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Performance of Tillage Implements in a Stubble Mulch System. I. Residue Conservation[1]

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SYNOPSIS. During initial tillage of winter wheat stubble, the amount of crop residue retained on the soil surface by a given implement varied with height of stubble, amount of pretillage residue, and spacing between stubble rows. During subsequent tillage, the amount of residue retained on the surface was very slightly affected by height or length of residue, moderately affected by amount of pretillage residue, but strongly influenced by previous method of tillage.

STUBBLE mulch farming is a year-round system of managing crop residues so that the soil surface is protected at all times against erosion hazards (4). Stubble mulching requires special tillage implements which will till the land and yet maintain a protective cover of residues on the surface. These requirements are best met by subsurface implements that cut vegetation roots and loosen the soil without major surface disturbance, or by disk and chisel implements that stir the soil without inversion.

Results of a three-year field study of the residue conservation characteristics of six different implements commonly used in stubble mulch farming are presented. The paper is concerned with crop residue conservation using different implements individually for initial and subsequent tillage operations. Subsequent papers will deal with effects of these implements on soil cloddiness and with the influence of different combinations of these implements on crop residues, soil cloddiness, weed control and wheat yields.

IMPLEMENTS AND PROCEDURES

Studies were conducted at Alliance, Nebraska, in 1959, 1960, and 1961 on a Keith very fine sandy loam. A tillage season ran from May 1 when initial tillage of undisturbed wheat stubble was performed to September 1 when the last rodweeder operation was completed. A 12-foot one-way disk equipped with 20-inch disks spaced 8 inches apart and operated at approximately a 38° angle, a 12-foot chisel machine equipped with 2-inch chisels spaced 12 inches apart, a 12-foot sweep implement equipped with five 32-inch V-sweeps, and 8-foot single V-sweep, and a 12-foot rodweeder equipped with 8-inch duckfoot shovels were used as initial tillage machines. Photographs and descriptions of these machines are found in a previous publication by Fenster (3).

A plain rodweeder and all of the above-mentioned implements except the 2-inch chisels were used in cultivations spaced about 1 month apart throughout the tillage season. One-way and 8-foot V-sweep tillage was performed on 6-, 8-, 10-, 12-, 14-, and 19-inch stubble. The remainder of the implements were used on 12-, 14-, and 19-inch stubble. Plots were 50 feet wide by 80 feet long. All treatments were replicated three times. Depth of initial tillage was 4 inches for all implements except the one-way, which was operated at both a 4- and 2-inch depth. Tractor speed was 4.0 to 4.5 miles per hour.

Surface residues were measured just before initial tillage and immediately after each tillage operation. Three square-yard samples were taken from each plot, each sampling giving a total of 9 samples per treatment. Sampling and processing of residues were performed in accordance with Agricultural Research Service Standardized Procedure.[4] Quantities of standing wheat stubble residue before initial tillage were expressed in units of density (pounds per cubic foot), and quantities of residue before subsequent cultivation tillage were expressed in terms of pounds per acre. Density as defined here is the weight of residue in pounds divided by the volume in cubic feet in which the residue is contained. The volume has a vertical dimension equal to the height of the stubble. Thus, density is affected by height and weight of stubble and the spacing between rows of stubble. The proportion of residue remaining on the land surface after a given tillage operation was expressed as a percentage of that just before the initial tillage or that just after the previous tillage operation. Thus, the combined influence of both the tillage operation and the decomposition between each tillage operation is evaluated.

Linear and curvilinear regression procedures were used to establish relations between percentage of residue remaining after each tillage operation with respect to amount or density of pretillage residue.

RESULTS

Crop Residues Remaining on the Soil Surface After Initial Tillage

Amount of residue conserved by a given implement was affected by density of pretillage residue, ρ_r (Figure 1).

The percentage of residue remaining on the surface after initial tillage, Y, can be expressed by a second degree curve $Y = a + b\rho - \rho_r^2$, where ρ_r is residue density and a, b, and c are constants determined by regression procedures. Examples of two such curves are shown in Figure 1. The values of constants a, b, and c, the regression coefficient, r,

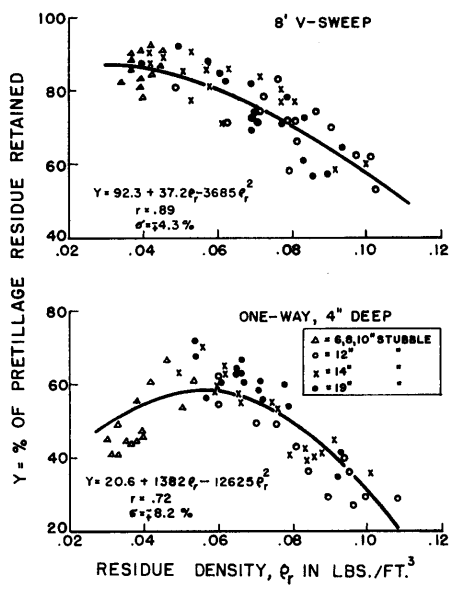

Figure 1. Percentage of residue retained on land surface after initial tillage with the 8-foot V-sweep and the one-way implements as related to density of pretillage residue.

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[4] USDA, ARS 41–68, July 1962.

Table 1. Values in the regression equation $Y = a + b(\rho_r) - C(\rho_r)^2$ for each implement used for initial tillage of wheat stubble.

Implement	Constants			Regress. coeff., r	Standard error of estimate, σ %
	a	b	c		
8-foot V-sweep	92.3	37	- 3,685	0.89	± 4.3
One-way, 4 inches deep	20.6	1,382	-12,625	0.72	± 8.2
Rodweeder with shovels	96.3	-196	- 1,782	0.56	± 9.8
One-way, 2 inches deep	55.2	623	- 7,322	0.75	● 8.0
32-inch sweeps	93.2	-114	- 2,392	0.50	±11.9
2-inch chisel cultivator	84.5	235	- 6,808	0.75	± 9.6

Table 2. Average percentage of wheat stubble conserved by initial one-way disk tillage, 4 inches deep, in relation to different heights and amounts of pretillage stubble.

Pretillage stubble, lb./A.	Percentage retained on surface when stubble height was:							
	6"	8"	10"	12"	14"	16"	18"	20"
600	49.4	44.1	40.4					
800	54.4	49.4	44.9					
1,000	57.4	52.9	49.4					
1,200	58.4	56.1	52.4	49.4				
1,400	57.4	57.9	55.3	51.9				
1,600	53.8	58.5	56.9	54.4				
2,000		56.2	58.5	57.4	55.3			
2,400			56.7	58.4	57.6	56.1		
2,800				57.4	58.4	57.9	55.5	
3,200				53.8	57.5	58.4	58.0	56.9
3,600				48.3	55.1	57.8	58.4	58.1
4,000				40.9	51.0	56.2	57.9	58.4
4,400				31.4	45.4	52.8	56.5	57.9
4,800					37.9	48.3	54.2	56.7
5,200					30.3	42.7	51.0	54.7
5,600						35.6	46.9	52.1
6,000						29.1	40.9	48.3
6,400							27.7	44.5
6,800								38.9
7,200								33.7

and the standard error of estimate, σ, are given for each of the six implements in Table 1.

Tables 2 through 5 present predicted percentages of residue conserved for different amounts and heights of pretillage residue as computed for each implement from the regression data of Table 1. Computations were confined to the limits of available experimental data.

For maximum retention of residues on the surface with a one-way disk operated at a 4-inch depth, there was an optimum height of stubble for each amount of residue (Table 2). With small quantities and short heights of stubble, percentages of residue retained on the surface increased with increased height and amount of stubble. The trend reversed after a certain amount and height of stubble was reached. The approximate position of the reversal of trend is shown by the stepped line drawn on Table 2.

The 8-foot V-sweep, the rodweeder with shovels, the 32-inch sweeps, the cultivator with 2-inch chisels, and the one-way disk working at 2-inch depth left the greatest percentage of residue on the surface where the available initial amount of stubble was the least and the available height was the greatest (Tables 3, 4, and 5). The greater the initial amount of stubble, the lower was the percentage of stubble retained on the soil surface; the taller the stubble, the greater was the percentage retained.

Crop Residue Retained on the Soil Surface by Second and Subsequent Cultivations

Generally, the implements performed differently on land previously tilled with subsurface sweeps than on land previously tilled with a one-way disk. It was evident that the percentage of residue retained by an implement was a function of the way the residue was positioned or oriented by previous tillage. The percentage of residue retained on the soil surface was a function of the amount and density of residue before the initial tillage.

Regression curves showing the relations between percentages of residue retained by each implement and amounts or densities of residue present before cultivation are shown in the following sections:

Table 3. Average percentage of wheat stubble conserved by initial 8-foot V-sweep tillage in relation to different heights and amounts of pre-tillage stubble.

Pretillage stubble, lb./A.	Percentage retained on surface when stubble height was:							
	6"	8"	10"	12"	14"	16"	18"	20"
600	90.5	91.5	91.8					
800	88.6	90.5	91.3					
1,000	86.2	89.3	90.5					
1,200	83.2	87.6	89.5	90.5				
1,400	79.6	85.6	88.1	89.7				
1,600	74.9	83.2	86.8	88.6				
2,000		77.8	83.2	86.2	88.1			
2,400		69.6	78.7	83.2	85.9	87.6		
2,800				79.6	83.2	85.6	87.0	
3,200				74.9	80.0	83.2	85.3	86.8
3,600				70.0	76.4	80.5	83.2	84.9
4,000				64.5	72.2	77.8	80.8	83.2
4,400				58.5	67.6	73.8	78.2	80.8
4,800					62.6	70.0	75.4	78.7
5,200					57.8	65.8	72.2	75.9
5,600						61.9	68.8	73.3
6,000						57.0	64.5	70.0
6,400							56.3	67.1
6,800								63.2
7,200								59.8

Table 4. Average percentage of wheat stubble conserved by initial 2-inch chisel cultivator and one-way disk 2-inch deep tillage in relation to different heights and amounts of pretillage residue.

Pretillage stubble, lb./A.	Percentage retained on surface when stubble height was:									
	12"		14"		16"		18"		20"	
	One-way	Chisel	One-way	Chisel	One-way	Chisel	One-way	Chisel	One-way	Chisel
2,000	68.3	80.9	68.4	83.3						
2,400	67.3	76.8	68.3	80.5	68.4	82.7				
2,800	65.1	71.7	67.3	76.8	68.3	80.1	68.4	82.0		
3,200	61.3	64.6	65.4	72.3	67.3	76.8	68.1	79.7	68.4	
3,600	56.5	57.1	62.5	66.8	65.7	72.9	67.3	76.8	68.0	79.2
4,000	50.6	48.5	58.7	60.6	66.1	69.0	65.9	73.5	67.3	76.8
4,400	43.4		53.9	53.4	60.2	63.0	64.1	69.7	65.9	73.5
4,800				45.3	56.5	57.1	61.6	65.4	64.4	70.3
5,200						50.5	58.7	60.6	62.1	66.2
5,600								55.3	59.7	62.2
6,000										57.1

Table 5. Average percentage of wheat stubble conserved by initial tillage with 32-inch sweeps (S) and rodweeder with shovels (RWw/S) in relation to different heights and amounts of pre-tillage stubble.

Pretillage stubble, lb./A.	Percentage retained on surface when stubble height was:									
	12"		14"		16"		18"		20"	
	S	RWw/S	S	RWw/S	S	RWw/S	S	RWw/S	S	RWw/S
2,000	82.9	83.5	85.1	85.9						
2,400	79.7	80.1	82.5	83.1						
2,800	76.1	76.5	79.7	80.1	82.2	82.8				
3,200	71.7	71.5	76.5	76.9	79.7	80.1	81.9	82.4		
3,600	67.3	67.7	73.1	73.4	76.9	77.3	79.7	80.1		
4,000	62.5	63.2	69.3	69.7	74.4	74.7	77.3	77.7	79.7	80.1
4,400	57.3	58.3	65.2	65.7	70.7	71.1	74.8	75.2	77.3	77.7
4,800			60.8	61.6	67.3	67.7	72.1	72.5	75.2	75.6
5,200			56.7	57.8	63.6	64.2	69.3	69.7	72.6	72.9
5,600					60.2	61.1	66.2	66.7	70.2	70.6
6,000							62.5	63.2	67.3	67.7
6,400									64.6	65.3
6,800										62.1

Eight-foot V-sweep. This implement when used for cultivation of residues previously positioned by subsurface sweeps was the only one that showed some dependence of its performance on density, ρ_r (Figure 2). Residue retention on the surface was increased with greater stubble height and was decreased as the amount of residue and the initial residue density was increased. More than 100 percent of residue retained means that the V-sweep lifted residue to the surface.

Cultivation with the 8-foot V-sweep after one-way disking produced extremely variable residue retention results. The average percent retained for all tests was 92.9 and the coefficient of variation was 27.9%. There was no evidence of relations between percent retained and amount or height of pretillage residue.

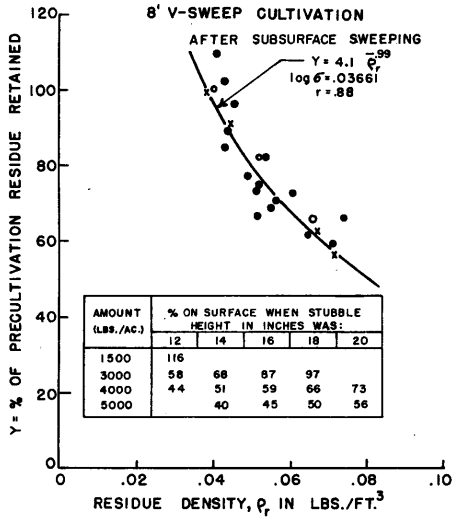

Figure 2. Percentage of residue retained on land surface after cultivation tillage of subsurface positioned residue with an 8-foot V-sweep as related to density of precultivation cover.

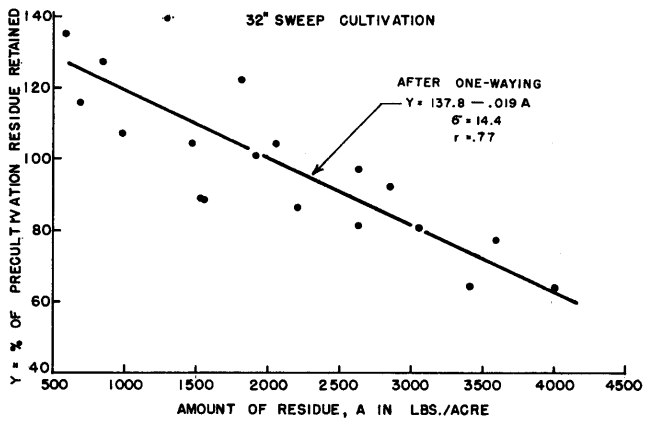

Figure 3. Residue retained on land surface after cultivation tillage of one-way positioned residue with 32-inch sweeps as related to amount of precultivation residue.

One-way disk. This implement used after tillage with a one-way disk and subsurface sweeps also produced extremely variable results. The average percentage of residue retained with a one-way after the land was previously one-wayed was 70.1. The coefficient of variation was 30.5%. The average percent retained with a one-way on land previously tilled with an 8-foot V-sweep was 52.7. The coefficient of variation was 38.1%. The one-way disk never increased the amount of residue on the surface but the percentage it buried varied with the kind of implement used previous to one-way disking.

Thirty-two-inch sweeps. This implement used after one-waying gave reasonably uniform results (Figure 3). The greater the amount of residue before cultivation with this implement, the lower the percentage of residue conserved on the surface.

Thirty-two-inch sweeps used after previous subsurface sweep tillage produced variable results. No definite relations between percentage retained and amount of precultivation residue were evident. The average percentage retained from tests working in residue quantities varying from 1,500 to 4,000 pounds per acre was 86.3. The coefficient of variation of the data was 20.6%.

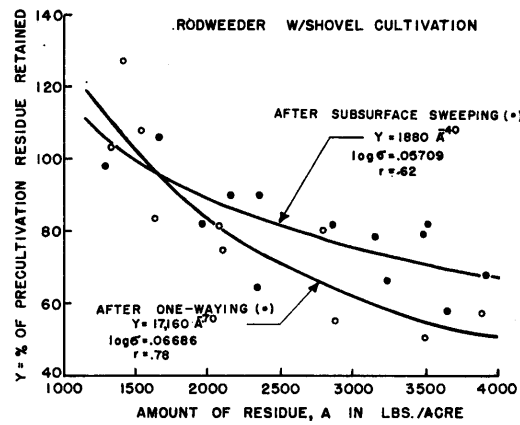

Figure 4. Residue retained on land surface after cultivation tillage of subsurface and one-way positioned residue with a rodweeder with shovels as related to amount of precultivation residue.

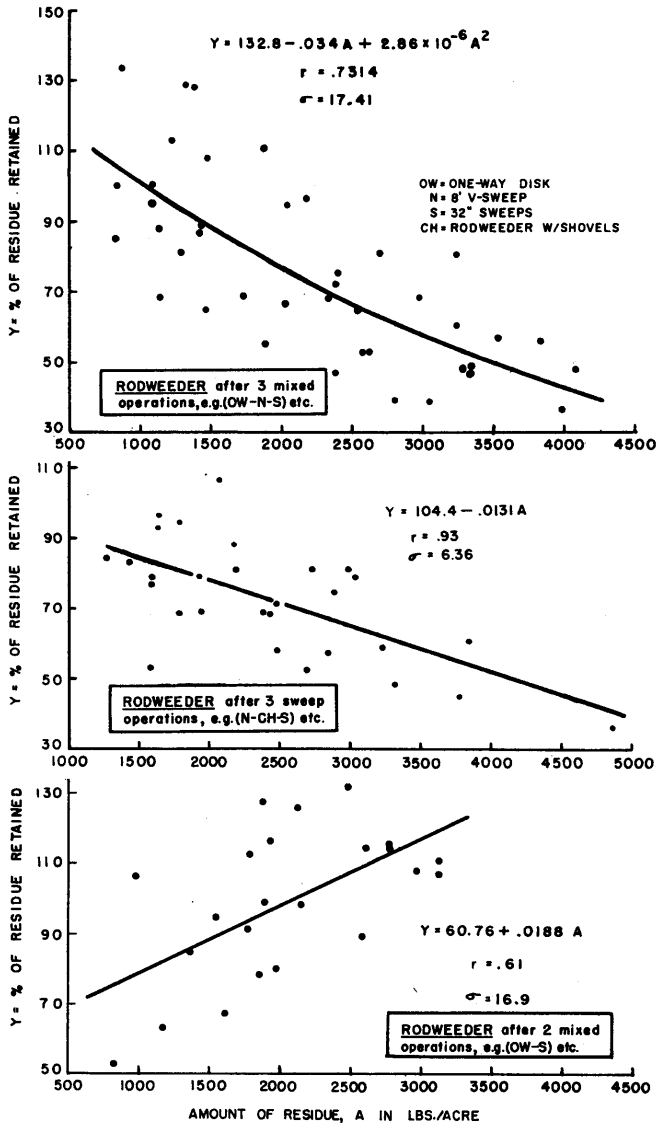

Figure 5. Percentage of residue retained on land surface after cultivation tillage with a plain rodweeder as related to amount of precultivation residue.

Rodweeder with shovels. This implement used after previous subsurface sweeping and after one-way disking produced reasonably uniform results (Figure 4). The greater the amount of residue, the smaller the percentage of residue conserved on the surface. The rodweeder with shovels lifted the residue and increased the amount at the surface when working in amounts less than about 1,500 pounds per acre (Figure 4).

Plain rodweeder. Analyses of data from cultivation with the plain rodweeder indicated that different results were obtained with this implement under different sequences of tillage. The data were grouped according to the following five tillage sequences:

1. First rodweeder operation after the land had received a one-way disk-subsurface sweep sequence of tillage.
2. First rodweeder operatioin after the land had received a sweep-sweep sequence of tillage.
3. Last tillage with rodweeder after a sweep-sweep-sweep sequence of tillage.
4. Last tillage with rodweeder after a one-way-sweep-sweep sequence of tillage.
5. Second rodweeder operation following rodweeding.

The relations between percentage of residue retained and amount of precultivation residue for sequences 1, 3, and 4 on the previous page are shown in Figure 5.

No definite relations between percentages retained and amount of precultivation residue were evident for sequences of tillage 3 and 5. The average percentage retained was 92.1 with a coefficient of variation of 19.0% for sequence 3 and 93.5% with a coefficient of variation of 25.2% for sequence 5.

DISCUSSION

Initial Tillage

Data from this study help to estimate how much crop residue can be retained on the soil surface with an 8-foot V-sweep, a 2-inch chisel-point cultivator, and a one-way disk. The regression equation for the 8-foot V-sweep accounts for about 80% of the variability. Somewhat less confidence can be placed on the one-way 2- and 4-inch depths of tillage and on the 2-inch chisel data because the regression equations account for only 50 to 60% of the variability. The rodweeder with shovels and the 32-inch-sweep data were extremely variable and the prediction equation could be expected to be correct only about 25 to 30% of the time. The poor correlation with rodweeder and 32-inch sweeps may be due to lack of sufficient data; however, Anderson (2) has also reported considerable variation in residue conservation patterns for these implements.

The data on the one-way disk used at a 4-inch depth showed the effects of the one-way used on short, small quantities of residue and tall, large quantities. The results are in fair agreement with the short-stubble, low-quantity data of Anderson (2) which show an increased percentage of residue retained for increased amounts of original cover. A reversal of the percent retained in relation to initial stubble is shown for 12- to 14-inch-high stubble at amounts of 2,000 and 2,400 pounds per acre. However, the data of Anderson for 2,800 and 3,400 pounds per acre with 13-inch-high stubble show an increasing percent in relation to initial stubble.

Figure 2 and Tables 2 through 5 show that differences in percentage of residue retained on the soil surface are between mixing and subsurface types of implements; i.e., there is little difference in the percentage of residue retained by an 8-foot V-sweep, a 32-inch sweep, or a rodweeder with shovels, but there are substantial differences between results from those machines and one-ways.

Comparable figures for these machines reported by other investigators are:

1. Anderson (1, 2)—80 to 95% retained with large sweeps working in 1,200- to 3,700-pound-per-acre residues; 44 to 58% with one-ways working in 1,350- to 3,400-pound-per-acre residues; and 30 to 50% with small sweeps (16-inch) working in 1,080 to 3,100-pound-per-acre residues.
2. Fenster (3)—90% retained with straight-blade implements, 50 to 75% percent with V-sweeps, 40 to 60% with rodweeders with shovels, 30 to 70% with one-way disks, 50 to 70% with chisels, and 90% with rodweeders.
3. Siddoway et al. (6)—60% retained with a one-way disk when residues were as much as 4,000 pounds per acre.
4. Krall et al. (5)—65 to 70% retained with one-way working in 4,000-pound-per-acre residues.
5. Woodruff and Chepil (7)—50% retained with one-way disk and 85% with 8-foot V-sweep when working in 2,000-pound-per-acre residues.

Second and Subsequent Cultivations

The cultivation results of the different implements were more variable than the data obtained from initial tillage. Previous positioning of residue by tillage influences the amounts of residue retained during cultivation. Amounts of precultivation residue are important with some of the machines. An effect of stubble height was evident with 8-foot V-sweep cultivation of residues previously positioned with sweeps.

The prediction equation obtained for the plain rodweeder used after 3 sweep operations and for the 8-foot V-sweep used after the V-sweep operations accounted for 86 and 78%, respectively, of the variability. Regressions for the 32-inch sweeps after one-way disking accounted for 60%; rodweeder with shovels after one-waying, 61%; and the plain rodweeder after 3 mixed operations, 54% of the variability. Other prediction equations are of limited value because they account for only about 37% of the variability.

Figure 5 indicates that the plain rodweeder varies in performance, depending upon conditions and sequence of operation. When used early in the tillage season after 2 mixed tillage operations (lower graph, Figure 5) the percentage of residue retained increases with increased amounts of precultivation residue. Later in the season following 3 mixed (top graph, Figure 5) or all sweep (middle graph, Figure 5) operations, percentages retained decrease with increasing amounts of precultivation residue.

SUMMARY

Results of a 3-year study of the residue conservation characteristics of 6 different implements used in stubble mulch farming are presented.

The percentage of residue remaining on the surface after initial tillage varied with height and amount of residue and with spacing between stubble rows. Regression relations were obtained between percentage of residue retained and residue density. These equations can be used to predict the

amounts of wheat residue that could be conserved on the soil surface by different implements.

Variation of the residue retention data from initial tillage was relatively low for the 8-foot V-sweep, the one-way disk, and the 2-inch-chisel cultivator. The rodweeder with shovels and the 32-inch sweeps produced erratic results, and only limited confidence can be placed in values computed from the prediction equations.

For maximum retention of residues on the surface during initial tillage with a one-way disk there was an optimum height of stubble for each amount of residue.

A comparison of machine performance during initial tillage showed substantial differences in surface residue retention between the subsurface implements and one-way disks.

Previous positioning of the residue had an important effect on amounts of residue retained on the land surface during second and subsequent cultivation. Amounts of precultivation residue are important with some machines and seem to make no difference with others. Height of stubble had an effect only with 8-foot V-sweep cultivation of land that had been tilled previously with subsurface implements.

The subsurface implements increased residues when used after some tillage implements, and decreased residues when used after others. Actual percentages of residue retained on the surface depended on the amount of residue which the implements were working and on previous positioning of the residue.

The plain rodweeder retained varying amounts of residue, depending on previous tillage sequences. Data are presented on effects of five different tillage sequences.

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