TILLAGE IMPLEMENT OPERATIONAL EFFECTS ON RESIDUE COVER

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ABSTRACT. *Crop residue cover protects soil from erosion caused by raindrop impact and runoff. Fall and spring season factorial field experiments indicated that operator-controlled adjustments of tool configuration, depth, and under certain conditions speed affected corn residue cover buried by a tandem disk harrow and chisel plow and soybean residue cover buried by a knife-type fertilizer applicator.*

A disk-gang angle of 13° buried 3 to 10 percentage points less corn residue cover after tillage than a disk-gang angle of 18°. Tillage depth of 51 mm (2 in.) or 76 mm (3 in.) buried four and nine percentage points less corn residue cover, respectively, than did tillage at twice these depths. Reducing disk speed from 7.2 km/h (4.5 mile/h) to 4.8 km/h (3.0 mile/h) buried six percentage points less corn residue cover in one experiment.

Chisel shovels 51 mm (2 in.) or sweeps 406 mm (16 in.) on a chisel plow, buried 7 to 11 percentage points less corn residue cover than 76-mm (3-in.) twisted shovels. Tilling 76 mm (3 in.) deep buried four percentage points less corn residue cover after tillage than did tilling 152 mm (6 in.) deep.

In the spring season a knife-type fertilizer applicator with a knife-only configuration buried 10 to 12 percentage points less soybean residue cover than was buried by using an additional coulter or a combination of coulter and covering disks.
Keywords. *Residue cover, Disks, Chisel plows, Anhydrous ammonia, Tillage, Crop residue, Residue management.*

Crop residues provide a protective cover for the soil surface. Crop residues reduce soil erosion resulting from raindrop impact and slow runoff (Wischmeier and Smith, 1978). Increasing residue cover, even by small amounts, decreases soil erosion potential (Laflen and Colvin, 1981).

Many factors affect the amount of residue that remains on the surface. The action of tillage implements in the soil generally decreases surface residue. Colvin et al. (1986) reported tillage implement effects on percent cover of corn and soybean residue from seven tillage experiments in Iowa over a five-year period. Individual implements had different effects. Percent cover of soybean residue was reduced more than corn residue with any given tillage implement. Secondary tillage resulted in smaller residue reductions than primary tillage with a given implement. Implement configuration, tillage depth, speed, and the season of operation were not specified.

Colvin et al. (1986) estimated that residue cover after a series of field operations was equal to the product of residue remaining factors for each implement. Residue remaining was considered to be the ratio of residue cover immediately after a field operation to residue cover immediately before a field operation.

Johnson (1988) evaluated various soil-engaging tools on a chisel plow and combination chisel plow with cutting blades (ASAE Standards, 1993) used in corn and soybean residue during fall tillage. The use of low and medium crown 406-mm (16-in.) sweeps buried six to eight percentage points less corn residue cover than did 51-mm (2-in.) chisel shovels. The use of sweeps and chisel shovels on a chisel plow buried 7 to 14 percentage points less corn residue cover than 76-mm (3-in.) concave twisted shovels. A given set of soil-engaging tools on a chisel plow buried about 10 percentage points less residue cover than a similarly equipped combination chisel plow with cutting blades.

Johnson (1988) also reported the effects of combination chisel plow tillage depth and speed on corn residue remaining after tillage. Residue remaining increased when the operating depth of a combination chisel was decreased from either 200 or 250 mm (8 or 10 in.) to either 100 or 150 mm (4 or 6 in.). Residue cover did not statistically increase with decreased operating speed until speed decreased from a range of 4.8 to 9.3 km/h (3.0 to 5.8 mile/h) to 2.4 km/h (1.5 mile/h).

M'hedhbi and Gregory (1989) developed a model of soil movement by a chisel plow to estimate effects on residue cover. They concluded that decreased operating speed and depth, and a narrower soil-engaging tool on wider shank spacing would decrease residue cover less than using the opposite extremes of operation. Shelton et al. (1994) observed that a blade plow with wider shank spacing than a field cultivator left more residue cover after tillage than did a field cultivator.

Observed levels of residue cover left behind tillage implements after field demonstrations have been compared

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with predicted values. Brown et al. (1992) demonstrated combinations of primary and secondary tillage in corn and soybean residue and noted that residue levels from some combinations varied considerably from predicted levels because of site-specific conditions. Wollenhaupt et al. (1993) found no correlation between measured values of corn residue levels and those levels predicted by the model of Stott et al. (1988) or predicted by SCS (Soil Conservation Service and Equipment Manufacturers Institute, 1992).

Field operations that do not have tillage as a primary purpose also affect residue cover. Using a knife-type fertilizer applicator without coulters in soybean residue, Burr et al. (1986) measured residue cover reductions of 35 and 29% in 760 mm (30 in.) and 250 mm (10 in.) row spacings, respectively. Shelton et al. (1994) observed that using a knife-type fertilizer applicator decreased final corn residue cover after planting by 8.7 percentage points as compared with similar systems without its use.

Slight differences in residue cover affect soil erosion potential. Research studies show tillage operations significantly affect residue cover, however, information on implement configuration, and operating depth and speed have usually been omitted. These parameters may be adjusted by the equipment operator. Fall tillage research with a chisel plow (Johnson, 1988) has shown some effects of these individual variables, but has not shown if these effects are interdependent. For example, leaving a greater residue cover with sweeps rather than twisted shovels on a chisel plow may be possible only with the chisel operating at a certain tillage depth. If sweeps leave greater residue cover regardless of tillage depth, or shallower tillage leaves greater residue cover regardless of soil-engaging tool, then both strategies may be used for an additive effect to leave greater residue cover. Operator-controlled variables may also have different effects after over winter or chemical-fallow periods of residue decomposition.

Besides chisel plowing, many other field operations affect residue cover. Tandem disk harrow operation in cornstalks and knife-type fertilizer applicator operation in soybean stubble reduce residue cover. Operational depth, speed, and the angle of disk-gangs on some tandem disk harrows, can be varied by the operator. Common procedures for use of knife-type anhydrous ammonia application restrict variations of speed and depth to maintain calibration and limit losses, respectively, but tool configuration can be varied.

Objectives

Objectives of this research were to determine if there are differences in amounts of residue cover remaining immediately after fall and spring field operations as a result of varying:

- Disk-gang angle, operating depth, and speed of a tandem disk harrow operated in corn residue.
- Soil-engaging tools and operating depth of a chisel plow operated in corn residue.
- Soil-engaging tools of a knife-type fertilizer applicator operated in soybean residue.

Materials and Methods

Site Conditions

Six experiments were conducted at the Boyd farm near Ames, Iowa. Soil types included Clarion loam (fine-loamy, mixed, mesic Typic Hapludolls), Coland-Spillville complex (fine-loamy, mixed, mesic Cumulic Haplaquolls/ Hapludolls), and Nicollet loam (fine-loamy, mixed, mesic Aquic Hapludolls). Within each experiment replicated, blocks were divided by predominant soil type. Turn areas adjacent to experimental plots allowed measurement areas to be untrafficked after harvest until the experimental operation. All residue/stubble row spacings were 760 mm (30 in.). Machine operation was always parallel to old-row direction.

Implement Types and Operation

The tandem disk harrow used was a pull-type Deere model 310 equipped with four disk gangs of 560-mm (22-in.) spherical disc blades spaced at 230-mm (9-in.) intervals. Machine width was 5.0 m (16.4 ft). Operating depth was controlled by hydraulic height adjustment of the frame transport wheels. Maximum operating depth with transport wheels fully raised was affected by the weight of the tandem disk harrow and ability of the individual disc blades to penetrate the soil.

Disk-gang angle was the angle made by the disk-gang axis of rotation with a line perpendicular to travel direction. Angles of both opposing front gangs and both opposing rear gangs were able to be varied with the travel direction. All four disk-gang angles were adjusted to either their least aggressive (13°) or most aggressive (18°) tillage positions for the experiment. Spring disk tillage depths were 76 mm (3 in.) and 152 mm (6 in.). With the tandem disk-gang angle in the 13° position, fall soil conditions limited maximum disk tillage depth to 102 mm (4 in.). Fall tillage depths were 51 mm (2 in.) and 102 mm (4 in.). Speeds were 4.8 km/h (3 mile/h) and 7.2 km/h (4.5 mile/h).

The chisel plow used was a pull-type, folding-wing White model 435 combination chisel plow. The front disk gang was raised with an existing turnbuckle so that it did not engage soil or residue. Wings were folded so that only the center 11 shanks were used. Shank spacing of 380 mm (15 in.) provided a working implement width of 4.2 m (13.8 ft). Operating depth was controlled by hydraulic height adjustment of the frame transport wheels.

A single chisel operating speed of 8.0 km/h (5.0 mile/h) was used and tool configuration and depth were investigated as the independent variables under operator control. Soil-engaging tools on implement shanks included 406-mm (16-in.) medium-crown sweeps, 51-mm (2-in.) chisel shovels, and 76-mm (3-in.) twisted shovels. Although chisel plows are frequently adjusted to till in a depth range from 152 mm (6 in.) to 203 mm (8 in.), it was desired to determine if residue burial could be reduced by decreasing tillage depth outside of this range. Operating depths were 76 mm (3 in.) and 152 mm (6 in.).

The knife-type fertilizer applicator was an anhydrous ammonia fertilizer tank and tool bar mounted on a pull-type frame. Knives spaced at 760-mm (30-in.) intervals were spring-mounted on the tool bar. The knife face was trapezoidal with a width of 22 mm (0.87 in.) at the tip and a width of 13 mm (0.50 in.) at the soil surface. Spring cushioned 560-mm (22-in.) smooth rolling coulters were mounted in front of each knife for each tool configuration treatment except the knife only. The space between the rear coulter edge and knife edge was 460 mm (18 in.).

Two of the four applicator tool configuration treatments used a pair of 350 mm (13.9 in.) diameter spherical covering discs mounted on a frame fastened by a pivoting-pin connection to the knife shank. Disc spacing as measured between points where the disc axis intersected the disc plane was 270 mm (10.6 in.). During field operation, the centerline of the disc axes was 230 mm (9 in.) to the rear of the knife shank. Angle of the plane of the disc-blade edges with the travel direction was adjustable and used as the tool configuration variable for the two treatments using covering discs. For the least aggressive treatment, disc angle was adjusted to be as nearly parallel to the travel direction (16°) as allowed by the attachment. For the most aggressive treatment, discs were adjusted to the greatest angle with travel direction that would accommodate residue flow, and it seemed, by subjective visual judgment, that a significant amount of knife-disturbed residue was being placed back on the surface by the trailing covering discs. Tool configuration treatments for the knife applicator were: 1) knife only (knife); 2) leading coulter and knife (coulter-knife); 3) leading coulter, knife, and covering discs set at a 16° angle to the travel direction (16° discs); and 4) leading coulter, knife, and covering discs set at a 19° angle to the travel direction (19° discs).

Experimental Design and Measurements

The tandem disk harrow, chisel plow, and knife applicator were each used in two experiments. The first experiment listed for each implement was conducted in fall and a second experiment was conducted in spring.

Experiments 1 and 2 were conducted with the tandem disk harrow on adjacent land areas following 1992 and 1991 corn crops, respectively. Disk-gang angle, operating depth, and speed were independently varied so that each angle, depth, or speed was used with all other combinations of the other two variables (i.e., factorial treatment combinations). Experiment 1 was conducted 28 October 1992 in cornstalks remaining from a 1992 grain yield of 10.4 Mg/ha (166 bu/acre). Experiment 2 was conducted 5 May 1992 in cornstalks remaining from a 1991 grain yield of 7.4 Mg/ha (118 bu/acre). Residue was previously undisturbed other than distribution by a combine-mounted straw-spreader mounted on a conventional cylinder combine. Experimental plots were 5.0 m (16.4 ft) wide and 15 m (49 ft) long. Within experiments 1 and 2, four replications of randomized complete blocks used all disk (factorial) treatment combinations.

Experiments 3 and 4 were conducted with the chisel plow on land areas adjacent to the tandem disk harrow experiments following 1992 and 1991 corn crops, respectively. Cornstalks were previously undisturbed except for processing by the conventional combine cylinder and combine-mounted straw-spreader. In experiment three residue cover remaining from a 1992 grain yield of 11.0 Mg/ha (176 bu/acre) was chisel-tilled on 28 October 1992. Residue remaining from a 1991 grain yield of 7.5 Mg/ha (120 bu/acre) was chisel-tilled on 4 May 1992 in experiment four. Experimental plots were 5.0 m (16.4 ft) wide and 15 m (49 ft) long. The measurement area was confined within the 4.2 m (13.8 ft) implement width. In experiments three and four, all (factorial) combinations of chisel soil-engaging tools and depth were evaluated in six replications of randomized complete blocks.

Experiments 5 and 6 were conducted with the knife-type fertilizer applicator in soybean stubble previously undisturbed except for processing during 1992 harvest by a combine-mounted straw-chopper on a conventional cylinder combine. Because differences were measured before the experiment in surface soybean residue behind the center of the five-row combine-swath and the edges, experimental plots were only two stubble rows wide and centered along the combine's travel path. Individual plots were 1.52 m (5 ft) wide and 30 m (98 ft) long. Experiment 5 was conducted 10 November 1992 on an area that yielded 3.6 Mg/ha (54 bu/acre). Experiment 6 was conducted 26 April 1993 on an area that yielded 3.6 Mg/ha (53 bu/acre). Experiments 5 and 6 included all four knife applicator configurations in six randomized complete block replications. The knife applicator was operated at 6.6 km/h (4.1 mile/h) and 175 mm (7 in.) deep.

For each experiment, the surface layer of soil equal to the tilled depth was sampled in each block for a gravimetric determination of soil water content. Two measurements of residue cover within each block were taken by the line-transect method and averaged to obtain a single measurement of residue cover before field operations for each block. Statistical analysis did not indicate differences in residue cover before tillage between blocks within each experiment. Two measurements of residue cover were made by the line-transect method within each experimental plot after field operations, as described by Johnson (1988). Lines used for measurement were 15.2 m (50 ft) long with 100 beads spaced equidistantly along the entire length. Two or three observers were used for each experiment, however, sample measurements within each replicated block were taken by the same observer so that all treatments were measured an equal number of times by any observer. All measurements were made within two days after tillage and before precipitation occurred. Percent residue remaining was calculated as the ratio of residue-cover percentage after the tillage treatment to residue-cover percentage before the tillage treatment and was expressed as a percentage.

Because two measures of residue cover were sampled within each experimental plot, a statistical analysis of variance with subsamples (Steel and Torrie, 1980) was used. A pooled experimental error variance among plots within treatment factors and interactions was used to test treatment effects for each experiment. Using the same number of levels (2) for each factor in the tandem disk harrow experiments resulted in an equal number of experimental observations (32) for each level of factor and a single value of least significant difference used to compare main effect differences within experiments 1 and 2.

Results and Discussion

Table 1 lists the date, implement, previous crop and yield, percent residue cover immediately before field operations, and coefficient of variation for single

Table 1. Date of use, implement, previous crop and yield, initial percentage residue cover immediately before field operations, and coefficient of variation for each experiment

Experi-ment	Date	Implement	Previous Crop	Grain Yield (Mg/ha)	Grain Yield (bu/acre)	Residue Cover (%)	Coefficient of Variation* (%)
1	10-28-92	Disk	Corn	10.4	166	91	7
2	5-5-92			7.4	118	83	19
3	10-28-92	Chisel	Corn	11.0	176	91	9
4	5-4-92			7.5	120	86	16
5	11-10-92	Knife	Soybeans	3.6	54	84	9
6	4-26-93			3.6	53	79	15

* Sample measurements within plots.

measurements within each experimental plot. Sampling variability within plots (included within experimental variability used to compare treatment effects) resulted in coefficients of variation within a plot ranging from 7 to 19% for the various experiments. Multiple within plot observations of residue cover lowered standard deviations of means of main treatment factors to a range of 1.1 to 2.1 percentage points (depending on experiment and factor) and allowed treatment differences to be detected. Average soil-water content for each tillage depth within each experiment is presented in table 2 as an indication of soil conditions during field operations.

Tandem Disk Harrow

Results of experiment 1 (table 3) showed that reducing disk-gang angle from 18° to 13° buried 10 percentage points less residue cover (significant at an $\alpha = 0.01$ level). Reducing tillage depth from 104 to 51 mm (4 to 2 in.) buried four percentage points less residue cover and reducing speed from 7.2 to 4.8 km/h (4.5 to 3.0 mile/h) buried six percentage points less residue cover.

Soil and crop conditions allowed deeper tillage in experiment two. Results of experiment 2 indicated that reducing tillage depth from 152 to 76 mm (6 to 3 in.) buried nine percentage points less residue cover (significant at an $\alpha = 0.01$ level). Reducing disk-gang angle from 18° to 13° buried three percentage points less residue cover. Possibly because of deeper tillage, depth had more effect than disk-gang angle in experiment 2. Reducing travel speed from 7.2 to 4.8 km/h (4.5 to 3.0 mile/h) also buried three percentage points less residue cover but was significant at only an expanded level of confidence (α = 0.10).

No interactions were significant in experiments 1 and 2 and thus effects of disk-gang angle, depth, and speed are independent. Two or more may be used for additive

Table 2. Soil water content of the tilled layer at the time of experimental measurements

Implement	Experi-ment	Tillage Depth (mm)	Tillage Depth (in.)	Soil Water (Mg/Mg)
Tandem disk harrow	1	51	2	0.109
		102	4	0.129
	2	76	3	0.118
		152	6	0.184
Chisel plow	3	76	3	0.141
		152	6	0.156
	4	76	3	0.151
		152	6	0.168
Knife applicator	5	178	7	0.210
	6	178	7	0.229

Table 3. Mean values of percent residue remaining and percent residue cover for each level of disk-gang angle, depth, and speed of a tandem disk operated in corn stubble

Factor	Expt. 1* Residue Remaining (%)	Expt. 1* Residue Cover (%)	Expt. 2† Residue Remaining (%)	Expt. 2† Residue Cover (%)
Disk-gang angle				
13° disk angle	79	71	30	25
18° disk angle	67	61	26	22
Depth, mm (in.)				
51 (2)	75	68		
76 (3)			34	28
104 (4)	70	64		
152 (6)			23	19
Speed, km/h (mile/h)				
4.8 (3.0)	76	69	30	25
7.2 (4.5)	70	63	27	22
LSD ($\alpha = 0.05$)‡	4	3	4	3§

* Previous crop grain yield was 10.4 Mg/ha (166 bu/acre).
† Previous crop grain yield was 7.4 Mg/ha (118 bu/acre).
‡ Least significant difference in each column within each factor for any two means.
§ Speed significant at only a = 0.10 level, but disk-gang angle significant at a = 0.05 level and depth significant at a = 0.01 level.

effects. Both disk-gang angle and tillage depth had significant effects on residue cover.

Table 4 compares the range of observed individual treatment means of percent residue remaining with other published values of Soil Conservation Service and Equipment Manufacturers Institute (1992) and Colvin et al. (1986). Treatment means of experiment 2 may have been smaller than other reported estimates or data because of over-winter residue deterioration or moderate amounts of initial residue.

Chisel Plow

Because Johnson (1988) found no significant differences in residue cover at typical operating speeds, a single speed of 8.0 km/h (5.0 mile/h) was used. In experiment 3 (table 5) 406-mm (16-in.) sweeps and 51-mm (2-in.) chisel shovels buried eight and seven percentage points less residue cover, respectively, than did 76-mm (3-in.) twisted shovels (significant at an $\alpha = 0.01$ level). Decreasing tillage depth from 152 mm (6 in.) to 76 mm (3-in.) buried four percentage points less residue cover.

In experiment 4 (table 5), 406-mm (16-in.) sweeps and 51-mm (2-in.) chisel shovels buried 8 and 11 percentage points less residue cover, respectively, than did 76-mm (3-in.) twisted shovels (significant at an $\alpha = 0.01$ level). Decreasing tillage depth from 152 mm (6 in.) to 76 mm (3-in.) buried four percentage points less residue cover.

No interactions were significant in experiments 3 and 4. Either changing the soil-engaging tool from a twisted shovel to a narrower chisel shovel or sweep or tilling at a shallower depth may be independently used to increase residue cover. Both strategies may be used together in an additive effect to leave greater residue cover. If only one strategy is used, selection of soil-engaging tool was more likely to leave greater residue cover than changing depth within this experimental range.

The range of individual treatment means of percent residue remaining are compared in table 4 with other published values of Soil Conservation Service and

Table 4. Published ranges of percent residue remaining and observed range of individual treatment means for tandem disk harrow, chisel plow, and knife applicator

	SCS and EMI (1992)		Colvin et al. (1986)*	Observed Range†	
Implement	Conditions	Residue Remaining (%)	Residue Remaining (%)	Conditions	Residue Remaining (%)
Tandem disk harrow	180-mm (7-in.) to 230-mm (9-in.) spacing	40-70	42-74	Expt. 1	59-83
	Light disking after harvest	70-80		Expt. 2	22-41
Chisel plow	Sweeps	70-85	25-53	Expt. 3	
	Chisel shovels	60-80		Sweeps	74-80
	Twisted shovels	50-70		Chisel shovels	73-79
				Twisted shovels	68-69
				Expt. 4	
				Sweeps	34-46
				Chisel shovels	43-44
				Twisted shovels	30-33
Knife applicator	Without closing discs	45-70	28-60	Expt. 5	
	With closing disks	30-50		Without closing discs	75-77
				With closing discs	75-77
				Expt. 6	
				Without closing discs	40-54
				With closing discs	39-42

* Mean ± 1 standard deviation.
† Observed range of individual treatment means.

Equipment Manufacturers Institute (1992) and Colvin et al. (1986). Experiment 4 treatment means were below Soil Conservation Service and Equipment Manufacturers Institute estimates possibly because of over-winter deterioration or moderate amounts of initial residue cover. Experiment 3 treatment means were greater than the data of Colvin et al. (1986) possibly because of large amounts of fresh residue cover.

Increased residue cover by tilling at a shallower depth was not as great as the results of Johnson (1988) showing 16 percentage points greater residue cover after fall tillage at a depth of 100 mm (4 in.) as compared to tillage at a depth of 200 mm (8 in.). Johnson also reported using 406-mm (16-in.) medium crown sweeps on a chisel plow to leave six percentage points greater residue cover than 51-mm (2-in.) chisel shovels and 13 percentage points greater residue cover than 76-mm (3-in.) twisted shovels. In contrast, however, little difference was seen between the sweep and chisel shovel as the sweep left only one percentage point more residue cover than the chisel shovel in experiment 3, and the sweep buried three percentage points more residue than the chisel shovel in experiment 4. Slightly wetter soil conditions during experiment 4 or lower previous crop yield may have limited the volume of soil fractured and thrown on top of residue by the narrow chisel shovel.

Table 5. Mean values of percent residue remaining and percent residue cover for each level of soil-engaging tool and depth of a chisel plow operated in corn stubble

	Expt. 3*		Expt. 4†	
Factor	Residue Remaining (%)	Residue Cover (%)	Residue Remaining (%)	Residue Cover (%)
Soil-engaging tool				
406-mm (16-in.) sweep	77	70	40	35
51-mm (2-in.) chisel shovel	76	69	44	38
76-mm (3-in.) twisted shovel	68	62	32	27
LSD ($\alpha = 0.05$)	5	5	6	6
Depth, mm (in.)				
76 (3)	76	69	41	35
152 (6)	72	65	36	31
LSD ($\alpha = 0.05$)	4	4	5	4

* Previous crop grain yield was 11.0 Mg/ha (176 bu/acre).
† Previous crop grain yield was 7.5 Mg/ha (120 bu/acre).

In general, for implements such as a tandem disk harrow and chisel plow used for primary tillage in corn residue, both tool configuration (disk-gang angle or soil-engaging tool) and tillage depth affected loss of surface residue coverage. Data presented for a tandem disk harrow and those reported by Johnson (1988) for a combination chisel plow imply that although slower speeds tend to limit the amount of surface residue buried compared with faster tillage speeds, speed has less effect than tool configuration or depth within typical speed ranges.

Although significant differences in final residue cover between main effects of tool configuration, depth, and speed only range from 3 to 11 percentage points, no interactions were significant; therefore, main effects are additive. This is evidenced by the wider range in individual treatment means with a maximum difference of 54 to 75% residue cover for fall tandem-disk treatments.

Using operational strategies of tool configuration, tillage depth, and operating speed to reduce the amount of surface residue buried impacts soil erosion. Assuming a fall disk-plant tillage system in corn residue using an average percent residue loss for a planter with double-disc openers of 20% and an over-winter weathering loss of 10% (Soil Conservation Service and Equipment Manufacturers Institute, 1992), final surface cover after planting would have been 39 or 54% depending on operator-controlled adjustments of the tandem disk harrow. Such a 15% difference may reduce soil erosion by 67% for an Ames, Iowa, location (Laflen and Colvin, 1981).

Knife Applicator

No differences were observed among treatments in experiment 5 (table 6). In contrast, in experiment 6, the knife-only configuration resulted in a 10 to 12 percentage points greater residue cover (significant at the $\alpha = 0.01$ level) than did other configurations.

Crop type, yield, tillage operations, and soil types were similar in the two experiments, but weathering and soil

Table 6. Mean values of percent residue remaining and percent residue cover for each level of tool configuration of a knife-type fertilizer applicator operated in soybean stubble

	Expt. 5*		Expt. 6†	
Tool Configuration	Residue Remaining (%)	Residue Cover (%)	Residue Remaining (%)	Residue Cover (%)
Knife only	77	64	54	43
Coulter-knife	75	63	40	31
16° discs	75	63	39	31
19° discs	77	65	42	33
LSD (α = 0.05)	NS	NS	7	5

* Previous crop grain yield was 3.6 Mg/ha (54 bu/acre).
† Previous crop grain yield was 3.6 Mg/ha (53 bu/acre).

moisture content were different. Although initial residue cover after weathering between fall and spring was only five percent less (table 1), microbial decomposition may have weakened the residue making it more fragile to manipulation by the additional soil-engaging tools (coulter and covering discs). Soil water content was 0.019 Mg/Mg greater in the spring experiment. The slightly wetter soil may have limited the amount of soil fractured and thrown by the narrow knife. Additional soil moisture may have increased soil adhesion on the coulter and/or covering disks and soil thrown by these tools.

Comparing the range of individual treatment means of percent residue remaining with other published values (table 4) shows that treatment means of experiment 5 were greater than other reported estimates or data. This may have occurred because of fresh residue cover.

An important observation from experiment 5 was that subjective visual differences were not confirmed with measured percent residue cover. Although covering discs appeared to move soybean residue disturbed by the coulter and knife back onto the disturbed area, such differences, if they existed, did not increase total percent residue cover.

Although, for all experiments, spring residue cover values after soil disturbance were always less than fall values, experimental design did not permit a meaningful comparison. Residue size reduction caused by tillage and increased deterioration over winter may offset the benefit of greater residue cover after fall tillage. Shelton et al. (1994) observed that using a knife applicator and/or stalk chopper in the spring, rather than in the fall, resulted in 14% greater corn residue cover. Initial residue cover for the spring soybean experiment was 5% less than for the fall experiment (table 1). Although previous soybean yields on the adjacent land areas were similar for the two knife experiments (table 1), over-winter residue decomposition (Stott et al., 1990) and the different land areas do not allow a direct comparison of fall and spring experiments.

Conclusions

Operator-controlled variables of implement use affected residue cover. Within the range of implement operational treatments observed, the data support the following conclusions:

- Disk-gang angle and tillage depth affect the burial of corn residue. A 5° lesser angle of the plane of disc blade edges with the travel direction and 51 to 76 mm (2 to 3 in.) shallower tillage depth buries 3 to 10 percentage points less residue cover. Slower speed may bury 3 to 6 percentage points less residue cover. Effects of disk-gang angle, depth, and speed are additive.
- Soil-engaging tools on a chisel plow and tillage depth affect the burial of corn residue. Both 406-mm (16-in.) sweeps and 51-mm (2-in.) chisel shovels bury 7 to 11 percentage points less residue cover than do 76-mm (3-in.) twisted shovels. Tillage at a 76 mm (3 in.) shallower depth buries four percentage points less residue cover. Effects of soil-engaging tool and depth are additive.
- A knife-only on a knife fertilizer applicator may bury 10 to 12 percentage points less soybean residue in wetter spring soil conditions than does an applicator used with coulters and/or covering discs. In a fall experiment no differences were observed.

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