Reprinted from AGRONOMY JOURNAL
Vol. 62, Nov.-Dec. 1970, p. 722-725

Summer Fallow Soil Water Losses on Intermountain Dryland and Its Effect on Cropping Winter Wheat[1]

T. W. Massee and F. H. Siddoway[2]

ABSTRACT

Intermountain drylands lose water from the root zone during the summer of fallow even though they receive a monthly average of 3.1 cm of precipitation. Soil water content in the 7.5- to 15-cm seed zone at the end of summer fallow was related to soil water content at the time tillage was initiated in the spring. Fall soil water content was not appreciably affected by variations in summer rainfall. Adequate soil water for winter wheat (*Triticum aestivum* L. em Thell) emergence was best assured by initiating summer fallow tillage when the water content in the 7.5- to 15-cm layer was relatively high, rather than depending on summer rain to rewet this layer.

Additional index words: **Germination, Tillage, *Triticum aestivum* L. em Thell.**

WATER conservation on fallow is primarily dependent on weed control. Smika and Wicks (1968), after comparing chemical and tillage fallow methods in the Great Plains, proposed that tillage per se results in soil and residue conditions less favorable for water storage.

Early spring dates of initiating fallow tillage in the Great Plains, an area of summer rainfall distribution, are not critically related to soil water storage. Thysell (1938) at Mandan, N.D., showed, however, that 2.5 cm of profile water was lost by delaying tillage from June 1 to July 1. He termed the June 1 date as "early plowing," indicating little need for tilling prior to this date – although weather conditions there normally permit tillage as early as April. Likewise, Luebs (1962) showed that there was no advantage in tilling

---

[1] Contribution from the Soil and Water Conservation Research Division, Agricultural Research Service, USDA; in cooperation with the Idaho Agr. Exp. Sta. Received Dec. 9, 1969. Approved July 17, 1970.

[2] Research Soil Scientist, Northwest Branch, Snake River Conserv. Res. Center, Kimberly, Idaho; and Director, Northern Plains Soil and Water Research Center, Sidney, Mont., respectively.

before May in Kansas. In contrast to these summer rainfall climates, Oveson and Hall (1957), under a winter precipitation climate at Pendleton and Moro, Oregon, and Bennett et al. (1954) at Nephi, Utah, under more evenly distributed precipitation, found yields were increased when fallow tillage was started as early in the spring as weather and soil conditions would permit.

In dryland conditions of southeastern Idaho, water in the surface soil is inadequate for winter wheat emergence in about one year out of three. Furthermore, inadequate water in the profile usually limits crop growth. This experiment was conducted to determine if water in either the 7.5- to 15-cm soil layer or the 180-cm profile at seeding time is affected by time of initiating fallow tillage. Other variables in the experiment were depth of tillage and date of planting.

METHODS

The experiment was conducted on the Tetonia Branch Experiment Station near Tetonia, Idaho. The soil, Tetonia silt loam, is an unrestricted deep loess with a pH of 6.8 in the Ap horizon and contains free lime below 45 to 50 cm. Average annual precipitation of 33 cm is uniformly distributed throughout the year. The cropping system was a winter wheat-fallow rotation, which is common to the area. To obtain results from both cropping and fallow each year, a block of each was maintained. In 1957, the initial year of the experiment, only a fallow block was maintained; in 1963, the final year, only the crop block was maintained.

A factorial arrangement of main plots (10.3 × 34.4 m) included three dates of initiating summer fallow tillage and three depths of tillage. Main plots were split for three dates of seeding winter wheat—August 15, September 1, and September 15. Dates of initiating summer fallow tillage to obtain "early," "medium," and "late" treatments were predetermined by sampling the soil water contents in the 7.5- to 15-cm zone. This zone normally begins a drying cycle after spring snowmelt. As long as weeds are not controlled, the cycle persists—within the limits of available water. When the soil water in this layer was decreased by weed transpiration and soil evaporation to 17, 13, and 9% water by weight, the respective plots were initially tilled. The 17% value coincided with the date when spring tillage operations could first be successfully started; 13%, when one-half of the available water had been depleted; and 9%, when nearly all of the available water had been extracted. Initial tillage depths of 8, 13, and 18 cm were the other main plot variables, but as they produced no measurable effect and as tillage depth is not related to the contents of this paper, results are not given herein. Four replications were used. Initial tillage was accomplished with a 2.1-m wide, V-blade sweep; subsequent tillage (about three operations) with a rod weeder as needed to control weeds. Hard red winter wheat (Wasatch or Itana Var.) was planted with a deep furrow shovel-opener drill, with openers spaced at 36 cm. Snow mold, a prevalent problem in the area, was controlled with a mercury-base fungicide.

Soil water was measured gravimetrically. The 180-cm profile was sequentially sampled by 30-cm increments: (1) after harvest, (2) the first week in May of the fallow year, (3) after seeding in late October, and (4) early May of the crop year. At each initial tillage and planting date, the surface 30-cm soil depth was also sampled by 0- to 7.5-, 7.5- to 15-, and 15- to 30-cm increments, except during the initial fallow year (1957) when the 0- to 30-cm depth was sampled as one increment. The water content of the 7.5- to 15-cm layer correlated best with wheat stands, and therefore only these data are presented.

Profile soil water (0- to 180-cm depth) is expressed as centimeters of water, while surface soil water (7.5- to 15-cm depth) is expressed as percent by weight of dry soil. Wheat yields were determined by harvesting with a combine.

RESULTS AND DISCUSSION

The 6-year average available soil water content per 180-cm profile depth in the spring at the "early" fallow tillage was 20.9 cm, as shown in Table 1. This amount was derived from a 16.1-cm increase between harvest and spring, plus an additional 4.8 cm which remained unused at harvest. Inasmuch as the 16.1-cm increase was derived from 20.0-cm precipitation occurring during this period, precipitation was 80.5% effective in adding to soil water storage. This soil profile contains 37.1 cm of water at one-third bar suction; therefore, the 20.9-cm figure indicates the soil water storage averaged only 56% of the potential amount. Percolation below the root zone was not considered a factor in water loss.

Soil profile water losses by evaporation on summer fallow after the May sampling date could be evaluated on only the "early" tilled plots, as weed growth played a role in water loss where tillage was delayed for the "medium" or "late" treatments. On the "early" tilled plots, an average of 4.5 cm water was lost by fall, in spite of 16.4 cm of precipitation and no runoff during this period. The largest individual summer fallow losses occurred following springs that had above-average profile storage. When profile storage was low, subsequent evaporative losses were also low. As examples of this trend, in May 1958 the soil profile contained 24.6 cm of water, but by fall had lost 8.4 cm by evaporation; whereas, in May 1959 the profile contained only 17.1 cm and subsequently lost only 1.4 cm. Using linear regression analysis to estimate the trend for all years, it was found that the profile water losses (Y) were related to May profile storage (X) by the equation:

$$\hat{Y} = -14.4 + 0.90X,\ r^2 = 0.73^{**}$$

The equation indicates that no loss would occur if 15.6 cm of water were present at the May sampling date, but that nine-tenths of any amount greater than 15.6 cm would be lost by fall.

Although, as shown in Table 1, precipitation during the summer-fallow period (May to October) had a large standard deviation (16.4 ±5.1 cm), precipitation by itself was not correlated with evaporative profile losses. Many of the summer storms failed to fully rewet the 0- to 7.5-cm surface soil. This layer normally dried to 3.5% (by weight) if given enough time between storms, and probably rewetted from a storm in a similar manner as described by Bodman and Coleman (1943) for air-dry surface soils. If so, and if the surface soil had dried to 3.5% water, about 3.2 cm of precipitation from a single storm would be required to advance the wetted front to a 7.5-cm depth where it could establish a continuous water film and con-

Table 1. Average precipitation during three periods of fallow and resulting available soil profile (0 to 180 cm) water storage showing either a standard deviation or Duncan's multiple range test value at 5% confidence level, 1957 to 1962.

Period of fallow	Precipitation	Increase in net soil water	Total soil water
	cm	cm	cm
At harvest	---	---	4.8 ± 1.7
From harvest until May of summer fallow year	20.0 ± 2.1	16.1 ± 2.9	20.9 ± 2.9
From May of summer fallow year to late October (post seeding)			
Early tilled	16.4 ± 5.1	-4.5 ± 3.1	16.4 a
Medium tilled	16.4 ± 5.1	-5.1 ± 2.7	15.8 a
Late tilled	16.4 ± 5.1	-7.1 ± 1.4	13.8 b

Table 2. Frequency distribution — precipitation received per storm during the study period from first fallow tillage operation to September 1.

Range	Percentage
0-1 cm	47
1-2 cm	19
2-3 cm	26
3-4 cm	8
	100

tribute to profile water storage. As may be seen in Table 2, only 8% of the precipitation between the initial fallow tillage date and September 1 was from storms greater than 3 cm precipitation. Therefore, most of the storms during this period provided only temporary delays in profile evaporation while the surface water was being evaporated.[3]

Using multiple regression to separate the effects of (1) May profile storage from (2) summer fallow period precipitation on evaporative profile losses provided further verification of the effect of precipitation. The R^2 value increased to only 0.77 from an r^2 value of 0.73 for May profile storage alone, and the standard partial regression coefficient for precipitation was only one-fourth the value for May profile storage. This fortifies the contention that quantitative May profile storage was the main variable associated with summer fallow evaporation losses under these climatic conditions.

Delaying initial fallow tillage until the "late" tillage date significantly reduced profile water at the October (post planting) sampling date as shown in Table 1. This reduction was eventually offset by subsequent storage from fall until the spring of the crop year. In the spring, yearly differences were small so that "early," "medium," and "late" tillage plots averaged 19.2, 19.9, and 19.6 cm profile water, respectively. Therefore main differences in wheat production due to treatment differences may be attributed to fall seedbed water conditions.

Larger relative differences were found in seed-zone (7.5 to 15 cm) soil water at planting time. Soil water at planting time was related to the water present in this soil layer when tillage was initiated as shown in Fig. 1. The 45 points in this figure represent water contents for each of the three planting dates — August 15, September 1, and September 15 — for each of three tillage dates and each of 5 years. Replications and tillage depths, which had no effect, were averaged. Nearly identical relationships between water at initial tillage and at planting existed for the two earlier planting dates. The later September 15 planting date is in a period when cooler temperatures are associated with slight water accumulation — especially on plots having low water content in the seed zone.

Using the data included in Fig. 1, three separate regressions and correlations were done, i.e., one for each planting date. However, the results from the first two planting dates were so nearly identical that they could be adequately described by one equation:

$$\hat{Y} = 1.3 + 0.8X,\ r^2 = 0.79^{**}$$

which also depicts what the relationship of Y on X in Fig. 1 would be if a third planting date were not included. At the third planting date, September 15, regression of Y on X accounted for only 47% of the variation:

$$\hat{Y} = 7.6 + 0.6X,\ r^2 = 0.47^{**}$$

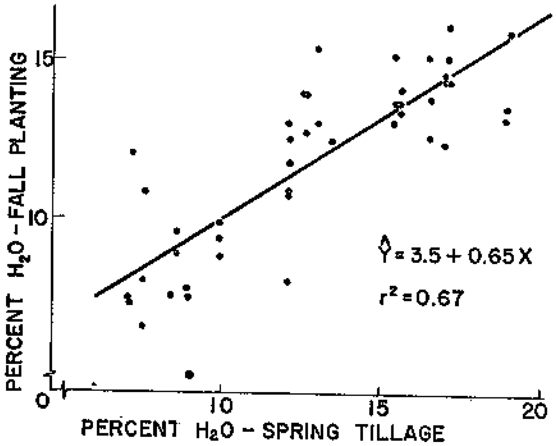

Fig. 1. Relationships between percent soil water in 7.5- to 15-cm soil depth at initial spring tillage for summer fallowing and subsequent soil water at fall planting.

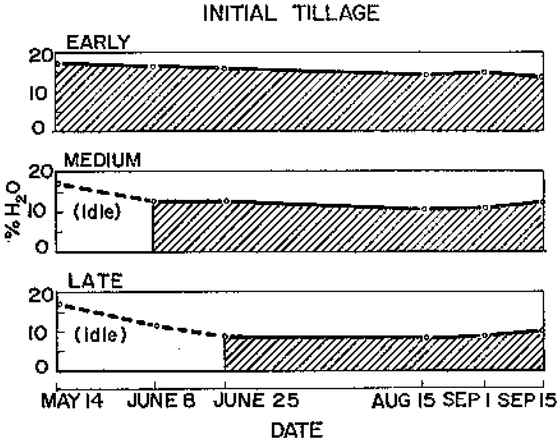

Fig. 2. Percent water in 7.5- to 15-cm soil depth from three dates of the initial spring tillage for summer fallowing through fall planting time.

The overall average[4] effect of seed zone water due to initial tillage is illustrated in Fig. 2. For this figure, the May 14, June 8, and June 15 dates represent average dates of initial tillage, while August 15, September 1, and September 15 are planting dates. These curves indicate the close association between 7.5 to 15 cm soil water at time of initial tillage and at planting, and indicate the slight increase in water by September 15 on the "medium" and "late" plots.

Yearly rainfall differences between time of initiating summer fallow tillage and planting caused only slight differences in the seeding zone water at planting time. As was found with changes in soil profile water, seedzone (7.5 to 15 cm) water at planting time was largely regulated by the quantity present when tillage was

---

[3] Free water surface evaporation during this period estimated at 0.62 cm/day from Climatic Atlas of the United States, 1968. Environmental Data Service, U. S. Dept. of Commerce. 80 p.

[4] The only data excluded in the averages were from samples taken on September 1 and 15 on previously planted plots where plant growth would influence water contents.

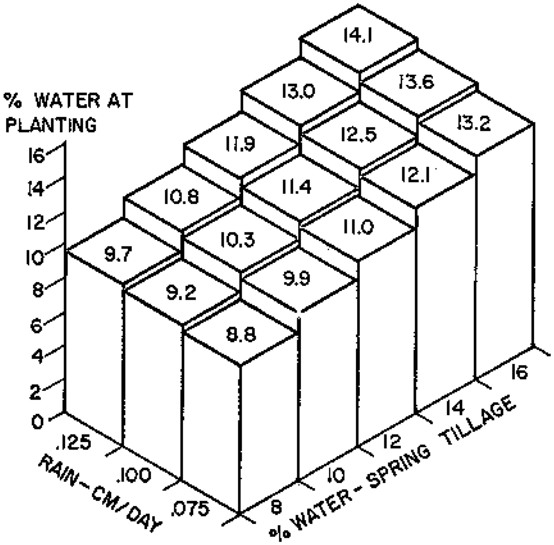

Fig. 3. Graphical presentation of regression analyses equation predicting percent soil water in 7.5- to 15-cm seed-zone at planting time resulting from amount present at initial tillage plus rainfall between tillage and planting.

initiated. To determine the extent to which rainfall, X_1, between time of initiating summer fallow tillage and planting, and water in the seed zone at initial tillage, X_2 affected seed zone soil water content at planting, Y, Y was regressed on X_1 and X_2. The same data as were used for simple regression in Fig. 1 were again used here, together with the precipitation data. As three tillage and three planting dates produced a duration of fallow variable, an attempt to remove this was done by entering rainfall as an average daily rate, i.e., centimeters per day. The resulting equation

$$\hat{Y} = 3.19 + 16.48X_1 + 0.55X_2,\ R^2 = 0.70^{**}$$

is shown graphically in Fig. 3. In this figure, the expanses of the X_1 and X_2 axes were drafted to be about two times the standard deviation of the individual variables. The $b'_{Y2\cdot1}$ value was 3.1 times as large as $b'_{Y1\cdot2}$ relating the importance of X_2 and X_1 on Y.

This study showed that ample water for fall planting was provided by initiating summer fallow tillage before weed growth could reduce the water content to below that needed for wheat germination and emergence, and that variation in summer and fall preplant rainfall affected seed-zone water very little.

During the experiment, wheat stands were always adequate on the "early" tilled plots, averaging 86%, but varied from year-to-year on the "medium" and "late" plots, averaging 79 and 53%, respectively. Almost one-half of stand variation was attributed to 7.5- to 15-cm soil water content at planting time as shown by:

$$\hat{Y} = -12.7 + 7.0X,\ r^2 = 0.47^{*}$$

where Y is stand and X is water content at time of planting (replications and tillage depths averaged before simple regression performed). Under these conditions of varying stands, subsequent wheat yields were primarily dependent on stand rather than some other factor such as profile water, which may have predominated had stands always been adequate for optimum production. According to Fig. 4, where the 45 points represent the same averaging of data as in Fig. 1, yields decreased approximately 23 kg/ha for each percent reduction in stand.

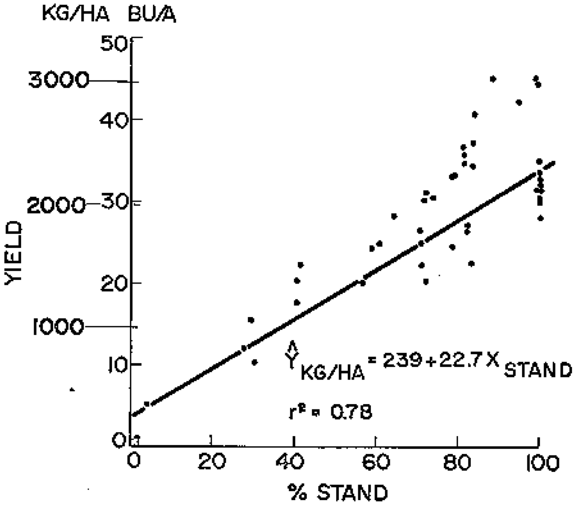

Fig. 4. Relationship between stands of winter wheat and subsequent yields.

LITERATURE CITED

Bennett, W. H., D. W. Pittman, D. C. Tingey, D. R. McAllister, H. R. Peterson, and I. R. Sampson. 1954. Fifty years of dryland research at the Nephi Field Station. Utah Agr. Exp. Sta. Bull. 371.

Bodman, G. B., and E. A. Coleman. 1943. Moisture and energy conditions during downward entry of water into soils. Soil Sci. Soc. Amer. Proc. 8:116-122.

Luebs, R. E. 1962. Investigations of cropping systems, tillage methods, and cultural practices for dryland farming at the Fort Hays (Kansas) Branch Experiment Station. Kansas Agr. Exp. Sta. Bull. 449.

Oveson, M. M., and W. E. Hall. 1957. Longtime tillage experiments on eastern Oregon wheat land. Oregon Agr. Exp. Sta. Tech. Bull. 39.

Smika, D. E., and G. A. Wicks. 1968. Soil water storage during fallow in the central Great Plains as influenced by tillage and herbicide treatments. Soil Sci. Soc. Amer. Proc. 32:591-5.

Thysell, J. C. 1938. Conservation and use of soil moisture at Mandan, North Dakota. USDA Tech. Bull. 617.