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Performance of Tillage Implements in a Stubble Mulch System: III. Effects of Tillage Sequences on Residues, Soil Cloddiness, Weed Control, and Wheat Yield[1]

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SYNOPSIS. The amount and height of crop residue influenced the effectiveness of tillage sequences to conserve residue on the soil surface. Tillage sequences produced no noticeable effect on soil cloddiness at the end of season. Better weed control was obtained with tillage sequences including one one-way disking. Tillage sequences seem to influence wheat yields more in dry years than wet years.

A NORMAL tillage period for preparing land for seeding winter wheat in a stubble-much farming system in the Central Great Plains starts during the latter part of April and ends about September 1. During this four-month period, three to five tillage operations at one-month to six-week intervals may be required to control weeds and prepare a seedbed. Various combinations of implements can be used to perform this tillage. This paper reports the results of a study designed to evaluate and compare various combinations of implements used in a sequence of tillage operations during the summer-fallow season.

METHODS AND MATERIALS

The data obtained from the tillage studies at Alliance, Nebraska, during the 1959–60, 1960–61, and 1961–62 seasons are included in this report. Experimental designs, number of replications and plots used, machine descriptions, and methods of sampling residues and clods are described in previous papers (11, 12).

The effects of tillage sequences were evaluated by performing 12 different sequences of 4 operations each. The sequences included either 2, 3, or 4 of the 5 implements described in a previous paper (11), i.e., a one-way disk, an 8-foot V-sweep, 32-inch V-sweeps, a rodweeder with shovels, and a plain rodweeder (Table 1). Tillage operations were performed at 1-month intervals starting about May 10 and ending about August 20.

Residues on the soil surface were measured before initial tillage and after each subsequent tillage. However, in this report, except for detailed information for tillage of a 3,600-pound-per-acre 14-inch stubble, residue conservation characteristics for the 12 sequences are compared only in terms of percentages of original residue remaining after the final tillage operation of each sequence. The amount of pretillage residue varied from plot to plot and therefore between tillage sequences. In previous research (11), the amount of residue conserved by a given machine was a function of both height and amount of pretillage residue. Residue percentages given in this paper were computed from average relations established for each machine as presented in a previous publication (11). Residue reduction characteristics are given for 12-, 14-, and 18-inch stubble heights with 2,000, 3,600 and 5,200 pounds per acre, respectively, of pretillage residue.

Comparisons of tillage sequence effect on soil cloddiness are presented in terms of the average percent of fractions greater than 0.84 mm. in diameter in the top inch of soil at the end of the tillage season. The percentages given are computed from the average effect of each individual implement during initial and cultivation tillage.

The effect of tillage sequence on weed control during the tillage season was measured by estimating weed growth immediately before the second, third, and fourth tillage. A scoring system was used whereby three persons separately scored weed control on each plot in terms of percentage of ground covered by weeds. The final score was taken as the average of the three scores.

Downy bromegrass (*Bromus techorum* L.) populations were evaluated in May of the 1961–62 season by counting the number of plants in a 12-foot section of the space between the 14-inch drill rows. This sampling was done in six locations per plot.

Winter wheat was seeded September 5 each year with hoe drills. Row spacings were 12, 13.5, and 14 inches for 1959, 1960, and 1961, respectively. Wheat was harvested in July. Wheat yields were determined for the 1960–61 and 1961–62 seasons by sampling one 14-foot combine width through the center of each 80-foot-long plot.

RESULTS AND DISCUSSION

Residues Retained on the Soil Surface as Affected by Tillage Sequence

Different combinations of machines used in a tillage sequence left different percentages of residue on the land surface at the end of the tillage season (Table 1). The effect of any given sequence of operation was strongly related to the amount of residue and slightly related to the stubble height. A larger percentage of the initial residue was retained on the soil surface when tillage was performed in small amounts of residue than in larger amounts. Residue conservation was affected less by stubble height than by quantity, but height did influence residue retention between tillage sequences. For example, a OW–OW–S–RW sequence used in 3,600 pounds per acre of residue having heights of 12-, 14-, and 18-inches left 35, 37, and 38%

Table 1. Percent of original residue retained on soil surface after the 4-operation tillage sequence.

Tillage sequence*	Stubble height† and amount of residue (lb./A.)						
	12 inches		14 inches			18 inches	
	2,000	3,600	2,000	3,600	5,200	3,600	5,200
	Percent of residue retained						
OW-OW-S-RW	49	35	49	37	23	38	29
OW-S-RW-RW	53	45	50	50	28	52	44
OW-N-S-RW	58	40	58	42	27	42	31
OW-CH-S-RW	67	39	67	40	27	40	29
C-S-RW-RW	75	52	77	59	‖	65	48
CH-S-RW-RW	62	50	64	54	43	52	52
N-CH-S-RW	5‖	39	61	41	30	42	32
N-OW-S-RW	54	36	55	38	27	39	29
N-N-S-RW	63	36	‡	40	28	47	33
N-S-RW-RW	64	52	60	57	43	62	54
N-S-S-RW	56	42	57	44	32	47	36
S-S-RW-RW	62	50	63	58	42	59	51

* OW-One-way disk. S-32-inch V-sweeps. CH-Rodweeder with shovels. N-8-foot V-sweep. C-2-inch chisels. RW-Plain rodweeder. † The 2,000 pounds of 18-inch and the 5,200 pounds of 12-inch stubble per acre were unavailable. ‡ 8-foot V-sweep cultivation was not used in 2,000 lb./A. residue. ‖ Chisel was not used in 5,200 lb./A. residue.

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residues, respectively, or nearly the same percentage for each height. A C–S–RW–RW sequence used in the same amount and heights of stubble retained 52, 59, and 65% residues, respectively. Because of the relationship of height and quantity of residue to residue retention under differing tillage sequences, one sequence may be most effective under one height-amount condition and another sequence under a different condition.

Table 1 gives the percentage of residue retained with various tillage sequences in different heights and quantities of stubble. The difference in percentage of residue retained with various tillage sequences under different heights and amounts of residue can be calculated, e.g., 3,600 pounds of 14-inch stubble varied 22%, or 800 pounds per acre, between the poorest (37%) and best (59%) sequence of operations. Other amounts may be computed from the table.

A comparison of results reported in this study with those previously reported (1, 4, 6, 7) indicates general agreement for all combinations of implements working in large amounts of residue and for subsurface tillage in both large and small amounts. Percentage figures reported here for one-way tillage of 2,000 pounds of residue per acre are higher than previously reported by Fenster (4) and McCalla and Army (7). For example, application of the percentage retention figures given by Fenster to a OW–OW–S–RW sequence indicates about 30% of the original residue would remain, but results reported here show 49% remaining. A similar calculation using the average data reported by McCalla and Army (7) indicates only about 21% remaining for the OW–OW–S–RW sequence. The main reason for the difference appears to be in the effect of small sweeps following a one-way. The present study indicates a substantial preservation and in most cases an actual increase (lifting) of residues (see Figure 1) by the sweeps, especially when working in small amounts of residue. Data of Fenster (4) and McCalla and Army (7) do not recognize lifting of residues and give an average reduction of about 10% for each sweep operation. Anderson (1) indicates 1.5 to 17.8% of the original residue returned to the surface by 2 secondary operations with the blade cultivator following a one-way, and as much as 27% returned by 3 cultivations with a blade cultivator following a one-way. Other minor differences in results between the present study and other studies are apparently due to the more detailed evaluation of implement performance. The results of implement performance have been given in detail in previous paper (11) and included recognition of the effects of residue amount, previous positioning of residue, and different implement performances when used both for initial and subsequent cultivations.

It is important to recognize that residue conservation percentages given in this paper (Table 1), and those of other investigators which are discussed, are averages. Previous research (11), considering individual implement performance, indicated rather large coefficients of variation for many of the implements, particularly when used subsequent to initial tillage. Large coefficients of variations would indicate measurements of residue conservation for a given implement or combination of implements used in a tillage sequence can, under some circumstances, indicate substantially more or less residue conserved than the averages indicated in Table 1 and Figure 1.

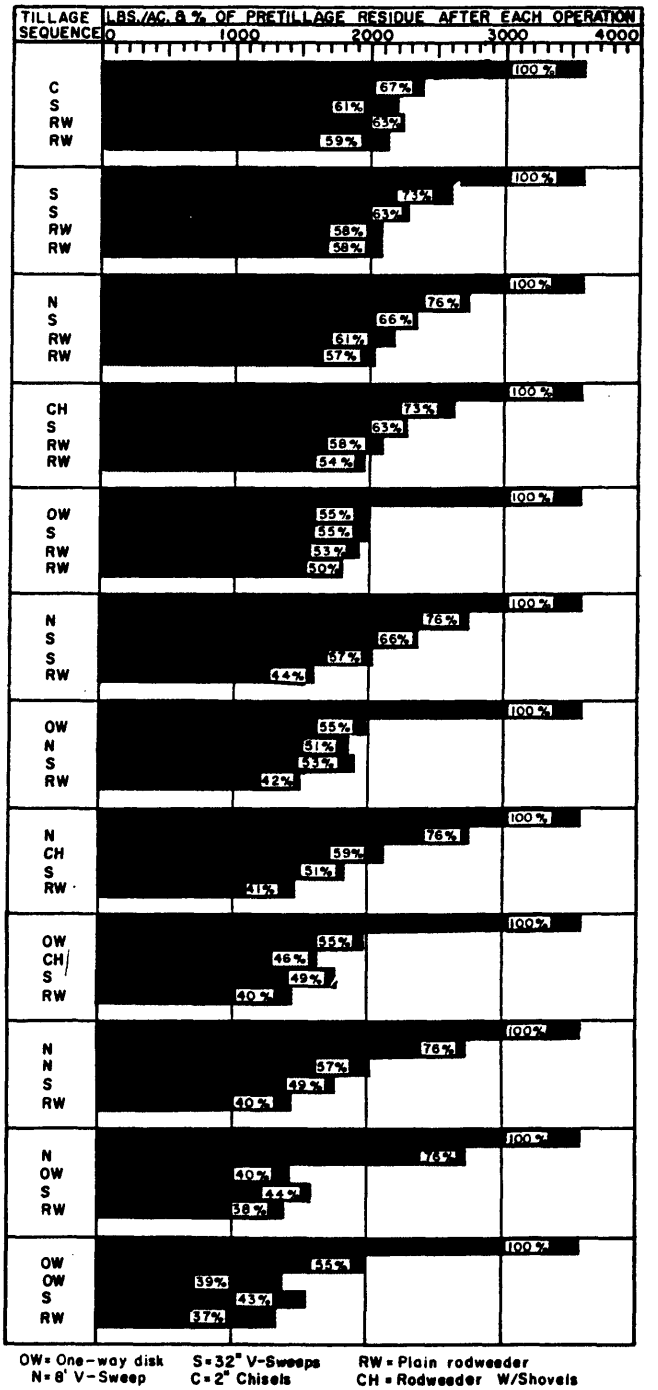

Figure 1. Residue conservation with different tillage operations. A comparison of 12 different sequences all on land having 3,600 pounds per acre of 14-inch wheat stubble.

Effect of Tillage Sequences on Soil Cloddiness

Surface soil cloddiness at the end of the tillage season was extremely variable. No statistically significant differences could be attributed to tillage sequence. There was about 10% average difference in soil cloddiness between the sequences producing the most and least cloddiness (Table 2). The data also indicate that sequences which use the one-way or 32-inch sweeps for initial tillage tend to leave a slightly more cloddy surface at the end of the tillage season than do sequences using all subsurface tillage implements. Table 2 indicates there were fewer soil clods greater than 0.84 mm. in diameter on the soil surface at the end of the tillage season than there were immediately

Table 2. Comparison of soil cloddiness at the end of the tillage season using 12 different 4-operation tillage sequences.

Tillage sequence*	% clods >0.84 mm. in diameter (cloddiness)		Tillage sequence*	% clods >0.84 mm. in diameter (cloddiness)	
	After last tillage (fall)	Change† from initial to end of season		After last tillage (fall)	Change† from initial to end of season
OW-S-RW-RW	64.6	- 6.8	N-OW-S-RW	59.0	- 6.2
OW-OW-S-RW	64.3	- 7.1	N-CH-S-RW	56.4	- 8.8
S-S-RW-RW	63.7	-10.1	C-S-RW-RW	55.7	-17.9
OW-CH-S-RW	63.5	- 7.9	CH-S-RW-RW	55.5	-11.8
OW-N-S-RW	60.8	-10.6	N-S-RW-RW	55.1	-10.1
N-N-S-RW	59.1	- 6.1	N-S-S-RW	53.4	-11.8

*OW-One-way disk. S-32-inch V-sweeps. CH-Rodweeder with shovels. N-8-foot V-sweep. C-2-inch chisels. RW-Plain rodweeder. † Minus indicates a breakdown of soil clods.

Table 3. Weed control obtained in 1 operation with 5 implements after initial tillage of wheat stubble.

Year	Implement	Control, %	*	Year	Implement	Control, %	*
1961	One-way	99		1959	One-way	88	
	2-inch chisels	83			2-inch chisel	87	
	Rodweeder w/shovels	47			8-foot V-sweep	80	
	8-foot V-sweep	44			Rodweeder w/shovels	80	
	32-inch V-sweeps	41			32-inch V-sweeps	63	

* Duncan's multiple range test. Means connected by the same line are not significantly different at 5% level.

Table 4. Weed control attained by 12 different 2-operation tillage sequences.

Tillage sequence*	Control	Duncan's multiple range test†
	Percent	
OW-OW	94	
N-OW	88	
OW-CH	83	
OW-S	82	
N-CH	74	
OW-N	72	
C-S	56	
CH-S	54	
N-N	48	
N-S	37	
S-S	34	

* OW-One-way disk. S-32-inch V-sweeps. CH-Rodweeder with shovels. N-8-foot V-sweep. C-2-inch chisels. RW-Plain rodweeder. † Means connected by the same line are not significantly different at 5% level.

after the first tillage operation. The C–S–RW–RW sequence with 17.9% fewer clods at the end of the season had the largest clod reduction and the N–N–S–RW sequence with only 6.1% fewer clods had the least reduction.

Previous investigations (6, 9, 10) have also indicated a slightly more cloddy surface at the end of the season for one-way than for sweep tillage, but no significant difference between tillage sequences at the end of the tillage season.

Tillage Sequence Effects on Weed Control

A composite analysis of variance of 2 years' data on weed control obtained by a single initial operation with each of 5 implements showed a highly significant implement times year interactions; therefore, an analysis was computed for each year. Table 3 presents average percentage weed control for each implement for each year and an indication of statistical significance.

Table 3 indicates considerable variation in control between years for the same implement, resulting in a rather indefinite evaluation of the effectiveness of the implements. Better weed control was obtained in a single operation, however, with a one-way than with 32-inch sweeps.

Composite analysis of variance for 3 years' data on weed control after 2 tillage operations showed a highly significant treatment effect with no significant difference among years. Table 4 presents information on average percentage weed control with different combinations of tillage tools. Sequences using the one-way exclusively or in combination with other implements provided significantly better

Table 5. Downy brome populations in wheat crop in May 1962, resulting from 12 tillage sequences performed in 1961 at Alliance, Nebraska.

Tillage sequence*	Average number of plants per 12-foot length †	Duncan's multiple range test‡
N-S-RW-RW	162	
S-S-RW-RW	136	
CH-S-RW-RW	117	
N-S-S-RW	113	
N-CH-S-RW	84	
OW-N-S-RW	67	
N-OW-S-RW	62	
N-N-S-RW	60	
OW-S-RW-RW	53	
OW-CH-S-RW	47	
C-S-RW-RW	44	
OW-OW-S-RW	26	

* OW-One-way disk. S-32-inch V-sweeps. CH-Rodweeder with shovels. N-8-foot V-sweep. C-2-inch chisels. RW-Plain Rodweeder. † Twelve-foot lengths between 14-inch rows at 6 locations in plot. ‡ Means connected by the same line are not significantly different at the 5% level.

Table 6. Winter wheat yields resulting from 12 different 4-operation tillage sequences.

Tillage sequence*	1961		1962	
	Yield, lb./A.	Duncan's multiple range test†	Yield, lb./A.	Duncan's multiple range test†
OW-OW-S-RW	1902		2426	
OW-S-RW-RW	1542		2268	
C-S-RW-RW	1416		2268	
OW-N-S-RW	1404		2334	
OW-CH-S-RW	1386		2322	
CH-S-RW-RW	1344		2202	
N-CH-S-RW	1236		1986	
N-OW-S-RW	1212		2406	
N-N-S-RW	1122		2208	
N-S-RW-RW	876		1830	
S-S-RW-RW	648		2082	
N-S-S-RW	414		2142	

No significant difference

* OW-One-way disk. S-32-inch V-sweeps. CH-Rodweeder with shovels. N-8-foot V-sweep. C-2-inch chisels. RW-Plain rodweeder. † Means connected by the same line are not significantly different at 5% level.

weed control during midsummer than did sequences using sweeps exclusively.

Analysis of the downy brome control in 1962 wheat, on land prepared with various tillage sequences in 1961, indicated significant differences in control between tillage sequences. Significantly better control of downy brome was obtained with tillage sequences using a one-way disk in combination with sweep implements than with sequences employing sweeps exclusively (Table 5). A OW–OW–S–RW sequence provided the best control. The poorest control was obtained with the N–S–RW–RW sequence.

Other investigators (2, 4, 5, 6, 10, 13) have also reported poorer weed control with subsurface (sweep) tillage than with implements that invert and mix the top soil layer, such as the one-way. Greb and Black (5) reported rerooting of undercut weeds when tillage was performed shortly before rain. Siddoway et al. (8) indicated the need of an additional rodweeder operation with sweep tillage to control weeds in Idaho. Krall et al. (6) stated that the degree of stirring action, the temperature, soil water, kind of weeds present, and the stage of growth all influenced weed control attained with any implement. Woodruff and Chepil (10) reported the most weed growth during summer-fallow tillage was evident in midsummer prior to third tillage and that amount and type of weed growth were related to depth and degree of stirring applied to the soil.

Effect of Tillage Sequences on Winter Wheat Yield

A composite analysis of variance of two years' of wheat yield data showed a significant year times sequence interaction. An analysis was run for each year. The effect of tillage sequence on winter wheat yield was variable. The first

year showed significant differences in yield between many of the sequences and the second year showed differences which were not large enough to be statistically significant (Table 6). It was evident during both years that higher yields were produced on land which was tilled with sequences using one-way disks than with sequences using subsurface tillage machines exclusively. Low yields were associated with 32-inch sweeps both years. Sequences employing two successive operations with sweep implements such as the S–S–RW–RW or N–S–S–RW produced yields that ranged near the bottom for both years.

Various analyses were computed to determine whether there was an association between wheat yield and amount of residue on the soil surface or between wheat yield and weed control during different times of the year. There was no significant relation between yield and amount of residue on the surface, between yield and downy brome control, or between 1962 yield and weed control during the tillage season. There was a significant relation between 1961 yield and weed control measured during the prior midsummer after two tillage operations had been completed. The correlation coefficient of 0.586 indicated a highly significant association between high wheat yields and good weed control. Since the 1960–61 season was extremely dry and 1961–62 was moderately wet, it appears that weed control is substantially important during dry years but may be less important during years when soil moisture is adequate for the crop.

Effects of tillage on wheat yields, as reported by other investigators, have varied. Siddoway et al. (8) reported yields from stubble-mulch tillage land were slightly higher than from either moldboard or disk tillage during a period from 1940 to 1953 in Idaho. Krall et al. (6) in comparing three different methods of summer fallow at three different locations in Montana reported that yields were not appreciably altered by method of fallow. Daniel et al. (2) reported the highest yields on one-wayed land and the lowest on stubble-muched land during the 1942 to 1951 period in Oklahoma. Duley (3) in long-time studies in eastern Nebraska reported yields of wheat grown with legumes about the same under stubble mulching and plowing and slightly better under plowing in nonlegume rotations. Zingg and Whitfield (13), in summarizing stubble-mulch farming results in the Western States, concluded that the trend is for stubble mulching to yield more than plowing when the climate is semiarid to arid and less than plowing when the climate is subhumid to humid.

SUMMARY

Substantial differences in average amounts of residue conserved at the end of the tillage season were found among many of the tillage sequences tested. Generally, more wheat-stubble residue was conserved with tillage sequences using subsurface implements exclusively than with those using one-way disks in combination with other implements. The effect of any given combination of implements was strongly related to amount, and slightly to height, of stubble. One combination of implements may be more effective for a given height and amount of stubble than for another combination. The variation in measurement of implement performance in the conservation of residues was also recognized.

Surface soil cloddiness at the end of a tillage season was extremely variable. Differences among tillage sequence were not statistically significant. Repeated tillage tended to remove much of the difference in cloddiness produced by initial tillage.

Significant differences in degree of weed control were obtained after the completion of the first two of four tillage operation sequences. Sequences employing one-way disks exclusively or in combination with other implements provided significantly better general weed control and specific downy brome control than did sequences using subsurface tillage machines exclusively.

Effects of tillage sequence on wheat yields were variable. Significantly higher yields in 1960–61 were obtained for sequences using one-way disks in combination with other implements than for sequences using subsurface implements exclusively. For the 1961–62 season, which was moderately wet, substantially higher yields were again found for one-way sequences. These differences were not statistically significant. A highly significant correlation between yield and weed control during the tillage season was also found for the dry 1960–61 season. The data suggest that weed control is of greater importance for increasing yields during dry years but less important during years when moisture is adequate.

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