Stubble-Mulch Tillage and Planting in Crop Residue in the Great Plains

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Both wind and water erosion occur in the Great Plains. The climate is variable and cyclic. Wet years with considerable water erosion may be followed by dry years with serious wind erosion and limited soil moisture for crop production. Cultural practices generally used in the production of the principal crops, wheat and sorghum, tend to expose the soil during certain times of the year, leaving it vulnerable to erosion. Stubble mulch farming is extensively practiced in the Great Plains because it manages plant residues so the soil surface is protected and is thus one of the most effective conservation practices available today to control erosion and conserve moisture in the semiarid climate.

Information is presented on (a) requirements of tillage and planting equipment for stubble mulching (b) kinds of equipment and sequences of operations used, (c) performance characteristics of equipment in terms of residue conservation, soil cloddiness, weed control and crop yield, and (d) problems associated with stubble-mulch tillage and planting in the Great Plains. The discussion is restricted to wheat and sorghum culture. The paper was prepared by solving the water erosion equation for the following values of the variables:

\[ A = RKLSCP \]  

for the following values of the variables:

- \( A \): average annual soil loss in tons per acre
- \( K \): soil-erodibility factor = 0.49, 0.32, and 0.17 for soils identified in Figs. 1 and 2
- \( C \): cropping-management factors = 0.55, 0.45, 0.25, 0.17, and 0.10 for Fig. 1, and 0.55, 0.45, 0.55, and 0.50 for Fig. 2
- \( L \): rainfall erosion factor = 100 (held constant)
- \( S \): length of slope = 400 ft (held constant)
- \( P \): erosion control practice = 0.6 (held constant)
- \( I \): erosion soil loss in tons per acre
- \( V \): vegetative cover = 1,000, 3,000, 6,000, and 8,000 for soils of Figs. 1 and 2
- \( K \): surface roughness = 1.0 (held constant)
- \( C \): climatic factor = 100 (held constant)
- \( L \): width of field = 400 ft (held constant)

The substantial quantities of residue shown to be required to control erosion emphasize the importance of the requirement that the machines leave residues on the land surface.

Planting equipment has a strong influence on residue conservation because of its effect on previous crop residue while a succeeding crop is being planted and because it controls plant population and row spacing. Figs. 3 and 4 illustrate the influence of row spacing and plant population on wind erosion.

Methods of Operation

The methods of operation used in stubble mulching in the Great Plains depend on the crops grown and on whether summer fallowing is practiced. If summer fallowing is practiced and the crop is winter wheat, it is harvested with combines in late June or early July and the stubble is allowed to stand through the succeeding fall and winter. The quantity of residue left on the land surface depends on the climatic situation during the previous growing season and can range from 1,000 lb up to about 6,000 lb per acre. Tillage starts in May and is carried out periodically as weed growth dictates through the summer. The land is planted to wheat in late September or early October.

If continuous wheat is grown, tillage starts immediately after harvest and wheat is planted in September.

If sorghum is grown in rotation with wheat, the wheat stubble is allowed to stand through the winter, tillage is started in April and May, and sorghum is planted in late May or early June. Grain sorghum is harvested with combines that leave a stubble ranging from 8 to 15 in. high and from 500 to 4,000 lb per acre. Sorghum stubble land may be left undisturbed or may be under-cut with subsurface sweeps and left to stand through the winter. Tillage starts in April or May with planting in late May or early June if the next crop is sorghum, or continues through the summer if the succeeding crop is winter wheat.

Kinds of Tillage Machines Used

Tillage machines used for stubble mulching in the Great Plains can be classified into two types: (a) those that stir and mix the soil, and (b) those that cut beneath the surface without stirring or turning the tilled layer.
stubble, about four operations at approximately 1-month intervals are required for weed control. The initial tillage, in April or May, usually is accomplished with a one-way disk or a large V-sweep machine. Subsequent cultivations may be with the same machine, but often small (32-in.) V-sweeps, rodder with shovels, or chisels and plain rodders are used for the second, third, and fourth operations. Each kind of machine available for stubble mulch tillage has a different effect on residue conservation, soil cloddiness, and weed control, all of which in turn affect crop yield.

Residue Conservation Several investigators (1, 2, 8, 20, 21) have evaluated residue conservation characteristics of different machines commonly used for stubble mulching in small grain residue in the Plains. Table 1 presents a composite of the results. The wide variations in the data are due to the amount of residue conserved on the land surface by the implements depending on factors related to the residue itself such as height and length of stubble, amount of pretillage residue during initial operations (Table 2) and previous positioning or orientation of residue (Table 3) and on factors relating to the implement, such as speed and depth of operation, angle and concavity of disks, and width, pitch, and angle of sweep blades. The data of Table 4 take into account effects of these factors and present information on the quantity of

### TABLE 1. RESIDUE MAINTAINED WITH TILLAGE IMPLEMENTS*

<table>
<thead>
<tr>
<th>Type of implement</th>
<th>Average maintained after each tillage operation</th>
<th>Range maintained</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percent</td>
<td>Percent</td>
</tr>
<tr>
<td><strong>Subsurface implements</strong>:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blades (36 in. or wider)</td>
<td>90</td>
<td>70 to 113</td>
</tr>
<tr>
<td>Sweeps (24 in. to 36 in.)</td>
<td>90</td>
<td>60 to 112</td>
</tr>
<tr>
<td>Rodweeder—plain rod</td>
<td>90</td>
<td>80 to 115</td>
</tr>
<tr>
<td>Rodweeder—chisels</td>
<td>85</td>
<td>55 to 105</td>
</tr>
<tr>
<td><strong>Mixing implements</strong>:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy-duty cultivator (18 in. to 24 in. sweeps)</td>
<td>80</td>
<td>50 to 100</td>
</tr>
<tr>
<td>Heavy-duty cultivator (24 in. chisels 18 in. apart)</td>
<td>75</td>
<td>30 to 90</td>
</tr>
<tr>
<td>One-way disk (24 in. to 26 in. pans)</td>
<td>70</td>
<td>30 to 90</td>
</tr>
<tr>
<td>Tandem or offset disks</td>
<td>50</td>
<td></td>
</tr>
</tbody>
</table>

* Data from Anderson (1, 2), Woodruff and Chepil (20), Fenster (6), and Woodruff et al. (21).

**TABLE 2. EFFECTS OF DIFFERENT HEIGHTS AND AMOUNTS OF WHEAT STUBBLE RESIDUE ON PERCENTAGES RETAINED AFTER TILLAGE***

<table>
<thead>
<tr>
<th>Pretillage residue, %</th>
<th>Percentage retained on surface with stubble height of:</th>
<th>12 in.</th>
<th>18 in.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>One-way</td>
<td>8 ft V-sweep</td>
<td>2 in. chisel</td>
</tr>
<tr>
<td>3000</td>
<td>75</td>
<td>75</td>
<td>65</td>
</tr>
<tr>
<td>3500</td>
<td>55</td>
<td>54</td>
<td>55</td>
</tr>
<tr>
<td>4000</td>
<td>44</td>
<td>47</td>
<td>40</td>
</tr>
<tr>
<td>4500</td>
<td>32</td>
<td>34</td>
<td>30</td>
</tr>
<tr>
<td>5000</td>
<td>31</td>
<td>31</td>
<td>30</td>
</tr>
</tbody>
</table>

* Data from Woodruff et al. (21).
residue that four different, commonly used sequences of tillage could be expected to conserve.

Tillage machine effects on sorghum residue conservation have not been studied as extensively as small grain residues. Research at Akron, Colo (7) and Manhattan, Kansas (18), investigated the effect of fall as opposed to spring tillage of sorghum residue. The Colorado studies showed no advantage and many disadvantages for fall tillage in areas where wind erosion is critical. However, the Kansas studies showed that fall disking of sorghum stubble increased stands and grain yields. The Colorado investigation showed that amounts of sorghum residue were reduced by 31 to 34 percent by winter weathering, which was about equal to the reduction caused by tillage machines (Table 5).

Soil Clodiness Research on the effects of stubble-mulch tillage implements on surface soil clodiness has produced extremely varying results. The clodiness that will be produced by any given implement is mainly determined by the soil moisture and density at tillage and the force pattern of the particular tillage point (12, 13). Measurements of soil clodiness after initial tillage of undisturbed wheat-stubble land produced the results shown in Fig. 5, but generally it has not been possible to find any significant difference in clodiness produced by different implements or different sequences of implements in subsequent tillage (8, 11, 19, 20).

Weed Control The degree of stunting action, the temperature, the soil water content, the kind of weeds present, and the stage of growth all influence weed control attainable with any tillage machine (11). There is considerable variation in control between years for the same implement, but generally better weed control is obtained with implements that invert and mix the top soil layer such as one-way disks, than with subsurface sweeps (6, 7, 11, 20, 23). Table 6 shows weed control obtained in Nebraska by initial tillage with five different implements.

Cheargrass and downy brome are particularly troublesome weeds with stubble mulching in the winter wheat areas (14). Cheatgrass population is influenced by methods of tillage and by cropping systems. Studies at Alliance, Nebraska, showed significantly better control of downy brome with tillage sequences using a one-way disk in combination with sweep implements than with sequences employing sweeps exclusively (Table 7). Research at St. John, Kansas, indicates that a serious cheatgrass problem develops in continuous wheat on sandy stubble-mulched land but it presents essentially no problem when the land was summer fallowed between wheat crops or if a wheat-cowpea rotation is followed.

Crop Yields Results from studies to evaluate the effects of tillage on crop yields have varied. Some investigators (15) have reported higher yields on land tilled with subsurface sweeps than on land tilled with disks or plows. Others (4) have reported higher yields on one-wayed land than on subsurface-sweep tilled land. Zingg and Whitfield (23) summarized stubble-mulch farming results in the western states and concluded that the trend is for stubble mulching to yield more than clean tillage when the climate is semiarid and less than clean tillage when the climate is subhumid.

Examination of year-to-year effects of tillage on winter wheat yields indicates that yields are generally related to weed control and to soil moisture at time of planting. Table 8 shows yield data for five different four-operation tillage sequences for a dry year (1961) and a relatively wet year (1962). Soil moisture was extremely critical at planting time in 1961 but was not in 1962. As a result, yields were sharply reduced in 1961 on land tilled with sweeps, which gave poor weed control. However, there was no significant difference in yields in 1962 when soil moisture was not critical even though weed control on subsurface-sweep tilled land was poor.

Planting

Quantitative data on the performance characteristics of planting machines

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* Annual report, (1964), Sandyland Experiment Field, St. John, Kansas. (Kansas Agricultural Experiment Station).

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TABLE 8. WINTER WHEAT YIELDS IN RELATION TO TILLAGE SEQUENCE FOR A DRY YEAR (1962) AND A WET (1962) YEAR AT ALLIANCE, NEBR.*

<table>
<thead>
<tr>
<th>Tillage sequence</th>
<th>Yield, lb per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1961</td>
</tr>
<tr>
<td>OW-GW-S-BW</td>
<td>1562</td>
</tr>
<tr>
<td>GW-N-S-BW</td>
<td>1404</td>
</tr>
<tr>
<td>N-GW-S-BW</td>
<td>1212</td>
</tr>
<tr>
<td>N-S-BW-N</td>
<td>844</td>
</tr>
<tr>
<td>N-S-BW-S</td>
<td>414</td>
</tr>
</tbody>
</table>

* Data from Fenster et al. (8).

Proper tillage point design — 60 to 70-deg V angles with 37-deg pitch on subsurface sweeps — 24-in. diameters with 3-in. concavity on disks.

Correct speeds of operation — 4 to 5 mph best for most implements.

Adequate disk-angle adjustments.

Flexible implement frames and widths — 5 to 8-ft sections desirable for better performance on uneven land.

Availability of a variety of adaptable equipment to regulate amounts of residue conserved, to obtain weed control, and to operate under a wide range of soil conditions.

Problems encountered in drilling and planting in heavy or bunched mulches can be alleviated by using stubble choppers prior to initial tillage, disk implements during initial and cultivation tillage, and skew or mulch treads after the last tillage operation and before seeding. Problems associated with drilling small grains also will be lessened if the drills meet these requirements:

1. Permit row spacing of 7 to 14 in., preferably 14 in. for heavy residues.
2. Have at least 20 in. of clearance between front and rear ranks of openers.
3. Have at least 17 in. of vertical clearance between frame and bottom of shotham.
4. Have a shoe width of no more than 6 in.
5. Have press wheels that pack seed firmly — close-type wheels are better than open-type.

Effective weed control is difficult to attain with stubble-mulch tillage because most of the machines do not invert the surface soil layer. Weed seeds are not buried and weeds that have already established a substantial root system are merely cut off beneath the surface, leaving the root in contact with the soil so it continues to grow, especially if rain immediately follows tillage. Installation of "fingers" or rods on the back of subsurface sweeps increases the intensity of the tillage action and shakes the soil from the weed roots, thus providing better weed kill. More effective weed control in stubble mulching also can be obtained by using herbicides. Fenster et al. (7) reported that Atrazine (5-chloro-2,4-diamino-S-triazine), Prometon (3-methoxy-4,6-bis(isopropylamino)-S-triazine) applied at 2 lb per acre satisfactorily controlled weeds during the fallow period in an alternate wheat-fallow rotation. Fairbanks et al. (5) found that Simazine (2-chloro-4,6-bis(ethylandino)-S-triazine) applied at 4 lb per acre immediately behind the till-planter controlled weeds in sorghum and corn but the chemical reduced sorghum seedling emergence. Armburst noted that Dibrom (8-(5,4-dichlorophenyl)-1,1-dimethylurea) and Prometryne (2,4-bis(isopropylamino)-S-triazine) applied at 2 lb per acre or Duclach (dichlofluanid) (5-chloro-1,3,4-oxadiazol-2-yl) tetrafluoroethylsulfonate) applied at 12 lb per acre gave good seasonal weed control in sorghum stubble at Big Springs, Texas.

The problem of preserving sufficient residue to control erosion when initial residues are meager occurs frequently in the Plains. During dry years the quantity of residue remaining immediately after wheat or sorghum harvest may be insufficient to provide effective erosion control. If the usual number of tillage operations are carried out during the summer fallow season, these already sparse residues are reduced to levels of significance for protection of the succeeding crops. Use of herbicides to control weeds, thereby eliminating mechanical destruction by tillage, is showing considerable promise as a method of preserving residue. Minimum tillage is another way of attempting to conserve more residue. However, preliminary investigation indicates that while less tillage conserves residues, excessive soil moisture is used because of poor weed control so wheat yields are drastically reduced (Table 9). It is apparent that more investigations and studies are needed before minimum tillage could be recommended.

**Fig. 4** The effect of plant population on soil removed from sorghum stubble as measured in a portable wind tunnel. Skaime et al. (16).
The compounds associated with residue that are toxic to plant growth have not been identified (14). However, there is evidence of retarded plant growth due to substances that are toxic to plant growth have been identified (14). There is evidence of retarded plant growth due to substances that are toxic to plant growth have been identified (14). There is evidence of retarded plant growth due to substances that are toxic to plant growth have been identified (14).

Only extremely limited and conflicting data are available on insects and plant diseases in relation to stubble mulching. Investigators in South Dakota have shown that moldboard plowing is more effective than subsurface tillage in controlling grasshoppers, but other studies have shown that insect control on stubble mulching is no more difficult than on clean tillage (14). There has been some evidence of increased incidence of root rot in wheat on stubble mulch at Cherokee, Okla., but 8 years of data from Alliance, Nebr., show that the problem is more severe on clean tillage than on stubble mulch. So diseases have not been proved to be more of a problem with stubble mulching than with plowing (14).

**Summary**

Stubble-mulch farming is practiced extensively in the Great Plains because it is one of the most effective conserva
tion practices available to control erosion and conserve moisture in a variable and cyclic climate. This paper presents information on (a) requirements of tillage and planting equipment for stubble mulching; (b) kinds of equipment and sequences of operations used; (c) performance characteristics of equipment in terms of residue conservation, soil clodiness, weed control, and crop yield; and (d) problems associated with stubble-mulch tillage and planting in the Great Plains.

Tillage equipment must (a) leave crop residue on the land surface, (b) maintain as rough and cloyy a soil surface as is compatible with good seed germination and crop production, and (c) conserve soil moisture by providing a mulch and effective weed control. Planting equipment generally must meet those requirements and in addition must place seeds through the mulch into moist, firm soil.

**Table 9. Effects of Several Different Experimental Minimum or Skip Tillage Summer-Fallow Treatments on Residue Conservation, Moisture Use, and Crop Yield at Colby, Kansas**

<table>
<thead>
<tr>
<th>Tillage sequence</th>
<th>Amount of residue retained at end of tillage season, lb per acre</th>
<th>Soil moisture loss from S-11 to S-58, in.</th>
<th>Wheat yield, bu per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-*2(M + TD)</td>
<td>1140</td>
<td>4.87</td>
<td>3.5</td>
</tr>
<tr>
<td>O/W-*2(M + TD)</td>
<td>1067</td>
<td>4.83</td>
<td>3.9</td>
</tr>
<tr>
<td>S-S start</td>
<td>1285</td>
<td>3.80</td>
<td>6.6</td>
</tr>
<tr>
<td>O/W-O-S</td>
<td>584</td>
<td>3.13</td>
<td>20.8</td>
</tr>
<tr>
<td>N-*2(S)</td>
<td>560</td>
<td>1.18</td>
<td>22.5</td>
</tr>
<tr>
<td>O/S-R-W-R-W</td>
<td>529</td>
<td>0.95</td>
<td>65.7</td>
</tr>
</tbody>
</table>

* Unpublished data from Woodruff and Harris.

**References**