Effect of Straw Mulch Rates on Soil Water Storage During Summer Fallow in the Great Plains[1]

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ABSTRACT

Net gains in soil water storage during fallow due to increased quantities of wheat (*Triticum aestivum* L.) straw mulch varied from 1.0 to 4.3 cm at Sidney, Mont., from 2.1 to 4.1 cm at Akron, Colo., and from 1.3 to 3.3 cm at North Platte, Nebr. These gains were made primarily during the spring months of the 14-month fallow season. More than 70% of the net gains in soil water under heavier amounts of mulch was found below the surface 61 cm of the soil profile at all experimental locations, thereby minimizing potential evaporation losses. Storage of water tended to increase with the delayed date of straw burial in Nebraska. Additional soil water was conserved at Akron, Colo. during the first fall by subtillage of wheat stubble at harvest when compared with spring subtillage; however, by the end of the fallow there was no significant difference between treatments. Fallow efficiencies averaged 22, 30, and 32% for all treatments at the Montana, Colorado, and Nebraska locations respectively.

Additional Key Words for Indexing: evaporation, subsurface tillage.

The advisability of utilizing summer fallow for crop production in the Great Plains has been questioned for two reasons: (i) low fallow efficiencies of 18 to 22%, and (ii) the continuous threat of wind erosion (8, 10, 15). However, these historical limitations pertaining to summer fallow may no longer apply. First, recent data from Sidney, Mont. (2) show fallow to be more efficient in storing soil water than previous studies have shown. Fallow efficiencies averaged 26% for a 21-month summer fallow for spring wheat over a 6-year period. Reducing the fallow period to 14 months, as in the case of winter wheat, would show somewhat higher fallow efficiency for the same experiments (2). Secondly, maintaining straw on the soil surface by subsurface tillage offers a practical solution to the wind erosion hazard (11, 17). And lastly, there is some evidence that preservation of surface mulches may result in increased soil water storage over conventional clean fallow (6, 9, 12).

Previous research has suggested that significant increases in stored soil water are obtained primarily at straw mulch application rates exceeding 12,000 kg/ha (11, 12). Other studies have shown that mulches conserve water during frequent rainy periods but decrease in water conservation value during prolonged dry periods (5, 12). Gardner (3) indicated that surface mulches may have little long-range benefit over a bare soil unless low evaporation rates permit a time lag for deeper percolation of water. Mulches tend to decrease evaporation from the immediate surface as long as the soil surface remains wet (1, 14). Hanks and Woodruff (5) showed that after the soil surface dries under mulch, the vapor transfer

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Table 1 —Field plot procedures used for soil water storage in summer fallow as affected by application rates of wheat straw

Experimental variables	Measurement unit	Great Plains locations		
		Sidney Mont.	Aro jColo.	North Platte ebr.
Length of experiment	years	2	3	4
Soil type		Sprole sandy loam	Weld silt loam	Holdredge silt loam
Slope of plot area	%	3 to 4	0.5	2 to 3
Exp. variables		rates of straw	rates of straw × dates subtillage	rates of straw × dates straw burial
Rates of straw	kg/ha	0, 1,680, 3,360, 6,720	1,680, 3,360, 6,720	3,360, 6,720, 10,080
Replications	no.	3	3	3
Plot water control		yes	yes	yes
Plot size	meters	7.6 × 25.4	9.1 × 25.4	4.6 × 25.4
Fallow tillage	no./yr	4	4 to 6	4 to 6
types:				
primary, sweep*	cm/blade	46 to 122	152	82 to 122
secondary, variable		sweep	miller rod†	miller rod†
Soil water sampling		gravimetric, oven-dry basis	gravimetric, oven-dry basis	neutron scatter
per plot	no.	2	2	2
times in year	no.	5	5	5
depth	cm	152	183	183

* Sweep V shaped blades used at least twice if no burial of straw. 61-cm one-way disk for straw burial at North Platte.
† Rotating bar with tongs which lifts straw and clods over the bar.

to the atmosphere may be inhibited more by dry soil than by cover of vegetative mulch.

One difficulty, however, in interpreting much of the literature regarding mulches is the lack of quantitative measurements of the amount of straw used in fallow field experiments. Consequently, it was felt that greater clarification of the effect of defined rates of straw mulch on soil water storage fallow was needed.

With these factors in mind, soil water storage data from three experiments which are being conducted within the Great Plains area utilizing various known quantities of initial rates of straw are hereby presented. These experiments do not have identical treatment interactions with the rates of straw used. Nevertheless, the methods of securing soil water storage data are similar enough for reporting as a unit. The location of these experiments include Sidney, Mont., Akron, Colo., and North Platte, Nebr. where the 1957-1965 average field production of wheat straw available for mulching was about 2,600, 3,800, and 6,000 kg/ha, respectively.

EXPERIMENTAL PROCEDURE

Procedures used for the three fallow experiments are given in Table 1. Each experiment had similar objectives and design, and included an alternate crop and fallow block of plots utilizing winter wheat (*Triticum aestivum* L.) as a source of straw. The length of summer fallow averaged 14 months, which extended from harvest near mid-July to seeding time, the second mid-September.

The yield of wheat straw was determined at harvest (16), and the designated application rate of straw mulch was obtained by either raking and, or mowing off any excess straw or adding needed straw by hand spreading.

Although somewhat different tillage implements were used for fallow at each location (see Table 1), the depth of subtillage, weed control, rate of straw loss, and maintenance of soil clods were quite similar. Extra tillages were used at the Colorado and Nebraska locations for certain treatments involving date of subtillage or date of straw burial. A single sweep tillage was used at Akron, Colo. during the first week of August as the fall tillage treatment. Similarly, a single oneway-disk tillage was used for fall straw burial treatment plots at North Platte, Nebr. Normal overwinter losses of straw weight (13), plus tillage, generally reduced the quantity of straw by mid-May to about 60% of the original application at all experiment locations.

Parallel dikes were maintained between plots at all locations to prevent migration of runoff water from plot to plot. Individual years of fallow experimentation included 1964 and 1965 for Sidney, Mont., 1963, 1964, and 1965 at Akron, Colo., and 1962 through 1965 at North Platte, Nebr. Available soil water reported for the individual locations and years was that amount of water held at less than 15 bars. Soil water sampling was restricted to a depth of 152 cm at Sidney, Mont. because of coarse gravel. Soil water was determined to a depth of 183 cm at the Colorado and Nebraska locations (Table 1). The soils in all these experiments would hold a maximum of about 30 to 34 cm of water in the 183-cm depth of soil. Such quantities were seldom achieved during summer fallow in any of these locations because of limiting natural rainfall.

RESULTS AND DISCUSSION

The results of soil water storage during fallow as modified by straw mulches for the three locations are summarized in Tables 2 to 5. In all cases, initial available soil water was relatively low at wheat harvest (beginning of fallow). Some soil water differences imposed by straw treatments were evident at all locations by early spring. However, the largest net gains in soil water storage as effected by various application rates of straw were made from the mid-April to mid-June period. From mid-June to the end of fallow in September there were only slight changes in the relative soil water levels already established. Summer drought at Sidney, Mont. and North Platte, Nebr. caused some decline in soil water storage for all treatments from late spring until the end of fallow. At Akron, Colo. there was a slight average increase in soil water storage from late spring to the end of fallow due to above-normal summer rainfall in 1963 and 1965.

Net gains of soil water at the end of fallow as credited to increasing quantities of straw mulches varied from 1.0 to 4.3 cm at Sidney, Mont., 2.1 to 4.1 cm at Akron, Colo., and 1.3 to 3.3 cm at North Platte, Nebr. These soil water gains in fallow as influenced by initial straw quantities showed linear characteristics at Sidney, Mont and to a lesser extent at the other two locations. The above field results are not unlike those recently reported in a test of soil water evaporation suppression by straw mulches under solar distillation (4). Soil water evaporation losses were reduced in a near linear fashion as the rate of surface straw increased from 0 to 90% soil cover (3,360 kg/ha) during 20 days of testing (4).

Table 2—Soil water storage by summer fallow periods as affected by application rates of wheat straw at three Great Plains locations

Location and years	Applied straw	Soil water storage at various periods during fallow: Harvest	Late fall	Early spr.	Late spr.	End fallow	Net gain soil water	Fallow* pptn	Fallow efficiency†
	kg/ha	soil water, cm							%
Sidney, Mont. 2 yr mean	0	3.8	4.3	11.4	11.6	9.4	5.6	35.5	16
	1,680	3.5	3.8	12.0	12.2	10.1	6.6	35.5	19
	3,360	4.0	4.4	11.4	12.6	11.9	7.9	35.5	22
	6,720	4.0	4.4	12.2	15.0	13.9	9.9	35.5	28
Akron, Colo. 3-yr mean	1,680	1.8	5.8	7.6	14.5	16.0	14.2	54.9	26
	3,360	1.5	4.6	8.1	16.0	17.8	16.3	54.9	30
	6,720	2.0	6.4	9.4	18.3	20.3	18.3	54.9	33
North Platte, Nebr. 4 yr mean	3,360	2.8	12.0	15.6	22.5	21.8	19.0	64.8	29
	6,720	4.3	13.5	19.3	24.9	24.6	20.3	64.8	31
	10,080	3.3	12.3	17.7	27.3	25.6	22.3	64.8	34

* Fallow period of 14 months; July to second Sept. each location.

† Fallow efficiency % = $\frac{\text{Net gain soil water, cm}}{\text{Fallow pptn, cm}} \times 100.$

Table 3—Soil water storage at end of fallow as a function of application rates of initial straw mulch for individual years at three Great Plains locations

Location and years	Fallow pptn	Soil water storage at straw rates (kg/ha): 0	1,680	3,360	6,720	10,080	LSD .05
		soil water, cm					
Sidney, Mont.							
1964	36.7	5.6	6.5	6.4	10.4	—	1.8
1965	34.3	5.6	6.7	9.4	9.4	—	2.0
Means	35.5	5.6	6.6	7.9	9.9		
Akron, Colo.							
1963	47.7	—	10.9	12.8	14.4	—	1.7
1964	58.3	—	16.0	17.0	18.6	—	N.S.*
1965	58.8		15.8	19.0	22.0	—	4.0
Means	54.9		14.2	16.3	18.3		
North Platte, Nebr.							
1962	62.3	—	—	18.3	20.1	21.7	1.8
1963	51.8	—	—	16.7	17.8	19.2	N.S.*
1964	74.6	—	—	22.4	23.8	27.8	3.5
1965	70.3	—	—	18.5	19.4	20.3	N.S.*
Means	64.8			19.0	20.3	22.3	

* Not significant at 95% level of probability.

Table 4—Effect of time of straw burial on soil water storage in summer fallow at 6,720 kg/ha surface applied straw at North Platte, Nebr. (4-yr means)

Fallow period	Soil water as affected by time of straw burial: fall	early spring	check*	LSD .05
	soil water, cm			
Harvest	1.8	2.0	2.8	NS†
Fall	12.5	11.9	13.0	NS†
Early spring	11.9	16.5	17.5	5.5
Late spring	21.6	22.9	24.4	1.6
End fallow	20.8	22.3	23.9	NS†
Soil water gain	19.0	20.3	21.1	

* Not significant at 95% level of probability.
† No burial.

Changes in soil water storage imposed by different quantities of straw mulch caused corresponding variations in fallow efficiency (Table 2). Fallow efficiencies ranged from 16 to 28 26 to 33, and 29 to 34% for the Montana, Colorado, and Nebraska locations, respectively. Means for all treatments were 22, 30, and 32% fallow efficiency for the same order of locations. The 2-year results at Sidney, Mont. under drought conditions were not unlike fallow efficiencies reported elsewhere (10, 15) but were less than had been obtained in a previous study at that location with more favorable rainfall (2). However, the Akron, Colo. and North Platte, Nebr. locations showed considerably higher fallow efficiencies than had been obtained in former years with less effective fallow equipment (8, 10).

Variations in soil water storage at the end of fallow by individual years per location are shown in Table 3. With only one exception, the data for all years at all locations showed a progressive increase in soil water storage with increasing application rates of straw mulch regardless of the quantity of precipitation occurring during the fallow year. Net soil water storage gains credited to higher applications of mulch were significant at the 95% level of probability in 6 of the 9 experimental years tested.

The distribution of soil water within the soil profile at the end of fallow for the experimental locations showed that the extra soil water gained by straw mulches tended to improve the soil water content throughout the soil profile (Fig. 1). Of particular value, more than 70% of this net gain was below the 61-cm depth at each of the locations tested. This deep penetration may explain why water storage gains established by mid-June showed little change during the remaining warmest 2 months of fallow.

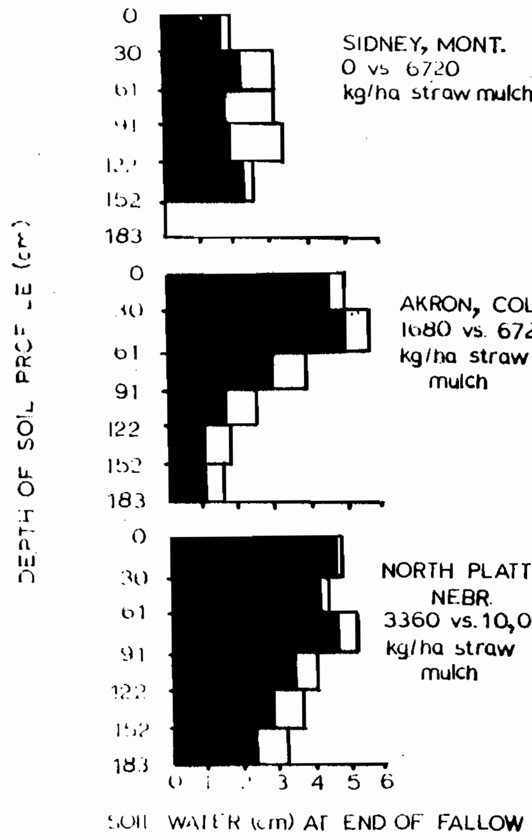

Fig. 1 Soil profile distribution and quantity of soil water at end of fallow at three Great Plains locations. Low mulch is colored black and high mulch is black plus white.

The effects of time of straw burial at North Platte, Nebr. and time of subsurface tillage at Akron, Colo. on soil water storage during various fallow periods are given in Tables 4 and 5, respectively. The results at North Platte, Nebr. indicated the net gain in soil water storage resulting from delayed straw burial was significant at the 95% level of probability earlier in the fallow season but was nonsignificant by the end of fallow.

Fall subtillage at Akron gave a water storage advantage of 1.8 cm early in the fallow season probably because of the elimination of weeds in the after harvest stubble (Table 5). However, the advantage with fall subtillage became less pronounced as the fallow season advanced to the next spring. Field observations revealed that straw left upright, but loosened by fall subtillage, was less efficient in retaining blowing snow than anchored, undisturbed straw. By the end of fallow there was no significant difference in soil water storage between the fall and spring subtillage treatments for the 3-year mean (Table 5). The possibility of conserving more of the 12 to 20 cm of rainfall expected to occur between harvest and fall dormancy by subtillage or chemical treatments to control weeds and volunteer wheat should be further investigated.

The results of these experiments conducted at three widely separated Great Plains locations showed that increasing quantities of straw mulch gave small but consistent increased storage of soil water during the summer fallow years tested. The mean net gains of soil water likely to be realized by mulches for the average 2,600, 3,800, and 6,000 kg/ha straw production at Sidney, Mont., Akron, Colo., and North Platte, Nebr., respectively, should approach 2.0, 2.5 and 1.5 cm per fallow season for the above same order of locations. With this increase in soil water by mulching, a small potential gain of grain yields of about 120 to 140 kg/ha is possible based on stored soil water at seeding time as estimated by Johnson (7), if other factors such as soil nitrates and soil temperatures are not limiting.

Table 5—Effect of time of subtillage of soil with 3,360 kg/ha surface applied straw on soil water storage in summer fallow, Akron, Colo. (3-yr means)

Fallow period	Soil water as affected by time of subtillage		LSD .05
	fall	spring	
	soil water, cm		
Harvest	2.0	2.0	NS*
Fall	6.9	5.1	1.5
Early spring	8.9	7.9	NS*
Late spring	17.5	15.7	NS*
End fallow	18.5	18.0	NS*
Soil water gain	16.5	16.0	

* Not significant at 95% level of probability.

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