# The Influence of Implement Type, Tillage Depth, and Tillage Timing on Residue Burial

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**Abstract.** *The ability of tillage implements to maintain surface residue coverage is largely dependent on the implement's main active component. Two categories of tillage implements were compared to determine their ability to maintain grain sorghum (non–fragile) surface residue coverage when operating at two different tillage depths for fall and spring tillage. Chisel–type implements were found to bury substantially less crop residue than disk–type implements. Disk–type implements were found to bury increased amounts of crop residue when operating at deeper tillage depths. Fall and spring tillage were also found to leave equivalent amounts of percent residue cover and total mass of crop residue remaining on the soil surface. A more thorough understanding of the ability of tillage implements to maintain adequate amounts of surface residue coverage should enable producers to select appropriate implements to maximize production while minimizing erosion.*

***Keywords.*** *Tillage, Implement, Residue, Chisel, Disk.*

Many tractor operators have learned from experience that increasing their tillage depth results in reduced amounts of residue present on the soil surface. For many years, this mattered little since residue was largely considered trash to be disposed of by burial. However, since agriculturalists and environmentalists began to recognize the significance of crop residue and the erosion control that can be associated with residue's presence, more credence has been given to maintaining adequate surface coverage.

A vast number of implements have been constructed for tilling the soil, and many leave significant residue coverage. However, many operational parameters can affect the effectiveness of tillage tools to maintain surface residue. Woodruff and Chepil (1958) first reported that an offset disk harrow would leave varying amounts of residue on the soil surface based on its depth of operation, speed, and angle of offset. A full discussion of all implements, including the effect of these operational parameters on each implement under varying soil and climatic conditions, is beyond the scope of any intended research. However, some assumptions about similarities in tillage action can be made about the various types of implements and their effects on residue burial and soil.

Tillage implements can be generally partitioned into two groups: (1) those that till the entire area of the field, and (2) those that only till within the row zone. The first tillage group consists of systems that uniformly treat the entire soil surface without considering the location of row or wheel tracks. This is the system that historically has been used in conventional tillage systems, where the entire soil surface was plowed, harrowed, and otherwise prepared so that seed could be placed anywhere in the field and have the same chance of germination and productivity. The second group of tillage implements has become much more popular in recent years as interest in maintaining residue coverage has emerged. This management system is referred to as "strip–tillage" and uses implements that only till the area adjacent to the row, leaving areas between rows undisturbed.

Four broad categories can be identified for tillage tools that have been developed for soil preparation:

***Chisel–type implements:*** Consisting primarily of shanks that are dragged through the soil and have no active, moving components. Chisel–type implements can be used for primary or secondary tillage (*ASAE Standards*, 1998) and may include chisel plows, subsoilers, and field cultivators.

***Disk–type implements:*** Consisting primarily of rotating disks that cut and move the soil. Disk–type implements are primarily used for secondary tillage but may be used for primary tillage in the form of offset disks or heavy tandem disks.

***Rotary–tillage–type implements:*** Consisting primarily of a powered, rotating shaft with attached tillage blades. Rotary–tillage–type implements can be used either for primary or secondary tillage.

***Inversion–type implements:*** Consisting primarily of shares/disks that invert the soil down to the depth of tillage, mainly consisting of moldboard plows. Inversion–type implements are mostly used for primary tillage and include moldboard plows.

It is recognized that these implement types vary broadly and overlap significantly because many tillage tools have components from several of the above categories. Combination primary tillage implements and secondary tillage implements use two or more dissimilar tillage components as integral parts (*ASAE Standards*, 1998). However, this categorization should allow broad assumptions to be made

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about the effect of operational parameters on various implements' performance relating to residue burial.

One of the operational parameters that tends to have the largest effect on residue burial by tillage implements is depth of tillage. Other than the previous reference to Woodruff and Chepil's research (1958), few researchers have addressed this operational variance. Fewer still have reported complete data about their tillage operations in residue, including depth of tillage, residue coverage, and amount of residue originally present. Johnson (1987, 1988) found that when tillage depth was reduced from 25 to 10 cm with a chisel plow, 20% less surface residue was buried. Hanna et al. (1995) found that reducing tillage depth from 10.4 to 5.1 cm with a tandem disk harrow buried 4% less residue.

The objectives of this research, therefore, are to:

- Determine differences in residue burial caused by two common implement types: disk–type implements and chisel–type implements.
- Determine differences in residue burial as a function of tillage depth.
- Determine differences in residue burial as a function of time of year of tillage.

# Methods and Materials

The study was conducted near Shorter, Alabama, at the E.V. Smith Research Center (32° 25.467′ N, 85° 53.403′ W) on a Norfolk loamy sandy soil (fine–loamy, siliceous thermic, Typic Kandiudults). Field plots were 15.2 m × 4.6 m, with four replications. Grain sorghum (Dekalb 55) was drilled by a John Deere Model B grain drill with 0.18 m spaced rows in 1998 and achieved a final stand density of 37 plants/$m^2$ with plots being harvested for grain yield, which was 955 kg/ha.

Two commercial implements were evaluated: (1) a John Deere 210 tandem disk harrow (double–offset) and (2) a DMI Tiger–Mate II high–residue field cultivator. Both implements tilled approximately the same width of soil, which was 3.8 m. One of these implements could be classified as a disk–type implement and the other a chisel–type implement. The tandem disk harrow had a front and rear setting of disk angle to adjust aggressiveness. The front disk gangs were set at the medium setting of 16.5°, while the rear gangs were set at the most aggressive setting of 14.3°. The diameter of the disks was 0.51 m, and the disks were spaced at 0.23 m intervals. The field cultivator had 25 sweeps of 0.18 m width spaced approximately 0.61 m apart on five members of the frame. A Transducer Techniques load cell (55.7 kN capacity) was used to acquire draft force of each implement. The speed of operation was maintained constant at 5 km/h. All operations were conducted with a JD 8300 tractor (8402 kg, 149 kW).

Two depths of tillage (7.6 cm and 15.2 cm) were conducted in the fall and spring of the year. Fall tillage was on 2 December 1998, and spring tillage was on adjacent plots on 6 April 1999. Glyphosate was used to control weeds during winter months. A no–till plot was also used for comparison purposes. Following tillage in the fall, surface samples for soil water content from depths of 0 to 15 cm depth were obtained at the time of tillage. Following tillage in the spring, four cores were obtained from each plot (Raper et al., 1999) and analyzed for bulk density and moisture content at depths of 0–50 mm, 50–100 mm, 100–150 mm, 150–200 mm, and 200–250 mm.

Two replications of line–transect measurements of 15 m length with 50 measurement points were used to determine percent residue cover after tillage treatments. Residues remaining on the soil surface were identified as standing or flat regardless of the state of soil attachment. Four 0.25 m × 0.25 m plots within each treatment were randomly selected and harvested, and the residue was washed, dried, bagged, and weighed. Ten 7.6 cm diameter core samples were taken from each plot after tillage, and the soil was removed by gently washing to determine the mass amount of residue found in the soil. Depths analyzed were 0–50 mm, 50–100 mm, 100–150 mm, and 150–200 mm.

The experiment was designed as a randomized complete block experiment, and data were analyzed using the General Linear Model (GLM) procedure of SAS (SAS, 1999). A significance level of $P \leq 0.10$ was established *a priori*. Single degree–of–freedom (SDOF) contrasts were also used for group comparison.

# Results and Discussion

The average gravimetric soil water content found across all plots when tillage was conducted in the fall of the year was 4.2% from 0 to 150 mm and 5.9% from 150 to 300 mm. When spring tillage was conducted, the water content was found to have been affected ($P \leq 0.001$) by the tillage treatments in those plots that had received tillage the previous fall (fig. 1). Plots that had been disked or chiseled the previous fall (particularly at the deepest depths) had reduced spring soil water content levels at all depths.

Bulk density values were not different due to tillage effect, except at the shallowest depth near the soil surface (fig. 2). At this depth, both fall chisel treatments and the no–till treatment had similar bulk density values, which were greater than all spring tillage treatments and the fall disk treatments.

Draft force (fig. 3) was significantly higher in fall and spring for the deep chisel treatment. These draft forces were more than twice the values for any other tillage treatment. The draft forces for the deep disk and shallow chisel treatments were relatively similar at both times. The lowest draft force was required by the shallow disk treatment.

In fall of 1998, the no–till plot was found to have 74% residue coverage according to the line–transect method (table 1). This value was assumed to be the percent residue cover present on all plots prior to tillage. This was significantly greater than any of the four tillage treatments, with shallow chiseling producing 54% residue coverage, shallow disking producing 42% residue coverage, deep chiseling producing 39% residue coverage, and deep disking producing 22% residue coverage. All treatments were statistically different, except for shallow disking with 42% residue coverage and the deep chiseling with 39% residue coverage.

In spring of 1999, the no–till residue coverage had decreased to 34% (table 1), which was still significantly greater than all other treatments. The next greatest amount of residue coverage belonged to the fall shallow chisel treatment, with 25% residue coverage. No statistical difference was found between fall shallow chisel (25%), spring shallow chisel (22%), spring deep chisel (22%), and fall shallow disk

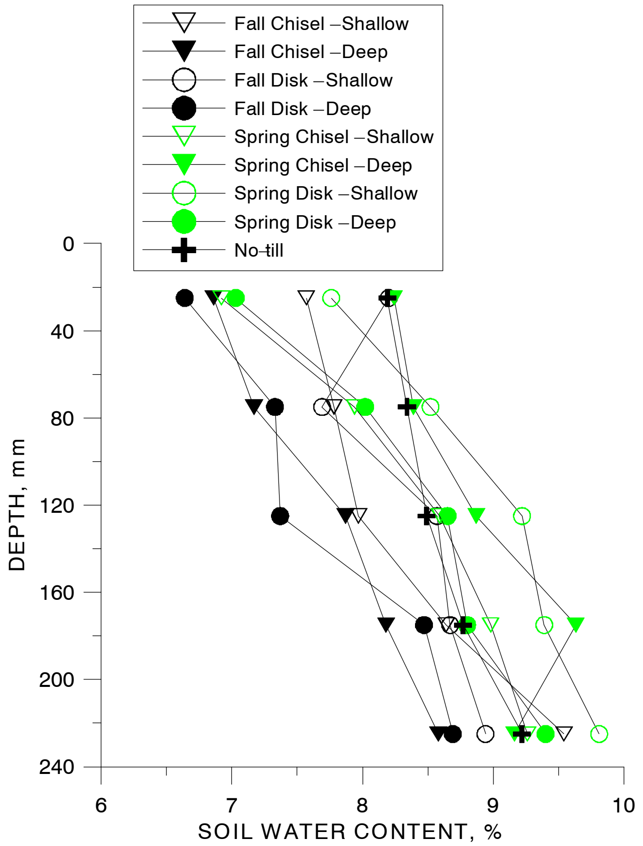


**Figure 1. Soil water content taken immediately after tillage in spring of 1999.**

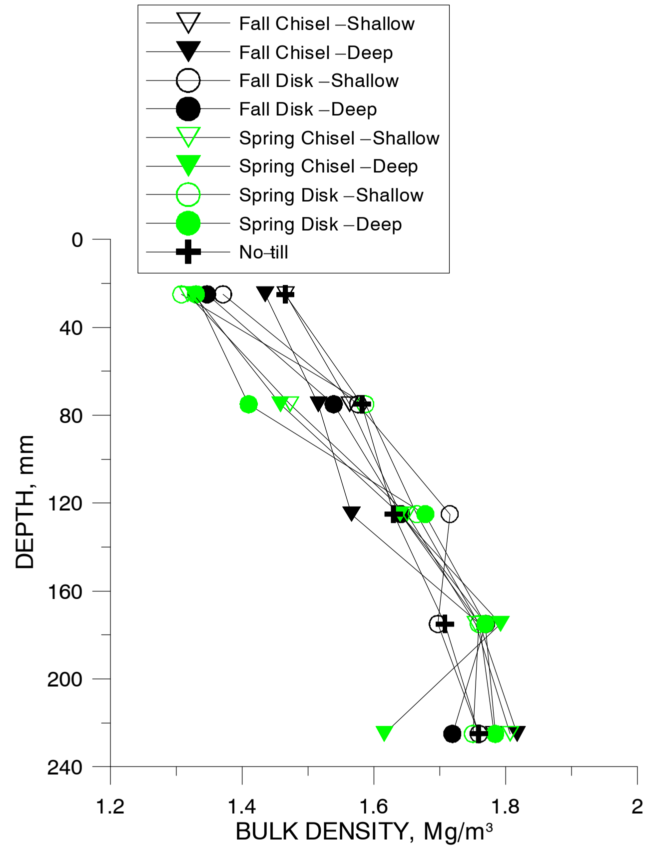


**Figure 2. Bulk density taken immediately after tillage in spring of 1999.**

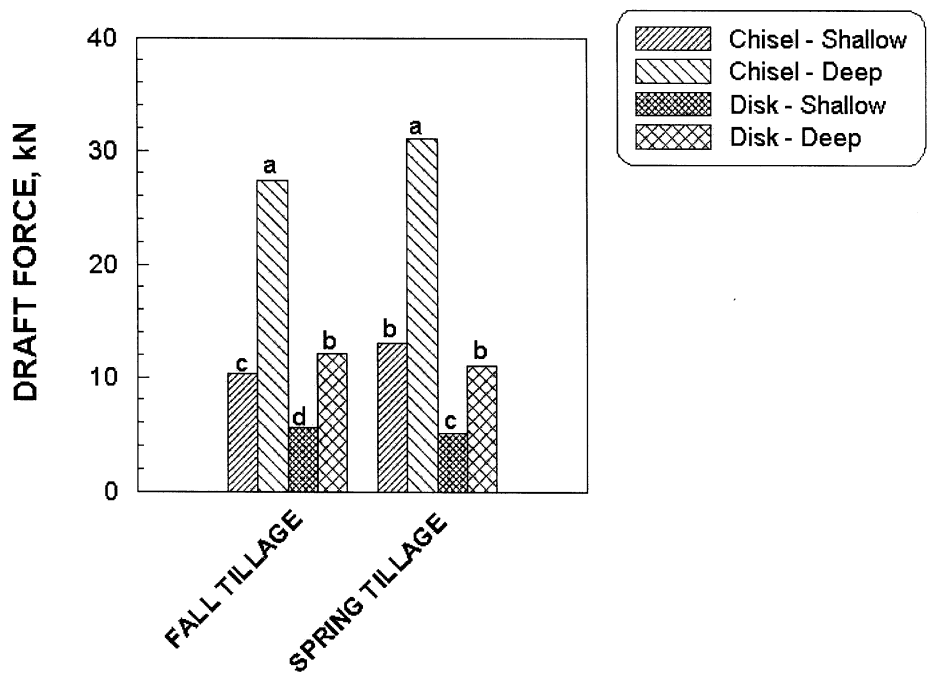


**Figure 3. Draft force measured in fall of 1998 and spring of 1999 when tillage treatments were applied. Letters indicate statistical differences within tillage application time at the 0.10 level.**

(22%). Minimum values of residue coverage were found in the deep disking treatments, with fall disking having statistically similar residue coverage (14%) as compared to spring disking (10%).

Single degree–of–freedom (SDOF) contrasts of the percent residue coverage remaining after tillage in the fall of the year showed chisel–type implements left significantly more residue cover than disk–type implements (46% vs. 32%; $P \leq 0.0025$). Deep tillage produced significantly reduced percent

Table 1. Percent residue cover remaining after tillage treatments were applied in fall of 1998 and spring of 1999.

| Treatments | % Residue Cover | |
|---|---|---|
| | Fall Sampling | Spring Sampling |
| No tillage | 74 a | 34 a |
| Fall shallow chisel | 54 b | 25 b |
| Fall deep chisel | 39 c | 18 cd |
| Spring shallow chisel | — | 22 bc |
| Spring deep chisel | — | 22 bc |
| Fall shallow disk | 42 c | 22 bc |
| Fall deep disk | 22 d | 14 de |
| Spring shallow disk | — | 16 d |
| Spring deep disk | — | 10 e |
| $LSD_{(0.10)}$ | 10 | 5 |

residue coverage as compared to shallow tillage (30% vs. 48%; $P \leq 0.0007$) using another SDOF contrast. In the spring of the year, SDOF contrasts found significant differences in percent residue coverage between chisel–type tillage vs. disk–type tillage (22% vs. 15%; $P \leq 0.002$) and deep tillage vs. shallow tillage (16% vs. 21%; $P \leq 0.0019$). However, no difference in percent residue coverage remaining in the spring of the year was found between fall and spring tillage.

No differences were found in the mass of residue left flat on the soil surface in the fall after tillage (table 2). However, statistically significant differences were found in the mass of residue left standing. The largest amount of standing residue was in the undisturbed no–till plots (2028 kg/ha), with similar values being found in the shallow chiseled plots (1916 kg/ha). The minimum mass of standing residue of 667 kg/ha was found in the deep–disked plots. The total amount of residue left on the soil surface was greatest in the no–till plots (3122 kg/ha) and the shallow chiseled plot (2882 kg/ha), with slightly less being found in the shallow disked plot (2533 kg/ha). Again, the minimum mass of total residue on the soil surface was found in the deep–disked plots (1301 kg/ha).

Comparing the above–ground mass after tillage treatments to the amount of mass found in the no–tillage plots demonstrates how different tillage treatments are able to maintain large amounts of surface residue. The fall shallow chisel treatment maintained the highest percentage of above–ground residue, with 95% of the residue still on the soil surface (table 2). The fall shallow disk treatment also maintained a large amount of residue (85%) on the soil surface. Significantly reduced amounts of residue were found on the soil surface as a result of fall deep chiseling (70%) and especially by fall deep disking (45%).

Residue samples collected immediately after spring tillage showed that the total mass of residue on the soil surface in the no–till plots declined by 15%, from 3122 kg/ha to 2644 kg/ha (table 2), while the percent residue coverage declined from 74% to 34% (table 1). This significant decrease in no–till residue coverage was probably due to degradation of the low–weight grain sorghum leaves, which left only stalks for soil protection. One interesting natural transition that occurred due to the wintering process was the marked increase in flat residue from 1094 kg/ha in fall to 1890 kg/ha in spring (table 2). This increase came at the expense of standing residue, which declined from 2028 kg/ha to 754 kg/ha.

Three groupings of data can be found in the total amount of crop residue remaining after spring tillage. As mentioned previously, the largest mass of total crop residue was maintained by the no–tillage plots, with 2644 kg/ha (table 2). All other tillage treatments, both spring and fall, had equivalent amounts of total mass residue remaining on the soil surface, with the exception of fall and spring deep disking. These two treatments had the lowest amounts of mass remaining on the soil surface, with fall deep disking having 712 kg/ha and spring deep disking having 439 kg/ha. This relationship is also found by examining the percent of mass remaining compared to the spring no–tillage plot. All tillage treatments, with the exception of the fall and spring deep disking treatments, had between 53% and 70% of the mass of crop residue remaining on the soil surface. Fall deep disking had 28% and spring deep disking had 16% of the mass of crop residue remaining on the soil surface, which were significantly less than all other treatments.

Of significant interest is the great reduction in total residue that was available in spring from plots that had been tilled the previous fall (table 2). The amount of total surface residue present in the spring resulting from fall shallow chisel was 47%. Fall deep chisel retained 20% of the mass of the surface residue, while fall shallow disk retained 37%, and fall deep disk retained 45%. The fracturing of the residue by the tillage process in the fall seemed to increase the decomposition process over the winter months for those plots that had tillage. This is illustrated by the larger amounts of reduction in mass cover for those plots that received tillage as compared to the no–till plots.

Table 2. Mass and percentage of mass of residue remaining after tillage treatments were applied in fall of 1998 and spring of 1999.

| Treatments | Fall Sampling | | | | Spring Sampling | | | |
|---|---|---|---|---|---|---|---|---|
| | Flat ($kg\ ha^{-1}$) | Standing ($kg\ ha^{-1}$) | Total ($kg\ ha^{-1}$) | Mass Remaining Compared to Fall No–Till (%) | Flat ($kg\ ha^{-1}$) | Standing ($kg\ ha^{-1}$) | Total ($kg\ ha^{-1}$) | Mass Remaining Compared to Spring No–Till (%) |
| No tillage | 1094 | 2028 a | 3122 a | — | 1890 a | 754 a | 2644 a | — |
| Fall shallow chisel | 967 | 1916 ab | 2882 a | 95 a | 1391 b | 122 c | 1513 b | 60 a |
| Fall deep chisel | 799 | 1306 c | 2106 b | 70 b | 1146 bc | 537 ab | 1683 b | 63 a |
| Spring shallow chisel | — | — | — | — | 1118 bc | 512 ab | 1630 b | 62 a |
| Spring deep chisel | — | — | — | — | 1094 bc | 707 a | 1800 b | 70 a |
| Fall shallow disk | 959 | 1574 bc | 2533 ab | 85 ab | 1326 b | 272 bc | 1598 b | 61 a |
| Fall deep disk | 634 | 667 d | 1301 c | 45 c | 674 cd | 35 c | 712 c | 28 b |
| Spring shallow disk | — | — | — | — | 1206 b | 107 c | 1313 b | 53 a |
| Spring deep disk | — | — | — | — | 397 d | 42 c | 439 c | 16 b |
| $LSD_{(0.10)}$ | ns | 404 | 738 | 17 | 485 | 296 | 521 | 21 |

The loss of structural integrity of the crop residue in the spring can be seen by the ability of the tillage implements to leave small amounts of standing residue as compared to the previous fall's tillage (table 2). For fall tillage, none of the tillage treatments resulted in larger amounts of flat residue than standing residue. However, in spring, the action of the tillage implements resulted in much greater amounts of the crop residue being flat rather than standing. However, it is interesting to note that both spring and fall tillage resulted in similar amounts of crop residue on the soil surface. The degradation of the crop residue over the winter months did not contribute to spring tillage burying more residue than fall tillage.

SDOF contrasts conducted on percent mass cover remaining after tillage in fall found significant differences between chisel–type tillage vs. disk–type tillage (83% vs. 65%; $P \leq 0.0256$) and deep tillage vs. shallow tillage (57% vs. 90%; $P \leq 0.0009$). Similar trends were found for percent mass cover remaining after tillage in spring between chisel–type tillage vs. disk–type tillage (64% vs. 39%; $P \leq 0.0009$) and between deep tillage vs. shallow tillage (44% vs. 50%; $P \leq 0.028$). However, no statistical advantage was found for either spring or fall tillage for the percent of mass residue left on the soil surface.

Chisel–type tillage conducted either in spring or fall showed similar values of percent residue cover (table 1) and total residue mass remaining on the soil surface (table 2) the following spring. Virtually no difference in either measurement was found due to depth of tillage or timing of tillage. However, large differences were seen due to depth of tillage for the disking operation, particularly for residue mass left on the soil surface after deep disking in fall (712 kg/ha) and spring (439 kg/ha) as compared to shallow disking in fall (1598 kg/ha) and spring (1313 kg/ha).

Data from published sources that reported tillage depths (Hanna et al., 1995; Johnson, 1987; McCool et al., 1989; Wagner and Nelson, 1995) were combined and analyzed as one data set. It should be noted that these data differ in many regards, including type of residue, age of residue, time since tillage, specific type of implement, soil type, soil strength, etc. Despite these differences and a large amount of scatter in the data, a linear regression was fitted to the reported data for the chisel–type and disk–type implements and is shown in fig. 4. Depth of tillage was found to have a more pronounced effect on disk–type implements over chisel–type implements, with a steeper line being projected. This result was verified by the data from the current study that were presented in tables 1 and 2 and are also plotted in fig. 4, which shows small differences in residue mass or cover remaining after chiseling due to differences in tillage depth, but large differences resulting from differences in depth of disking. It is important to note that despite greater amounts of percent residue cover left on the soil surface by the implements from the published data as compared to our experimental data, remarkable similarities in the slopes of the lines exist, with depth of tillage having much less effect on chisels than disks.

A portion of the original above–ground residue mass was redistributed by the various tillage treatments to below–ground residue mass (table 3). After tillage in fall of 1998, no differences were seen at the 0–50 mm depth or at the 150–200 mm depth. Significant differences in buried residue were found at the 50–100 mm depth, with the fall deep disk treatment (1230 kg/ha) exceeding all other treatments. This same effect was also found at the 100–150 mm depth, with the fall deep disk treatment having more than twice the below–ground buried residue of the other treatments (680 kg/ha).

Samples obtained in the spring showed similar effects (table 3). Again, differences in buried residue mass were not

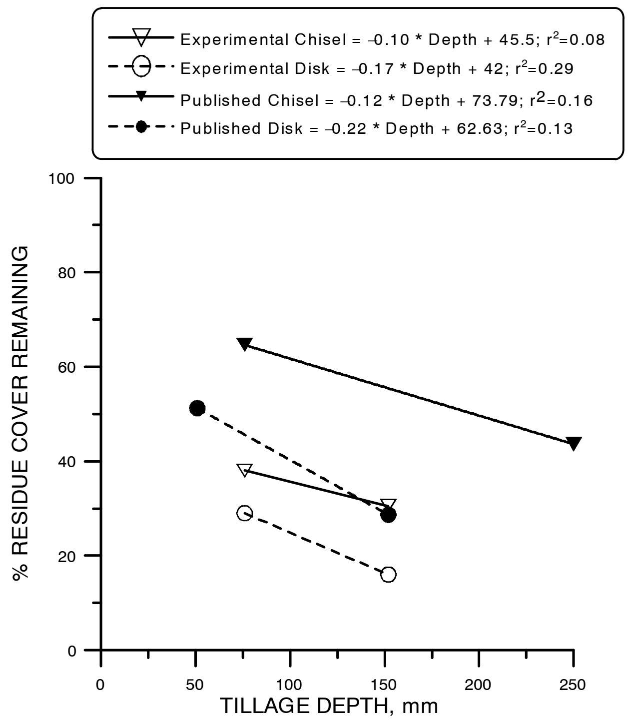


**Figure 4. Linear fits of selected published data of percent residue cover remaining after tillage for two classes of tillage implements, shown with linear fits of current research results.**

**Table 3. Mass of residue remaining in the soil (kg $ha^{-1}$) after tillage treatments were applied in fall of 1998 and spring of 1999.**

| | Fall Sampling | | | | Spring Sampling | | | |
|---|---|---|---|---|---|---|---|---|
| Treatments | 0–50 mm | 50–100 mm | 100–150 mm | 150–200 mm | 0–50 mm | 50–100 mm | 100–150 mm | 150–200 mm |
| No tillage | 955 | 524 b | 145 b | 45 | 712 | 295 cd | 118 | 18 |
| Fall shallow chisel | 1055 | 385 b | 249 b | 58 | 992 | 241 cd | 71 | 45 |
| Fall deep chisel | 1496 | 409 b | 309 b | 36 | 1384 | 600 ab | 209 | 19 |
| Spring shallow chisel | — | — | — | — | 1106 | 200 d | 64 | 24 |
| Spring deep chisel | — | — | — | — | 885 | 264 cd | 103 | 20 |
| Fall shallow disk | 1025 | 687 b | 120 b | 34 | 1056 | 521 bc | 88 | 172 |
| Fall deep disk | 1026 | 1230 a | 680 a | 147 | 1649 | 847 a | 224 | 24 |
| Spring shallow disk | — | — | — | — | 1308 | 641 ab | 225 | 33 |
| Spring deep disk | — | — | — | — | 854 | 685 ab | 151 | 18 |

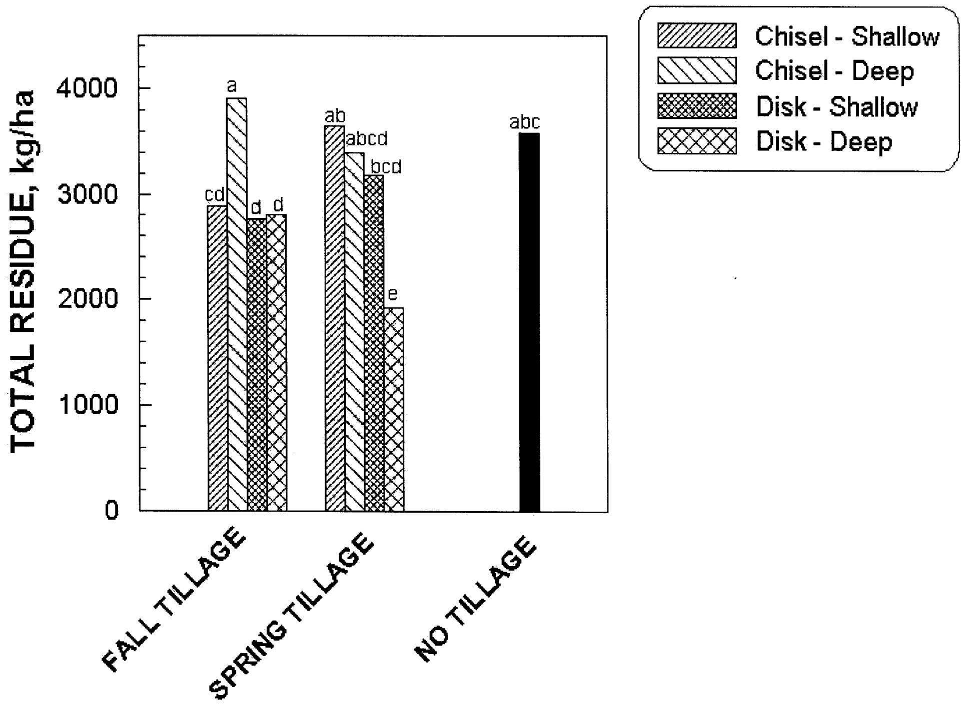


**Figure 5. Total residue combined from above–ground and below–ground measurements in spring of 1999 after tillage treatments were applied. Letters indicate statistical differences at the 0.10 level.**

found at the shallowest (0–50 mm) or deepest (150–200 mm) depth sampled. At the 50–100 mm depth, the fall deep disk treatment still had the statistically largest amount of buried residue (847 kg/ha). It is important to note that this value had declined from 1230 kg/ha taken in the fall of the year and that no further tillage had taken place. The lowest values of buried residue at this depth were found in the spring shallow chisel treatments (200 kg/ha).

A check of the total amount of above–ground and below–ground residue shows no differences in fall 1998 (data not shown). A mean value of 3985 kg/ha was found with no treatment effects. Statistical differences were found, however, in spring 1999 (fig. 5). Due to various tillage treatment effects on the buried and above–ground standing and flat residue, and the degradation of the residue, the total amount varied from 3902 kg/ha for the fall deep chisel treatment to 1922 kg/ha for the spring deep disk treatment.

## Conclusions

Broad classifications of tillage tools were created to assist in making general determinations about an implement's ability to retain crop residue on the soil surface. Two commonly used implement types (chisel and disk) were compared to determine their ability to retain surface residue as a function of tillage depth and time of year of tillage. Specific conclusions are:

- Disk–type implements were found to bury significantly more residue than chisel–type implements.
- Disk–type implements buried substantially more residue when tillage depth was increased. Chisel–type implements, however, were found to bury similar amounts of crop residue at different tillage depths.
- The time of year when tillage was conducted was not found to affect the percent residue cover nor the total mass amount of residue remaining on the soil surface in the spring of the year.

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