Bulletin No. 358 - Effect of Cropping Practices on Water Intake Rates in Northern Great Plains

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Effect of Cropping Practices on WATER INTAKE RATES in Northern Great Plains

By O. K. Barnes and D. W. Bohmont
Effect of Cropping Practices on Water-Intake Rates in Northern Great Plains

By O. K. BARNES and D. W. BOHMONT

MOISTURE CONSERVATION to dryland farm operators rates high as a factor in their operation. Rainfall is, of course, the first essential in dryland operations. With rainfall comes the opportunity for manipulating use of the moisture. The crop selected will effect efficiency of moisture utilization. Water losses through evaporation and runoff also enter into the efficiency of moisture use. Since 1954, water-intake measurements have been made at the Sheridan Station to evaluate various crop and soil-management practices in terms of ability to absorb water during heavy rainstorms and during the winter when the soil is frozen. This bulletin summarizes results obtained in these studies.

Storm intensities vary across the country. In some areas and on certain soils little or no water is lost through runoff. Obviously, special practices designed to catch and hold more water would have little application to such sites. However, in most of the plains area, storm intensities often exceed the water-intake rate of the soil and valuable water is lost as runoff. In such cases with special management practices, soil losses may be reduced and water may be trapped in the soil for later crop use. In addition to water losses from summer storms there are warm periods during the winter when snowmelt on frozen soils results in the loss of water.

Studies were established to evaluate different dryland farming practices through determining water-intake efficiencies during heavy rainstorms under controlled conditions. No attempt has been made to associate rainfall intensities to that which may be expected in any specific area. However, the principles derived from these studies may be of value wherever dryland farming is practiced.

EXPERIMENTAL PROCEDURE

All results reported here were obtained on a deep, silty clay loam in the Ulm soil series at the Sheridan Experimental Station near Sheridan, Wyoming. These soils on the station are unusually uniform. Most comparisons reported here were from plots on a slope of 2 to 3 percent. A few of the test plots with fall tillage were located on the same soil series but on an 8 percent slope.

1Research reported herein is a joint effort and is part of the Wyoming regional research contributing project to W-32.
2Superintendent, Sheridan Experiment Station and Soil Scientist, Soil and Water Conservation Research Division, ARS, USDA; and Head, Department of Agronomy, University of Wyoming, Laramie, Wyoming, respectively.
Water-absorption measurements were made with a mobile infiltrometer shown in Figure 1. This equipment can be adjusted to apply simulated rainfall at any desired intensity up to 6 inches per hour. Most tests were made with a storm intensity of about 3 inches per hour for a 1- or 2-hour period. The water from the supply tanks in the truck is pumped under constant pressure to a nozzle in the top of the tower. This spray falls on a drip screen 4 feet below the nozzle. This drip screen has pieces of yarn at 1-inch intervals to form uniform drops of water that fall on the test plot area. Drop size can be varied by changing the size of the yarn. The simulated rainfall covers a circular area of 13 sq. ft. and centered within this area is a test plot of 4 sq. ft. This test area is protected with a knifedged iron runoff frame, 6 inches high, which is pressed into the soil 2 inches below the surface with the remaining 4 inches above the surface. All runoff water from this plot is picked up with a suction hose and deposited in a measuring container. The application rates are carefully checked before, and at the end of each test and with the known applied rate and measured runoff the difference gives the amount absorbed. This equipment has proven very useful in that a series of tests provide a good measure of what a soil condition or treatment may do under natural rainstorms.

Variations in soil moisture prior to the test runs were usually small. In all cases within group comparisons the intake tests were completed without interference of natural rainstorms.
during the period when the tests were being made. There were, of course, differences in soil-moisture content on fallowed plots and the recently harvested stubble land but in most cases direct comparisons are not made between treatments with appreciable soil-moisture differences.

RESULTS

Water-intake rates are shown graphically so that a rapid comparison can be made at any point during the 1- or 2-hour test. Intake rates at the end of the run and total water taken in during the simulated rainstorm are also shown.

Water-Intake Rates on Three Cover Conditions
Bare Fallow—"Trashy" Fallow—Perennial Sod Cover

Three adjoining one-tenth-acre plots with different kinds of surface cover were tested for ability to absorb water during heavy rainstorms. Four separate tests were made for each condition. With such contrasting conditions as fallow and sod cover some differences existed in soil moisture at the time the tests were started in July. The bare fallow had 17.3 percent moisture at the 0-6 in. depth and 20.7 percent at the 6-12 in. depth. The "trashy" fallow had 12.7 and 18 percent and the sod ground 9 and 14.5 percent for the same depths. Such differences in initial soil moisture would have some influence on water-intake rates during the first part of the 1-hour simulated rainstorm. However, for the full period of the simulated storm such differences would not be expected to greatly change the relative water-intake rates for these three cover conditions. Water-intake rates are shown in Figure 2 for a 1-hour artificial rain. Figure 3 shows the cover conditions of these three treatments at the time the comparisons were made.

The bare or "black" fallow was plowed land where all surface residue had been turned under, the "trashy" fallow was subsurface tilled stubble land with a good cover of residue on the soil surface while the sod cover was a good established stand of crested wheatgrass and alfalfa. Residue measurements were not made on the "trashy" fallow and grass/alfalfa at the time the tests were made. Estimates of the amount of cover were 2,000 lbs. per acre on the "trashy" fallow and 800 lbs. on the grass/alfalfa plots.

At the end of the 1-hour run the "black" fallow plot had a water-intake rate of .34 in. per hour, as compared with 2.26 in. per hour for the "trashy" fallow and 1.20 in. per hour on the grassland. Total water absorbed by the soil during the full 1-hour run amounted to 1.55 in. on the "black" fallow, 2.80 in. on the "trashy" fallow and 2.11 in. on the sod land.

In another test to evaluate cover effects, a series of runs were made on a stubble field recently combined. In these tests the soil was extremely dry and total water intake was higher.
than in the above test. Three conditions were evaluated; first, straw and residue as it was left after combining with a total of 2,850 lbs. per acre; second, all loose straw raked and removed leaving only the standing stubble which amounted to 1,130 lbs. per acre; and third, the stubble and residue was burned leaving no ground cover.

Water-intake tests showed that the burned area took in 1.80 in. of water in 1 hour as compared with 2.33 in. where all loose straw had been removed leaving only the standing stubble and 3.51 in. in 1 hour where all stubble and residue was left undisturbed. The appearance of these conditions is shown in Figure 4 and the water-intake rates in Figure 5.

In the above comparisons the data indicate the importance of cover as well as the condition of the cover on water absorption. This points up what would be expected, that a given amount of residue in an erect condition is less effective in maintaining high water-intake rates than residue in prostrate position. As shown in Figure 5 there was little difference in the water-intake rate at the end of the hour where stubble had been burned or where loose straw had been raked leaving 1,130 lbs. of residue per acre at time of the test.
Fig. 3-A—The surface condition shown in this view during a heavy simulated rainfall of 1 hour allowed the soil to absorb 1.5 inches of water. At the end of the hour the beating and sealing action of the rain had reduced the water-intake rate to 0.34 inch per hour.

Fig. 3-B—The same soil as above when covered with residue as shown in this view allowed the soil to absorb 2.8 in. of water in 1 hour. With this protection the water-intake rate at the end of the hour was at the rate of 2.3 in. per hour.

Fig. 3-C—Next to the above 2 fields, tests were run on a good stand of grass and alfalfa that is regularly cut for hay with the usual amount of cover left after haying. The average amount of water absorbed with this cover condition was 2.1 in. in 1 hour. The water-intake rate at the end of the hour run was at the rate of 1.2 in. per hour.
Fig. 4-A — Stubble and residue as left after combining with 2854 lbs. per acre at the time water-intake measurements were made. A total of 3.5 in. of water was absorbed in a 1-hour run.

Fig. 4-B — Stubble after raking and baling loose straw, leaving 1128 lbs. per acre mostly in the form of standing stubble. This condition absorbed 2.3 in. of water in 1 hour.

Fig. 4-C — Plots where all residue was burned leaving a bare surface. A total of 1.8 in. of water was absorbed in a 1-hour run.
Effect of Fall Tillage on Water-Intake Rates

Several types of tools have been tested for tilling and loosening stubble fields in the fall while the soil is dry as a means of increasing water absorption. Three of the tools used are shown in Figure 6. All three have produced marked improvement in water-absorption rates in the fall and winter. The toolbar with the alfalfa-renovator teeth at 9 in. intervals and operated at 6- to 8-in. depths has been especially effective on stubble land.

<table>
<thead>
<tr>
<th>Total Water Absorbed in 1 hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>2854 lbs. per acre as combined</td>
</tr>
<tr>
<td>1128 lbs. per acre standing stubble only</td>
</tr>
<tr>
<td>All residue burned</td>
</tr>
</tbody>
</table>

Fig. 5—Effect of different amounts of cover on water-intake rates.

(Intake rates in inches per hour at 5-minute intervals.)
Fig. 6-A—Various tools may be used for loosening the soil in the fall, when soils are dry, and still retain most of the stubble in a standing condition. Heavy chisel points set at 4-ft. intervals and operated at 10- to 14-in. depths have been effective in improving water-intake rates under some conditions.

Fig. 6-B—Another effective tool for fall tilling has been a toolbar with alfalfa-renovator teeth spaced at 9-in. intervals. When the straw and residue left after combining amounts to 1 ton or less per acre, clogging has not been a serious problem, and the tool has done an excellent job of loosening the soil 6 to 8 in. deep.

Fig. 6-C—The Noble blade shown here has been effective in loosening the soil and leaving the stubble in a standing position. For fall tillage it has been operated at 8- to 10-in. depths. Somewhat more power is required for this type of operation.
where the residue amounts to 2,000 lbs. per acre or less. Quantities greater than this result in excessive machine clogging. Heavy chisels spaced at 4-ft. intervals and operated at 10- to 15-in. depths in very dry soil produce a good shattering and loosening effect and can be used on fields with greater amounts of residue. However, at the 4-ft. spacing there is a zone between the chisel marks that receives little disturbance and water-intake rates in this area are very slightly improved. The Noble blade, operated at 8- to 10-in. depths in the fall when the soil is dry, does an excellent job of shattering, loosening and creating conditions receptive to water. Considerably more power is required to operate the Noble blade under these conditions than is required for the other two tools. One of the advantages of the above type of fall tillage is the loosening effect without seriously disturbing the standing stubble.

Water-intake measurements were made on land treated with these three implements soon after treatment and compared with undisturbed stubble-land. Results of two 1-hour tests shown in Figure 7 show that treated stubble land took in water 60 to over 100 percent faster than the non-treated stubble land. Deep chiseling greatly increased water absorption, but was less effective than the Noble blade or a ripping treatment with the alfalfa implement.

Additional tests of water-intake rates were made the next summer on
The fields tilled the previous fall. This was done after the usual summer-fall operations, which had included a subsurface tillage and a disk operation for weed control. At the time water-intake tests were made during the summer there was little surface residue remaining. Only two treatments were completely evaluated in terms of water-intake rates. Tests made were on the stubble land that was fall treated with the Noble blade as compared with stubble land that had received no fall tillage. Results of these tests are shown in Figure 8. In the average of a series of 2-hour runs there was no appreciable difference in the rate of water absorption on the land that had been tilled the previous fall with the Noble blade as compared with land receiving no fall tillage. In other words, the summer-tillage operations had erased the advantage that had existed during the fall and winter on land receiving a fall-tillage treatment. The other fall treatments would be expected to follow a similar pattern.

These tests strongly indicate that ripping or similar tillage operations in the fall would generally have little influence on water-intake rates after mechanical tillage was used for summer weed control. If chemical weed control can be used and thereby retain the shattering and loosening ef-

Fig. 8—Water-intake rates measured in late summer on land fall-tilled with Noble blade as compared with non-fall-tilled land after similar summer tillage operations.

(Water-intake rates in inches per hour at 5-minute intervals.)
ects of the fall tillage the results have shown an advantage for fall tillage. Fall tillage of a stubble land in some areas is usually beneficial during the winter where water losses occur from fast snowmelt.

Water-Intake Rates During the Winter

Some preliminary work was done during the winters of 1957 and 1958 at Sheridan on water absorption when the soil was frozen to a depth of 1 ft. or more. In these tests an attempt was made to simulate flowing water as would occur with melting snow. The temperature of the water used in these was reduced to about 35 degrees. On the different test plots a continuous flow of a known quantity of water was maintained for 1-hour periods. This applied amount minus the measured runoff provided a relative measure of water absorbed in the soil.

Stubble fields on finer-textured soils when ripped or tilled in the fall while the soil is dry usually are well shattered and loosened by such treatment. This condition is shown in Figure 9. During the winter when the soil is frozen this loosened soil has taken in flowing water at a rate of over 6 in. per hour. Stubble fields that are left undisturbed in the fall freeze in a consolidated condition that is almost impervious to water. In a series of hour-long runs on frozen soil on undisturbed stubble ground, less than \( \frac{1}{2} \) in. of water was taken in by the soil, and this was in the top 2 in. of

Fig. 9—Appearance of wheat stubble in the fall following tillage with a toolbar with alfalfa-renovator teeth at 9-in. intervals operated at 6- to 8-in. depths. A good shattering and loosening job is obtained but still leaves much standing stubble to hold snow and protect the soil. This operation is followed the next summer with chemical fallow, which retains this standing stubble until after winter wheat is again seeded.
surface soil. Water held in this zone would usually be lost by evaporation. Thus, in locations where water is commonly lost during snowmelt and particularly on fields where consider-
able snow drifting may occur, fall tillage of stubble land may be worthwhile as a means of getting water into the soil at a depth where it will be retained for growing-season use.

**Water-Intake Rates on Different Fallow Methods**

Recognizing the importance of surface cover to maintaining high water-intake rates, a study was started in 1954 to find a method of using chemicals to control weeds on fallow land and thereby preserve residue cover. Studies made during this period indicate that chemical fallowing on some soils results in some undesirable soil conditions but a combination of tillage and chemical weed control appears desirable.

A number of tests have been made of these methods in terms of ability to handle intense storms. Wheat yields were studied also and information on this may be obtained from the Wyoming Experiment Station at Laramie.

Figure 10 shows the water-intake rate from land fall-ripped with an alfalfa renovator and then fallowed with Dowpon and 2,4-D all the next summer with no mechanical disturbance except drilling of the wheat at the end of the fallow season. This method is compared with conventional fall plowing and with mechanical summer fallowing. The third method

![Water-intake rates on three different fallow methods.](image)

*Fig. 10—Water-intake rates on three different fallow methods.*
*(Water-intake rates in inches per hour at 5-minute intervals.)*
compared is chemical fallow with no mechanical tillage at any time.

Water-intake data in Figure 10 represent an average of nine 1-hour runs for each treatment. The results show that the plowed or "black" fallow in midsummer took in an average of 1.67 in. of water in 1 hour as compared with 2.57 in. on the fall-ripped chemical fallow and with 2.12 in. on the chemical-fallow land. Intake rates at the end of the 1-hour run on the plowed fallow were .69 in. per hour as compared with 2.16 in. on the fall-ripped chemical fallow and 1.18 in. per hour on the chemical-fallow land.

At the time the above tests were made the fall-ripped chemical-fallow land had an average of 2,050 lbs. of surface residue per acre as compared with 3,150 lbs. on the chemical-fallow land and no residue on the plowed fallow. It is apparent that the fall-ripping operation in connection with the chemical fallow has provided a surface condition that is sufficiently more receptive to water entry to offset the usual effects of the greater amount of residue that was present on the chemical-fallow land. Also, the data indicate that, when chemical fallow is used after fall tillage, the treatment benefit persists through the summer.

**Effects of Chemical Fallow for Four Years on Water-Intake Rates**

When the chemical-fallow studies were started at Sheridan, water-intake measurements showed relatively large advantages for this method as compared with plowed fallow. The surface protection provided by the chemical-fallow method resulted in water-intake rates of from 1 to more than 2 times greater than on the plowed fallow land. However, as the same land was kept in chemical fallow with no mechanical disturbance, the evidence began to indicate the development of a dense, compact soil condition that may interfere with water movement. Figure 11 shows water-intake rates on plots under a chemical-fallow system that has not been plowed or mechanically disturbed since 1953 as compared with soils that have been plowed every other year for fallowing. In 1957 the chemical fallow took up 2.27 in. of water in 1 hour compared with 2.08 in. on the plowed "black" fallow. Three years previously the same plots showed a difference of about 100 percent in favor of the chemical fallow.¹

On the basis of data collected to date, it appears that on finer-textured or "heavier" soils some form of mechanical tillage is probably necessary in connection with chemical fallowing. It appears that a hard, dense layer develops after a few years in the top 2- to 4-in. of soil which adversely affects water entry as well as plant development. All indications to date are that some type of tillage for shattering and loosening at depths of 6- to 12-in. when the soil is dry improves this condition.

**Effect of Surface Conditions on Water-Intake Rates**

Comparisons of water-intake rates were made on the same plots of "black" fallow in 1956 and 1957. In 1956 the surface soil was mellow and

¹Water-intake measurements made by Frank Rauzi, ARS, in 1954.
would be considered in good tillth. In 1957 one tillage operation left the surface with numerous clods of 1 to 3 in. in diameter. These became baked and extremely hard. This condition persisted throughout the summer. To evaluate these two conditions of "black" fallow, a series of runs were made with the rainfall simulator. The data collected on these conditions are shown in Figure 12. In this series of 1-hour tests the hard, cloddy condition took in 2.30 in. of water as compared with 1.67 in. where the surface was less cloddy. As shown in Figure 12, the cloddy surface conditions absorbed a storm of 2.85 in. of water per hour for 30 min. as compared with only 10 min. for the soil with the more pulverized surface. The appearance of these two soil conditions is shown in Figure 13.

**Long-Time Cropping Effects on Water-Intake Rates**

Numerous variations in cropping methods have been studied at the Sheridan Station over the past 40 years. In general most cropping practices through this period have resulted in a loss of 20 to 40 percent of the organic matter since the land was first broken from virgin sod in 1916. One continuous cropping rotation included the use of barnyard manure every third year throughout this period. This practice has maintained the organic matter at approximately the same level that was present in
1916. An adjacent plot that had the same crop rotation but with no manure, lost approximately 36 percent of its organic matter since 1916.

In 1956 both of these plots were in "black" fallow with no evident difference in surface condition. A series of water-intake tests was made to test these two conditions for water absorption during an intense storm. Figure 14 shows the results of this test. Under an intense simulated storm and with no residue protection on the surface there was little difference in water absorption for soil where the organic matter had declined by 36 percent as compared with soil where the organic matter level had been maintained through the period of years by addition of manure. It should be emphasized that these tests were with an intense rain of nearly 3 in. per hour and that the surface had no residue cover.

Another comparison was made on soil where a green-manure crop had been turned under every year since 1916. No crop had been removed from this land; it had produced a crop of peas each year but these were plowed under for green manure. The adjoining plot had been cropped each year, alternating small grains and corn, and the crop was harvested and removed each year. Turning the peas under each year had no significant effect on the organic matter of the soil during this period, as compared with the normally cropped land. Water-intake measurements were made to evaluate these two soil-management practices.

![Figure 12: Comparison of water-intake rates on cloddy soil surface with mellow, well-pulverized surface.](Image)

(Water-intake rates in inches per hour at 5-minute intervals.)
At the time intake tests were made, both plots were in "black" fallow with no surface residue. Figure 15 shows the results of the water-intake tests and that the rate of the water entry was almost identical for both soil treatments.

The results of such tests appear to emphasize the need for surface cover to accommodate heavy rainstorms. Extreme differences in organic matter within the soil or in soil management practice failed to make any important difference in water-intake rates during intense storms when the soil was unprotected.

**Water-Intake Rates for Long-Duration Storms**

To determine the behavior of these soils when exposed to long periods of rainfall, tests were made for a 6-hour period. In this test the surface was covered with straw in an amount equal to 5000 lbs. per acre. This provided complete surface protection.

Tests had been made previously to determine the amount of water intercepted and held by straw. These tests showed that 4000 lbs. of straw per acre took up .07 in. of water. Thus, with 5000 lbs. of residue the first .09 in. of rainfall would be intercepted and held by the residue. This amount of water would vary slightly with the kind and condition of residue, but in any event this amount would be a mi-
(Water-intake rates in inches per hour at 5-minute intervals.)

nor factor under the conditions of the tests reported here.

Figure 16 reports the results of the 6-hour test. An application rate of 3 in. per hour was used and the data show that for a period of 30 min. no runoff was produced and at the end of 1 hour the water-intake rate was 2.9 in. per hour. At the end of 6 hours the water-intake rate was still .8 in. per hour and a total of 8.98 in. was absorbed by the soil in the 6-hour period. This is reported to indicate the capacity of the soil over a longer period of time and with complete surface protection.

**SUMMARY**

One opportunity for increased moisture conservation in the Great Plains is by reduction of water loss from runoff during intense storms and from rapid snowmelt. In an effort to evaluate effectiveness of a number of soil and residue-management practices in terms of water-absorption rates, a study was set up at the Sheridan Station to apply simulated rainfall on various soil conditions of cropping and residue-management. A mobile infiltrometer was constructed and a number of soil conditions were evaluated in terms of their capacity to handle the intense type of storm. Limited work was done also on water absorption during the winter when soils were frozen.

Comparisons were made of water-
Fig. 15—Water-intake rates on land where peas grown since 1916 and returned each year as green manure, compared with land with normal crop removal each year (Tests made on bare fallow).

(Water-intake rates in inches per hour at 5-minute intervals.)

Total Water Absorbed in 1 hour

Peas returned as G.M. each year 1.49 inches
Crops normally harvested 1.33 inches

Intake rate at end of 1 hour
0.48 in./hr.
0.43 in./hr.

Fig. 16—Water-intake rates over a 6-hour period with a residue cover equal to 5000 lbs. per acre.

(Water-intake rates in inches per hour at 30-minute intervals.)

Total Water Absorbed in 6 hours
8.98 inches
intake rates on bare fallow, "trashy" fallow, and perennial sod cover. Land in grass as commonly left after a hay- ing operation absorbed water 25 per- cent slower than "trashy" fallow. Both conditions absorbed from 30 to 75 percent more water in 1 hour than did bare fallow land.

Raking and baling loose straw from a stubble field reduced water-intake rates by over 30 percent. On a recently combined stubble field with an average of 2850 lbs. of residue per acre, the removal of 1720 lbs. of straw by baling and leaving 1130 lbs. in the form of erect standing stubble reduced the water absorption capacity from 3.51 in. to 2.30 in. per hour. Burning the residue reduced water absorption by nearly 50 percent.

Effects of different types of fall till- age were studied. Various types of rip- ping and tilling that leaves most of the stubble standing have made the soils more receptive to water. How- ever, when mechanical tillage was used for weed control the next sum- mer, the loosening effect of the fall tillage was lost. Chemically fallowing for weed control retained some of the loosening effects through the sum- mer, and water-intake rates were thereby improved. Fall tillage im- proved water absorption during snow- melt when soils were frozen. This ap- pears due to the honeycomb condi- tion of the fall-tilled land that goes into the winter in a loosened and well-shattered condition.

There were indications that a sys- tem of fallowing with chemicals with no mechanical disturbance at all, created soil conditions after 3 or 4 years that are unfavorable for high absorp- tion rates. This possibility has not been fully explored, but all indica- tions point to the need for some me- chanical tillage in connection with chemical fallowing.

Water-intake studies were made on certain crop-rotation plots that were started in 1916 and continued to the present time. One group of rotations comparing the use of manure to no manure shows that the land receiving no manure lost 36 percent of the soil organic matter since it was taken out of sod in 1916. The rotation receiving manure held its own during this period, with no organic-matter loss. A series of water-intake meas- urements on this land failed to show any important difference in water ab- sorption during a 1-hour intense sim- ulated rainstorm. The test plots on both soil conditions were bare at the time the simulated rainfall was applied. Had the surface been protected with residue, differences in water in- take might have developed between these two soil conditions.

With all the different conditions measured, the importance of surface cover was consistently brought out regard- less of past or present manage- ment.