 (Table 3). This layer had no available water in the spring of 1969 (Figure 1). The water content increase at any depth between 12 and 60 inches varied among years. For example, in 1967 when available water content in the spring was about an inch at all depths there was little change at any soil depth, whereas in 1969 when the greatest change occurred, some of the layers had no available water in the spring. Water moved below the 60-inch depth in at least three years (1969, 1970 and 1972). In two of these (1970 and 1972) the 12 to 36-inch depth had over 3 inches of available water in the spring, enough to make production on recropping competitive with fallow (Bauer, 1968). These same data illustrate the role of fallow in contributing to recharge of layers below the root zone, which in turn can cause saline seeps (Doering and Sandoval, 1976). They also show another reason for inefficiency of fallow as a water management practice in that water moving below the root zone becomes "positionally" unavailable for crop use.

Precipitation storage efficiency within the upper 60 inches of soil ranged from zero to 18 per cent (Table 4.) Efficiency was lowest in 1970 and 1972 when the available water content in the spring was more than 4.2 inches in the upper 48 inches of soil. Haas and Willis (1962) reported an average storage efficiency of about 17 per cent from seeding to harvest (April 20 to August 3) during 1915-1954 period. The 40-year average was 1.46 inches of water stored to 6-foot soil depth from 8.43 inches of rain. The lower efficiency reported here likely can be attributed to the longer interval between measurements, especially since the measurement interval extended into autumn. In late summer and autumn, rain-free intervals usually are longer, precipitation is less, and soil temperature is lower in the upper portion of the rooting zone. As a result of the lower temperature at or near the surface, evaporation is enhanced because net water vapor movement is upward.

Table 4. Precipitation amount, water stored to 60 inches soil depth, and water storage efficiency of fallow.

Period		Precipitation[1]	Water stored[2]	Storage efficiency
mo/day	year	inches	inches	%
6/28 to 10/25	1967	4.09	.09	2.0
4/11 to 10/30	1968	13.31	1.39	10.4
4/15 to 9/10	1969	13.01	2.40	18.4
5/5 to 9/29	1970	13.97	- .43	0.0
5/5 to 10/31	1971	15.11	1.56	10.3
4/26 to 10/11	1972	16.82	.48	2.9

[1] *Normal precipitation amounts at the Dickinson Station, April through October, respectively, are: 1.26, 2.00, 3.89, 2.06, 1.71, 1.19, and 0.85 inches.*

[2] *0- to 60-inch depth in 1967, 1968, and 1969, and 6- to 60-inch depth in 1970, 1971, and 1972 (Table 3).*

Summary and Conclusions

Tillage intervals of fallow, ranging from four to seven weeks, had no affect on water storage from spring to autumn to the 60-inch soil depth in five of six years; in the sixth year tillage at four or seven-week intervals resulted in about 0.25 inches more water than tillage at five or six-week intervals. Available water content in the 6 to 12-inch depth was lower in autumn than spring in five of six years;

Table 5. Spring wheat grain yields as affected by tillage interval of fallow, Dickinson 1968 to 1972.[1]

Tillage interval	Year 1968	1969	1970	1971	1972
weeks	bushels per acre				
4	38.8	43.0	19.5	46.8	28.1
5	37.4	43.3	19.1	46.0	27.2
6	38.6	40.3	18.4	44.2	28.3
7	39.5	38.0	16.8	44.2	27.2
LSD[2/]	4.8	7.1	7.0	3.7	4.6

1/ Bauer and Conlon (1974).

2/ Indicates the yield difference needed for significance at the 95% probability level.

in the other year there was essentially no difference. This loss of water from spring to autumn is attributed to evaporation.

Water from seasonal precipitation moved below the 60-inch depth in three of the five years studied. In one of these three years (1969), water moved below 60 inches even though the available water content to the 24-inch soil depth in the spring was only about 1.05 inches, an amount less than 25 per cent of the available water capacity.

Water storage efficiency to the 60-inch soil depth ranged from zero to 18 per cent. Efficiency was lowest when available water in the spring at the 6 to 48-inch depth exceeded about 4 inches.

Results of this study reinforce suggestions that a decision on whether to recrop or to fallow should be based, largely, on the available soil water supply in the first spring of the 21-month fallow period. Not only is precipitation storage efficiency affected by soil water available in the first spring, but the chances of water moving below the rooting zone are enhanced by a high available water content. Water moving below the rooting zone can contribute to environmental problems, such as saline seeps. Another negative aspect of fallowing soil that has sufficient available water to support a potentially high-yielding crop is the waste in fuel and energy used in tilling the fallow.

Since evaporation exhausted the available soil water supply in the upper foot by autumn in most years, tillage to control weeds rooting only in the upper foot of soil, especially in the autumn, appears unneeded. Weed growth under these conditions may be beneficial for trapping snow and for wind erosion control.

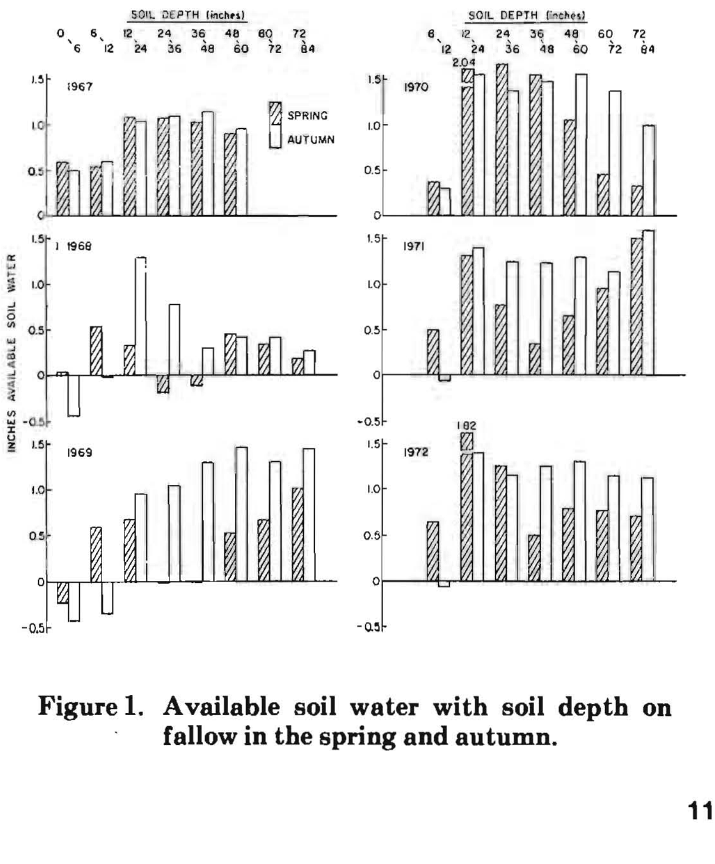

Figure 1. Available soil water with soil depth on fallow in the spring and autumn.

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