MOISTURE CONSERVATION FOR WHEAT PRODUCTION

in the Upper Snake River Dryfarming Area

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in the Upper Snake River Dryfarming Area

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INTRODUCTION

Although improved tillage practices, application of commercial fertilizers, and improved crop varieties have raised the general production level in the Upper Snake River dryfarming areas, the benefits realized from these advances are generally limited by moisture supply. This has been demonstrated by the wide range of crop yields associated with year-to-year fluctuations in stored soil moisture and precipitation.

Fallowing, which is practiced in most of this region, is an inefficient method of conserving moisture for the subsequent crop. At the Tetonia Branch Experiment Station near St. Anthony, Idaho, precipitation from harvest until the spring of the crop year averaged 21.6 inches (table 1). Only 6.4 inches of this precipitation were stored in the soil. The remaining 15.2 inches were lost, mainly through evaporation and runoff. This runoff from melting, snow and torrential rain also causes serious soil erosion when the land is not adequately protected by a vegetative cover.

In 1939 the United States Department of Agriculture, in cooperation with the Idaho Agricultural Experiment Station, initiated studies on problems of soil and water conservation in relation to crop production on the Intermountain drylands. The objectives of these studies were to (1) reduce runoff and erosion; (2) conserve moisture; (3) maintain soil fertility and organic matter; and (4) increase soil moisture utilization efficiency by crops.

This report summarizes research results obtained from several experiments that were directed toward achieving these objectives. Results are presented from investigations on stubble management, fall tillage after harvest, rotary subsoiling after planting, initial fallow tillage operations, and cropping systems.

TABLE 1.—*Precipitation and soil moisture conditions from the harvest of one wheat crop to the initial spring growth of the next wheat crop at the Tetonia Branch Experiment Station, St. Anthony, Idaho*[1]

Portion of fallow period	Precipitation	Soil moisture gained during period	Net soil moisture accumulated
	Inches	*Inches*	*Inches*
Harvest to initial summer fallow tillage (mid-August to early May)	9.0	6.6	6.6
Initial summer fallow tillage to seeding (early May to late August)	4.2	-1.6	5.0
Seeding to spring growth (late August to early May)	8.4	1.4	6.4
Total	21.6	6.4	6.4

[1] Values were averaged from the fall of 1953 through the spring of 1961. Moisture conservation practices consisted of leaving stubble standing, soil chiseling in the fall after harvest, and stubble-mulch summer fallow.

EXPERIMENTAL LOCATION, SOILS, AND CLIMATE

The Tetonia Branch Experiment Station is located 28 miles southeast of St. Anthony in the dryland farming area of southeastern Idaho (fig. 1). The elevation at the station headquarters is 6,200 feet above sea level. Topography is gently rolling to steeply sloping. Native vegetation consists of sagebrush and grass. The station soil has been tentatively classified as Tetonia silt loam and was developed from deep windblown deposits. The pH in the plow layer ranges from 6.7 to 7.4, and free lime is found in the subsoil beginning at a depth of 1 to 2 feet. The organic matter content of the soil is approximately 3 percent, which gives the soil a dark grayish-brown color. Natural soil fertility is usually adequate for near-maximum crop yields with average available moisture.

Precipitation is distributed uniformly throughout the year, averaging approximately 1 inch per month with the exception of May and June; each of these months averages slightly more than 1.5 inches per month. Variations in annual and seasonal precipitation are wide and droughts are occasionally experienced. Figure 2 shows the number of years that annual and growing season (May through August) precipitation (1939 through 1961) fell within the indicated ranges.

The growing season has a 30-year average frost-free period of only 51 days, as frosts may occur almost any time during the summer months.

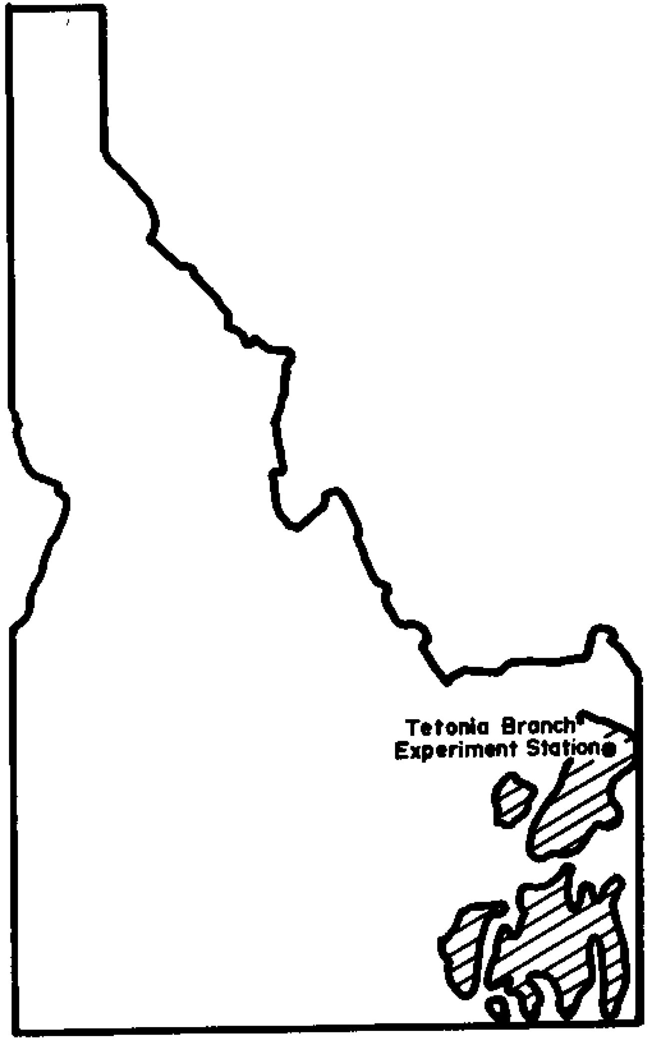

FIGURE 1. — Dryland farming areas of eastern Idaho and location of experiment station.

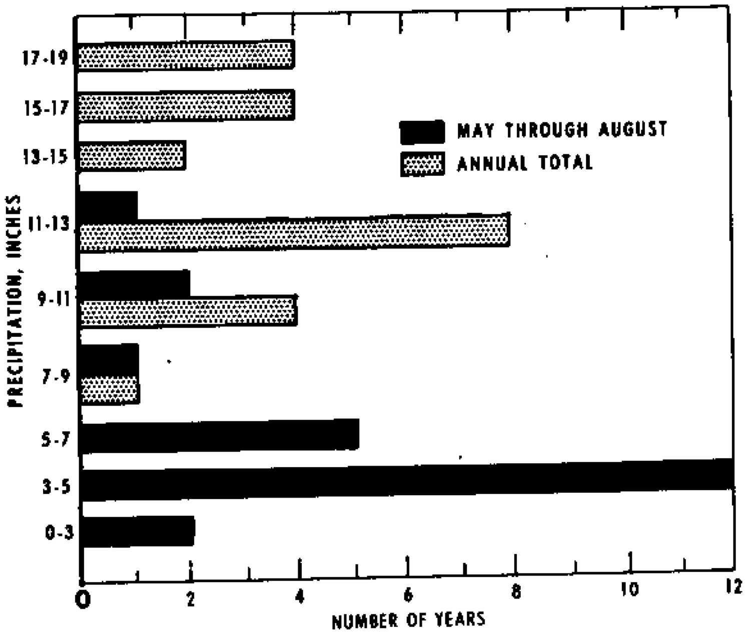

FIGURE 2. — Frequency of precipitation occurring during May through August and annual total precipitation, 1939-61, Tetonia Branch Experiment Station.

EXPERIMENTAL METHODS

Experiments included the following:

1. Stubble management—
   A. After harvest (fall), stubble was (1) left standing, (2) cut and removed, or (3) burned.
   B. Spring of summer fallow year, stubble was (1) burned or (2) not burned.
2. Fall tillage—
   A. After harvest (fall), stubble land was (1) chiseled, (2) disked, or (3) not tilled.
   B. After drilling winter wheat (fall), land was (1) not tilled or (2) rotary subsoiled.
3. Initial fallow operations—
   A. Implements used were (1) moldboard plow, (2) disk, or (3) subsurface sweep tiller.
   B. Initial sweep tillage was performed when soil (3- to 6-inch depth) was (1) moist (near field capacity), (2) medium-moist (50 percent available moisture), or (3) dry (wilting point).
   C. Initial sweep tillage was performed at depths of (1) 3, (2) 5, or (3) 7 inches.
4. Annual and wheat-fallow cropping systems.

Crop yields were measured on all the treatments listed above. In most experiments, soil moisture was measured gravimetrically to a depth of 6 feet in the spring and fall. Soil organic matter content was determined on selected long-term test plots.

Cloddiness and vegetative residue were determined and surface roughness was usually estimated, to evaluate the susceptibility of the soil to wind erosion on experiment 3-B.

Wheat stand was measured on experiment 3-B. Protein content and bushel weight of grain were measured on most experiments.

RESULTS AND DISCUSSION

Stubble Management After Harvest

Snowfall in this dryland area contributes the major portion of the moisture stored in the soil for subsequent crop use. Since moisture supply most often limits crop production, every effort should be made to intercept and hold the snow where it falls, to trap drifting snow, and to facilitate entry of the snowmelt into the soil.

Three methods of managing stubble and straw after harvest were studied from 1954 through 1958. In the fall after harvest, the stubble was (1) left standing, (2) cut and removed, or (3) burned. Initial summer fallow tillage was accomplished by either moldboarding or sweep tilling, and subsequent tillage was by rod weeding.

Soil Moisture

Soil moisture was measured in the spring and the fall of the fallow year, and the spring of the crop year from the fall of 1955 through the spring of 1958. These results are given in table 2. The stubble-left-standing plots (see table 2) gained more moisture because they retained more snow and prevented deep frost penetration. This, in turn, decreased snowmelt runoff and erosion. During winters when the snow drifted, stubble height regulated snow depth. The snow blown from bare fields accumulated in drifts in protected areas. For example, in November of 1956, stubble-left-standing plots had 7.8 inches of snow, with a water content of 1.5 inches, and no frozen soil; stubble-cut-and-removed plots had 3.2 inches of snow, with a water content of 0.6 inch, and 1 inch of frozen soil; and stubble-burned plots had 2.1 inches of snow, with a water content of 0.2 inch, and 3 inches of frozen soil. The next spring these three treatment plots averaged 9.8, 7.1, and 5.2 inches of available soil moisture, respectively.

Crop Yields and Protein Content

Average yield of winter wheat (table 3) was significantly higher where stubble remained over winter after harvest. Yields from the stubble-cut-and-removed and stubble-burned plots were not significantly different. The increase in yields from leaving stubble stand is attributed to greater soil moisture conserved by this method.

The differences in protein content (table 3) among treatments were not statistically significant. The trend toward higher protein content on the stubble-burned treatment should be expected, as protein content is usually highest where moisture is limited and yields are lower.

Fall Tillage After Harvest

During short spring thaws, the rate of snowmelt often exceeds the rate at which the soil can absorb this snowmelt and runoff occurs. Loss of water for crop production, soil erosion, and downstream flooding of lowlands are the natural consequences of this rate differential. The runoff rate increases with steepness of slope, with degree of slope exposure to the sun, and with depth of soil frost.

TABLE 2. — *Available moisture in the 6-foot soil profile for 3 methods of managing stubble — averaged from fall of 1955 through spring of 1958*[1]

Time of sampling	Available soil moisture for treatment —		
	Stubble left standing	Stubble cut and removed	Stubble burned
	Inches	*Inches*	*Inches*
Spring of fallow year	9.8	7.1	5.2
Fall of fallow year	6.4	5.4	4.6
Spring of crop year[2]	6.2	5.5	5.4

[1] A different number of years were averaged to arrive at the mean treatment values among the times of sampling. Although differences due to treatment are valid, differences in moisture among times of sampling should not be compared to arrive at average moisture gains or losses during a period.

[2] Winter wheat had made some spring growth at this time.

TABLE 3. — *Winter wheat yields and protein content from 3 methods of managing stubble after harvest — averaged from 1954 through 1958*

Treatment	Yield	Protein
	Bu./acre	*Percent*
Stubble left standing	29.0	12.3
Stubble cut and removed	25.7	12.6
Stubble burned	24.3	13.0
L.S.D. at 5-percent level	2.8	N.S.

In experiments from 1954 through 1958, subsoiling (by rotary subsoiling and chiseling) and disking were done after harvest while the soil was still dry. All implements, except the one-way disk, left most of the stubble standing. These plots were located on a 7-percent slope and the tillage was done on the contour. Both fallow and crop were represented each year.

Moisture samples were taken from all plots in the fall, and again in the spring after the snowmelt runoff. Summer fallowing involved initial tillage with a blade sweep in the spring and rod weeding during the rest of the fallow season. Winter wheat was grown each crop year except 1957. Dry seedbed conditions in the fall of 1956 prevented the establishment of satisfactory winter wheat stands and spring wheat was substituted.

Commercially available implements were used for the treatments itemized in table 4. The chiseling and rotary subsoiling were done with the mounted tool bar and rotary subsoiler shown in figure 3.

Soil Moisture

Fall chiseling or rotary subsoiling reduced runoff, and in turn increased the amount of moisture stored in the soil (table 4). This increase averaged 1.53 inches

TABLE 4. — *Available moisture gains from harvest until spring, and available moisture losses from spring until fall of the fallow period in the 6-foot soil profile*

Implement	Tillage depth	Shank spacing	Soil moisture	
			Gain from harvest to spring[1]	Loss during summer of fallow[2]
	Inches	*Feet*	*Inches*	*Inches*
Broadpoint chisel[3]	10	7	6.32	1.58
Broadpoint chisel	14	7	6.63	1.53
Diamondpoint chisel[3]	10	3	6.56	1.54
Diamondpoint chisel	14	3	6.74	1.81
Diamondpoint chisel	8	1	6.34	1.66
Rotary subsoiler	14	[4]3	6.65	1.72
Average		....	6.54	1.64
One-way disk	7	....	4.48	1.01
No treatment			5.01	1.20
L.S.D. at 5-percent level			0.63	N.S.

[1] 1953 through 1957 average.

[2] 1954 through 1957 average.

[3] The broadpoint chisel point was 6 inches wide by 6 inches long and the diamondpoint was 3 inches wide by 6 inches long with a diamond-shaped tip.

[4] Produced pits in a 3- by 3-foot grid pattern.

FIGURE 3. — Two types of implements well adapted for fall subsoil operations. The chisel (top) operates well at a depth of 10 to 12 inches. The rotary subsoiler (below) is especially adapted for rolling topography.

per first overwinter period — 30.5 percent more than was stored in untilled plots with standing stubble. Plots one-way disked, however, gained 0.53 inch less moisture than the nontreated plots, since the stubble capable of trapping snow was practically eliminated.

The mechanism whereby subsoiling increases moisture intake is not fully understood. In the absence of soil frost, this soil is quite permeable and neither chiseling nor rotary subsoiling significantly increases moisture intake. Soil frost, however, is the usual condition associated with runoff, and both chiseling and rotary subsoiling apparently alter the soil in some manner that enhances its ability to take in runoff water from melting snow.

Chiseling should be done on the contour — preferably when the soil is dry. There is no experimental basis for tilling deeper than 8 to 10 inches with diamondpoint tools spaced 3 feet apart. Much more power was needed when the tools operated at a depth of 14 inches. In contrast to the chisel implements, the rotary subsoiler can be operated off the contour without seriously contributing to gullying and erosion. However, a row of pits up and down the slope can cause gullying if runoff is heavy.

Despite appreciable summer precipitation, there was a net soil moisture loss during the summer of the fallow period. Therefore, less moisture was available at fall planting time than the preceding spring. The magnitude of this loss was dependent on two factors — summer rainfall and stored soil moisture the preceding spring. The following equation[1] predicts the amount of available moisture in the fall of the fallow year (M^2) from the inches of available moisture in the spring of the summer fallow period (M^1) and the inches of precipitation received during the summer of the fallow period (P):

$$M^2 = 0.64M^1 + 0.36P$$

This equation shows that approximately one-third of the available moisture in the top 6 feet of soil in the spring and two-thirds of the summer rainfall is lost during the summer months. For example, if a soil profile contained 6 inches of available moisture in the spring of the fallow year, one-third of this, or 2 inches, would be lost during the summer. However, if 6 inches of rain fell during the summer, two-thirds of this, or 4 inches, would be lost. Therefore, the larger moisture loss from chiseled plots (table 4) is attributed to the plots having more stored moisture in the spring.

Soil sampling soon after harvest showed that winter wheat used most of the available moisture to a depth of 6 feet. Occasionally, rainfall occurred between the time wheat stopped using moisture and the time of moisture sampling. For this reason, an average of 1.4 inches of available moisture was left in the 6-foot profile after harvest. Soil moisture used by wheat is given in table 5.

Crop Yields

All fall subsoil treatments, except two, significantly increased yields above the check or the one-way disk (table 5). In addition, there were significant differences between some fall subsoil treatments. Differences in moisture use between the various chiseled and rotary subsoiled plots were not significant. Figure 4 shows the improved growth of winter wheat on land that was chiseled after harvest.

[1] From multiple regression analysis made be E. L. Cox, Biometrical Services, Agricultural Research Service, Beltsville, Md.

Wheat yields were directly correlated with available soil moisture. Each additional inch of available soil moisture at the beginning of the growing season increased the yield 2.5 bushels per acre. This relation is indicated in table 5 where the better tillage treatments increased moisture nearly an inch and, proportionately, yielded more grain.

Tillage treatments did not significantly influence protein content or bushel weight of wheat.

TABLE 5. — *Effect of different tillage treatments on yield and soil moisture used by winter wheat from the 6-foot soil profile—averaged from 1955 through 1958*

Implement	Tillage depth	Total soil moisture used	Wheat yield
	Inches	*Inches*	*Bu./acre*
Broadpoint chisel	10	6.88	25.7
Broadpoint chisel	14	7.06	26.8
Diamondpoint chisel	10	7.02	27.0
Diamondpoint chisel	14	7.34	26.2
Diamondpoint chisel	8	7.24	27.2
Rotary subsoiler	14	7.10	28.1
Average	....	7.11	26.8
One-way disk	7	6.82	25.0
No treatment	....	6.05	25.2
L.S.D. at 5-percent level	....	N.S.	1.5

FIGURE 4. — Winter wheat grown on fallow land on a farm north of Newdale, Idaho. Other than chiseling, all operations were the same on both fields. The moisture gained almost 2 years previously by fall chiseling carried through to produce the better growth on the left.

Fall Rotary Subsoiling of Winter Wheat

Trials were carried out in 1952 and from 1959 through 1962 to evaluate the effect of rotary subsoiling after fall seeding on soil moisture storage during the following winter and on subsequent yields.

Although fall rotary subsoiling after planting winter wheat increased the soil moisture intake in the winter an average of 1.35 inches (21.6 percent), this tillage damaged the winter wheat stand and yields were reduced about 1 bushel per acre. Therefore, even though this practice did conserve moisture, it cannot be recommended for general farm usage until the problems associated with decreased yield are solved.

Methods of Summer Fallowing

The maintenance of a straw cover — stubble mulch — to protect the soil against the forces of wind, rain, and runoff water is a proven and accepted method of erosion control on summer fallow lands. The development of specialized farm machinery over the past 20 years has made the task of accomplishing the stubble-mulch condition almost routine. In the Upper Snake River area, the proportion of straw maintained on the surface is largely determined by the tillage implement used for the initial tillage, because subsequent tillage (weeding operations) is done almost exclusively with the rod weeder. The moldboard plow buries practically all of the stubble residue; the one-way and offset disks leave approximately 20 percent on the surface; and the sweep or subsurface implements leave 80 to 90 percent. Depending on the number of operations, rod weeding further reduces the quantity of residue, but not seriously.

An experiment[2] was conducted from 1940 to 1958 to compare various methods of summer fallowing. These treatments are shown in table 6. After the initial tillage treatment, all plots were rod-weeded to control weeds. The moldboard plow treatments were usually followed by harrowing soon after plowing to minimize loss of moisture by evaporation. The stubble was burned either in the fall or spring of the year before initial tillage, depending on suitability of conditions for burning.

Crop Yields

Average winter wheat yields over an 18-year period are shown in table 6. The highest average yield was from tillage with a subsurface implement (as shown in fig. 5) where the stubble was left unburned. The general effect of burning during the first 6 years of the experiment

[2] For more detail concerning this experiment, see Idaho Agricultural Experiment Station Bulletin No. 252, March 1956. (Out of print.)

was to increase yields, but after that, yields were usually depressed by burning. The decreased yields from burning were also more pronounced during low-moisture years when crop yields were below average.

The relative yield for the unburned treatment

$$\left(\frac{\text{yield of unburned}}{\text{yield of burned}}\right) \times 100,$$

designated as Y_u, is related to the number of years of cropping (N), and average yield in bushels per

FIGURE 5. — Two types of sweeps used for stubble-mulch fallowing: Either implement can be modified for fall chiseling.

acre (A) by the following regression equation:[3]

$$Y_u = 101.95 + 1.17N - 0.36A$$

The fluctuations in Y_u were influenced mainly by N and to a lesser extent by A. As crop yields reach an equilibrium with time for this particular soil, the observations over the past 18 years indicate that yields from unburned land will level off at a higher value than the yield from burned land. Figure 6 is a graphic presentation of the foregoing equation and illustrates the yield trends over the test period.

The 4,000 pounds of residue per acre treatment produced no definite yield response, as compared to the other treatments — which initially had less than one-half this amount. This indicates that more residue than is normally available could be used for obtaining erosion control and for

[3] R value for this equation = 0.60 (significant at 5-percent level). Standard partial regression coefficients and t values are $b'(Y_u)\ 1{\cdot}2 = 0.5172$ with t value of 2.406 (significant at 5 percent), and $b'(Y_u)\ 2{\cdot}1 = -0.2117$ with t value of 0.98 (N.S.).

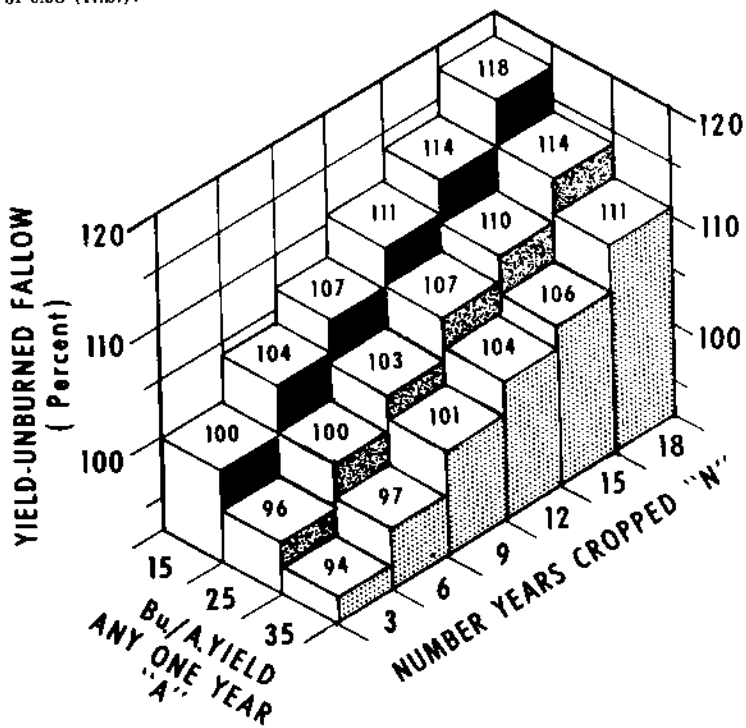

FIGURE 6. — A graphic presentation of equation $Y_u = 101.95 + 1.17N - 0.36A$, which relates relative unburned yield with yield for any one year and number of years cropped.

improving the soil physical condition without decreasing crop yield.

Protein content (table 6) was increased by burning stubble, by fall plowing, and by applying nitrogen. Where stubble was utilized as a mulch, protein content decreased. Yields, however, were generally greater on the stubble-mulched plots.

Soil Organic Matter

The soil organic matter content of each plot was measured at the initiation of the experiment in 1938 and at each 5-year interval thereafter through 1958. Since the trend is still downward, organic matter content has not stabilized during this period under most tillage systems. Organic matter content from all plots (excluding those which had straw maintained at 2,000 or 4,000 pounds per acre) averaged 2.94 percent in 1938, 2.86 percent in 1948, and 2.75 percent in 1958. The average 20-year loss from burned plots was 8.90 percent of the initial content, whereas the average loss from comparable nonburned plots was 7.26 percent. The only plots that did not lose organic matter during the 20-year period were those maintained at a level of 4,000 pounds of straw per acre — starting in 1938 with 3.01 percent and ending in 1958 with 3.04 percent. Where 2,000 pounds of residue were maintained, losses averaged 3.66 percent of the original content. Soil erosion was negligible in this experiment and, therefore, did not affect organic matter changes.

TABLE 6. — *Winter wheat yields and protein content as influenced by methods of fallowing — averaged from 1940 through 1958*[1]

Initial fallow treatment	Yield	Protein content
	Bu./acre	*Percent*
Moldboard plowing:		
a. Stubble burned	23.4	15.2
b. Stubble not burned	23.3	14.5
One-way disking:		
a. Stubble burned	22.5	15.1
b. Stubble not burned	23.6	14.6
Subsurface tilling:		
a. Stubble burned	23.4	15.2
b. Stubble not burned	24.5	14.2
One-way disking:		
a. 15 pounds nitrogen applied per acre per crop year	23.8	14.9
b. Straw added or removed to provide 2,000 pounds per acre	23.7	14.4
c. Straw added to provide 4,000 pounds per acre	23.4	14.4
Fall moldboard plowing	23.9	15.1
Average	23.6	14.7

[1] Yield average excludes 1952 data because of frost damage. Protein content was not analyzed in 1945, 1952, or 1958.

Initial Summer Fallow Tillage

Since summer rainfall is often inadequate to insure the establishment of satisfactory stands of winter wheat, the tillage program should be managed to conserve and maintain the moisture at the soil seeding depth.

This experiment was started in 1957; data were obtained from 6 fallow periods and 5 crop years. The plot site was uniformly chiseled in the fall after harvest and sweep-tilled[4] in the spring at depths of 3, 5, or 7 inches at three moisture levels as follows:

1. Moist — tilled in the spring as soon as the land could be satisfactorily worked. On this first date of tilling, soil moisture averaged 16.9 percent in the 3- to 6-inch soil layer.
2. Medium-moist — tilled when about one-half of the available moisture in the 3- to 6-inch soil layer remained, or when average soil moisture content at time of tillage was 13.0 percent.
3. Dry — tilled when the available moisture in the 3- to 6-inch soil layer was virtually depleted (average moisture level 8.7 percent).

Soil moisture levels 2 and 3 were obtained by delaying spring tillage until volunteer wheat, weeds, and surface evaporation reduced soil moisture to indicated amount. Subsequent tillage was done with a rod weeder.

Soil Moisture

Soil moisture in the 3- to 6-inch layer at fall planting time was related to moisture conditions when fallow was initiated. Table 7 shows that fall (September 15) moisture levels for the moist and medium-moist treatments were less than the spring moisture levels. The dry plots accumulated moisture from precipitation during successive seeding dates, whereas the moist plots lost moisture by evaporation in excess of the precipitation. This accumulation on dry plots, however, was not sufficient to estab-

[4] The sweep implement shown in the upper part of figure 5 was used for initial tillage.

TABLE 7. — *Moisture content in the 3- to 6-inch soil layer as influenced by time of initiating fallow tillage — averaged from 1957 through 1962*

Initially tilled when —	Moisture when tilled in spring	Moisture at subsequent sampling dates		
		August 15	September 1	September 15
	Percent	*Percent*	*Percent*	*Percent*
Moist	16.9	13.8	14.8	13.6
Medium-moist	13.0	12.0	12.7	12.8
Dry	8.7	7.4	8.8	10.3

lish good stands of fall-planted wheat.

There was significantly less moisture (table 8) in the 6-foot soil profile of the dry treatment than in either of the other two treatments. The difference in profile moisture content between the moist and medium-moist treatments was not significant.

Wind Erodibility

Wind erodibility[5] in the fall of the fallow year was estimated from soil roughness, soil cloddiness, and quantity of surface residue. The plots were moderately erosive, ranging from an erodibility value of 0.5 to 1.0 ton of soil per acre. The surface of the medium-moist plots was 1.2 times more erodible than the moist plots, and the surface of the dry plots was 1.7 times more erodible than the moist plots.

The amount of surface residue was the primary factor that contributed to differences in wind erodibility. There was more residue on the moist plots, because they produced more wheat growth the previous year than the other plots. The proportion of nonerodible clods was slightly less on the dry plots than on the other two. Soil roughness was approximately the same under all treatments.

Weed Control

Weed infestations in the wheat crop were much worse on the dry and medium-moist plots than on the moist plots. Cheatgrass and other annual weeds had an opportunity to establish themselves on the dry plots before the initial tillage for the fallow year was done. This established cheatgrass on the dry plots reseeded after the initial tillage despite rod weeding during the year and contributed to further infestation.

Where wheat stands were poor to fair, weeds had less competition and flourished during the spring of the crop year. Broadleaf weed control with 2,4-D was not so successful on these plots as on others with good wheat stands.

[5] Estimated by method described by Chepil, W. S., and Woodruff, N. P.: Estimations of wind erodibility on farm yields. U.S. Dept. Agr. Prod. Res. Rpt. 25, 21 pp. 1959. (Out of print.)

TABLE 8. — *Available moisture in the 6-foot soil profile as influenced by time of initiating fallow tillage — averaged from 1957 through 1962*

Initially tilled when —	Available moisture in fall
	Inches
Moist	6.75
Medium-moist	6.56
Dry	5.87
L.S.D. at 5-percent level	0.46

Crop Stands and Yields

The success of establishment of winter wheat depended on surface soil moisture content at seeding time. By sweep tilling in the spring as soon as the soil could be properly worked, winter wheat stands averaged 86 percent over a period of 5 years (table 9). If spring tillage was delayed until approximately one-half of the available moisture in the tillage zone was depleted or until all of the available moisture in this zone was depleted, the respective winter wheat stands were reduced to 79 and 53 percent, respectively.

Yields were highest from the moist treatment (table 10). Average yields decreased from 29.4 to 26.5 bushels per acre when tillage was delayed until the surface soil was medium-moist. Yields for the 4 years that acceptable stands were obtained on the dry plots averaged 23.2 bushels per acre. Figure 7 shows differences in wheat growth on dry, medium-moist, and moist plots.

The data from tables 9 and 10 indicate that a 50-percent stand produced a two-thirds yield. Because of the relatively lower pro-

FIGURE 7. — Stand and growth differences in winter wheat resulting when seedbed was tilled while (A) dry, (B) medium-moist, and (C) moist.

TABLE 9. — *Relative winter wheat stands resulting from time of initiating fallow tillage — 1958 through 1962*

Initially tilled when —	Stand[1]					
	1958	1959	1960	1961	1962	Average
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Moist	98	91	59	97	85	86
Medium-moist	95	76	51	87	84	79
Dry	58	53	1	72	79	53

[1] The percentages shown indicate estimates of viable seed that produced plants. Stands were quite uniform within plots during all years.

TABLE 10. — *Yield of winter wheat resulting from time of initiating fallow tillage — 1958 through 1962*

Initially tilled when —	Yield 1958	1959	1960	1961	1962	Average
	Bu./acre	*Bu./acre*	*Bu./acre*	*Bu./acre*	*Bu./acre*	*Bu./acre*
Moist	23.4	31.1	24.4	25.6	42.4	29.4
Medium-moist	19.6	29.5	21.0	26.8	35.7	26.5
Dry	14.9	23.2	[1]17.0	20.7	33.8	21.9

[1] Spring wheat was planted in these plots.

ductivity of spring wheat, reworking a 50-percent winter wheat stand in the spring and seeding to spring wheat usually result in a yield no higher than if the winter wheat had been left. At the Tetonia Branch Experiment Station, 1922-60 average yields of spring wheat have been 5 bushels less than those of winter wheat. Test weight and protein content of wheat were not significantly influenced by the moisture level treatments.

Effect of Tillage Depth

Differences in moisture storage and yield due to tillage depth were not significant. Although the 3-inch tillage depth does seem quite shallow, no tillage difficulties were experienced. The seedbed was more firm when initially tilled at 3 inches than when tilled deeper. Shallow tillage takes less power and costs less; therefore, there is no advantage in tilling any deeper than necessary.

Summer Fallow Cropping of Winter and Spring Wheat

Winter wheat usually outyields spring wheat when these crops are grown after fallow. Because winter wheat matures earlier than spring wheat, it is less susceptible to drought. The drought resistance of winter wheat is also increased by its earlier and deeper rooting. Soil samples taken on May 18, 1960, showed that winter wheat already had roots below the 4-foot depth, whereas spring wheat had just been planted and had not yet emerged. Winter wheat roots penetrate at least 6 feet, if soil moisture is available to that depth; spring wheat roots extracted a negligible amount of moisture below the 4-foot depth at the Tetonia station.

Winter wheat at this location has outyielded spring wheat by about 5 bushels per acre. In hard red wheat variety trials conducted from 1922 through 1960, Turkey winter wheat averaged 27.6 bushels per acre, whereas Marquis spring wheat averaged 22.4 bushels per acre.

Annual Cropping With Winter and Spring Wheat

Winter Wheat

Annual cropping of winter wheat was compared with wheat grown after fallow from 1940 through 1948. For this period, annually cropped winter wheat yielded 11.2 bushels per acre per year as compared with 13.6 bushels per acre per year for winter wheat after fallow. Precipitation was above average during this trial period. Therefore, the yield differences between annual and summer fallow cropped winter wheat were narrower than would be expected under average moisture conditions. With time, weed populations became increasingly more severe on the annually cropped plots and, by 1948, cheatgrass had become such a problem that the trial was discontinued.

Even after fallowing, inadequate seedbed moisture often makes it difficult to obtain good winter wheat stands in the fall. Because of this moisture limitation, it is doubtful that annual cropping of winter wheat has a place in this dryfarming region.

Spring Wheat

Three spring wheat cropping systems were compared — wheat was grown (1) continuously on land that was not fall chiseled, (2) continuously on land that was chiseled in the fall (fig. 8), and (3) after fallow where chiseling was done after harvest. This experiment was conducted for 6 years and includes 5 years of comparative yields. Nitrogen fertilizer was applied on all cropping system treatments at rates of 0, 10, 20, 40, and 80 pounds per acre each crop year. Baart spring wheat was seeded at a rate of 40 pounds per acre.

FIGURE 8. — Annually cropped spring wheat showing differences due to fall chiseling.

Moisture Storage. — The moisture gained from harvest until planting was similar under annual cropping and after fallowing, where both were chiseled after harvest (table 11). When annually cropped plots were not fall chiseled, the moisture gained was 2 inches less than on the other two treatments.

Crop Yields. — Continuously

TABLE 11. — *Available moisture in the spring of the crop year under 3 cropping systems — averaged from 1955 through 1960*

Cropping systems	Moisture in 6-foot soil profile
	Inches
Annual cropped, not chiseled	6.2
Annual cropped, fall chiseled	8.5
Cropped after fallow, chiseled after harvest	8.9

cropped spring wheat yielded 6.1 bushels more per year than spring wheat grown after summer fallow, where the continuously cropped plots were fall chiseled.

As table 12 shows, fall chiseling on the annually cropped plots improved yields in 1956, 1959, and 1960. During these years, spring runoff occurred and chiseling facilitated moisture intake.

Crop yields varied considerably during the period of the experiments, ranging from a low of 5.7 to a high of 27.6 bushels per acre. Low yields occurred only if available soil moisture was less than 6.5 inches in the spring of the year. Since the soils at this location will hold slightly more than 2 inches of available moisture per foot, 6.5 inches of moisture wet the soil to a depth of about 3 feet.

The lower rates of nitrogen fertilizer increased yields on all cropping systems if moisture was sufficient to produce yields in excess of 15 bushels per acre. There was an average increase of 3 bushels per acre from the 10- and 20-pound rates of nitrogen. Higher nitrogen rates were generally not justified and sometimes decreased yields.

The annually cropped plots were more weedy (mainly Russian-thistle) than summer fallow cropped plots. Although all wheat was sprayed with 2,4-D, weeds probably reduced yields slightly on the annually cropped plots.

There were no crop failures during the 5 years of this experiment under the following conditions, even though precipitation was below normal. Therefore, it may be concluded that annual cropping of spring wheat is feasible if (1) the soil is deep and medium or fine textured, (2) moisture at planting time has penetrated to at least 3 feet, (3) a small amount of commercial nitrogen (15 to 20 pounds per acre) is applied, and (4) weeds can be satisfactorily controlled.

TABLE 12. — *Yields from 3 spring wheat cropping systems — 1956 through 1960*

Year	Annually cropped		Cropped after fallow, fall chiseled
	Not chiseled	Fall chiseled	
	Bu./acre	*Bu./acre*	*Bu./acre*
1956	5.7	18.9	20.9
1957	17.3	14.8	19.4
1958	21.9	20.6	27.6
1959	9.4	12.4	16.1
1960	12.8	15.1	19.1
Average/crop year	13.4	16.4	20.6
Average/year	13.4	16.4	10.3

SUMMARY

Fallowing is an extremely inefficient method of storing soil moisture in the Upper Snake River dryfarming area, because there are periods when evaporation exceeds precipitation. Runoff further decreases the moisture storage potential and also causes erosion.

When snowdrifting occurred during these studies, stubble land retained more snow than bare land. Because of this additional snow, frost penetration was decreased and moisture storage and crop yields were increased.

Postharvest subsoiling in standing stubble significantly increased moisture intake from melting snow and increased crop yields. However, fall rotary subsoiling in newly established winter wheat damaged the stand and reduced yield even though moisture intake was increased.

Stubble-mulch fallow was superior to other fallow methods for wheat production. Burning stubble prior to fallowing increased the rate of soil organic matter loss and, although yields were initially increased, they became significantly lower with additional years of burning.

Tillage for fallowing as early in the spring as moisture conditions permitted increased soil moisture retention and resulted in better winter wheat germination and increased yield. When this tillage was delayed until about one-half of the available moisture in the 3- to 6-inch depth remained, the proportion of wind-erodible soil aggregates was greater and weed infestations in the succeeding crop were more serious. Loss from wind-erodible soil was greater and weed infestations were intensified when the tillage was delayed until no available soil moisture remained. Depth of tillage did not significantly influence moisture storage or crop yield.

Continuous cropping produced higher annual spring wheat yields than cropping after fallow where both were preceded by chiseling stubble after harvest. This system of annually cropping spring grains seems to be the most efficient means of capitalizing on the relatively high moisture storage during the first winter after harvest.

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