# Row-Zone Tillage Systems and Implements

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## ABSTRACT

"Row-Zone Tillage" systems apply tillage procedures only to narrow strips of land where the next crop rows will be planted. The tilled zones are no more than 25% of the field area. Row-zone tillage procedures for crop production are conservative, wherein the soil remains partially covered with protective residues while crops are planted, fertilized, grown, and harvested in the row-zones. Specially adapted implements are being developed for these operations. There is potential for minimizing farm machinery inventories. Limited crop response data are available from Canada and the USA.

Keywords: Tillage, Zone, Soils, Residues, Management, Review, Results

## INTRODUCTION

"Row-Zone Tillage" is one of many types of conservation tillage systems for row crops. Conservation tillage encompasses many types of cultural practices that result in the protection of soil and control of surface water runoff. In comparison, intense tillage buries crop residues and results in unprotected soil. Soil and water protection is achieved by the maintenance of old-crop residues, as partial coverage and protection of the soil surface. Most conservation tillage systems till or disturb all of the soil surface at least once a year. In contrast, "no-till" is a conservation tillage system that disturbs only very narrow slits in the soil for planting and fertilizer application. The trend in the USA is for farmers to use less tillage, leaving more crop residue on the soil surface. Many of the recent innovations in tillage implements and cultural practices are attempts to address how to accomplish field operations in soil which is partially covered with protective residues. The essence of the row-zone tillage concept is to provide uncovered, tilled row-zones where proven "conventional" planters and fertilizer applicators can be operated without the encumbrance of residues. Residues are maintained in non-tilled interrow areas.

## ELEMENTS OF ROW-ZONE TILLAGE

Definition of Row-Zone Tillage. As a conservation-tillage practice, row-zone tillage is defined as any row-crop cultural practice that restricts soil and residue disturbance to less than 25% of the field area (Fig. 1). For example, for crop rows spaced at 76 cm, tillage strips should be less than 19 cm in width. The definition presumes that the intervening 75% or more of the field surface area will be at least partially covered by residues and that the soil will not be intensely disturbed. This includes the assumption that all weed control in the undisturbed areas will be controlled with herbicides or with low-disturbance cultivators. It also assumes that row ridges requiring tillage and intense disturbance of the interrow areas will not be formed in the field. Tillage within the row-zones may be shallow, deep, minimal, or intense. The practices and implements used will depend upon the soil, climate, crop, and management scheme. This system can be equally applicable to one-row or 20-row implement-size farming operations.

Appropriate Soils for Row-Zone Tillage. All mineral soils may be candidates for the use of row-zone tillage. If this seems contrary to what is known about the tillage requirements for "hard-setting", high clay, and other problem soils, it is necessary to remember that appropriate tillage is conducted in the row-zones, while the untilled interrow zones are protected with crop residues. Two cultural procedures are conducted simultaneously in a field; one for the row-zones and another for the interrow areas. Primary and secondary tillage are commonly limited to the top 15 to 20 cm, in topsoil. Therefore, any cultural procedures which may be required to maintain desirable soil structural properties could be included in the row-zone tillage system for that particular situation. For the interrow zones that are not disturbed, the soil must be protected so that it does not erode. These interrow zones serve as repositories of stored soil water and nutrients. Additionally, they serve as traffic lanes for tractor, harvester, and implement wheels. Therefore, the soil surface in the interrow zones must be protected, have a soil structure that is open to water infiltration, and support wheel traffic.

The Role of Residue Cover. Protective crop residues are either cleared from the narrow row-zones and accumulated in the interrow areas or incorporated into the soil when the row-zone tillage procedures are conducted. Stubble with root clumps may be cleared into the interrow areas. Residues in the interrow areas support the loads of wheel traffic to reduce sinkage and make machine mobility possible under wet soil conditions (Bashford et al., 1987). This is especially important on clay soils that have only one-third to one-forth the bearing strength of sandy soils when wet (Dao et al., 1994). Because farming systems tend to be based on a certain numbers of rows for all machines, the wheel traffic is concentrated in certain interrow areas, making row-zone tillage similar to controlled-traffic systems. Infiltration of rainfall and intercepted runoff water is necessary in the interrow areas, because they consitute 75% or more of the field surface. Residues provide microimpoundment of surface water to reduce runoff by providing raindrop energy dissipation to reduce surface sealing, and more time for water infiltration to reduce surface sealing (Mutchler and Young, 1975).

Weed Control. Because there are two simultaneous cultural procedures being conducted in the same field, we have the potential to conduct two different weed control systems; one in the row-zones and another in the interrow areas. Options include:

a). Incorporation of herbicides into the row-zones with tillage.
b). Shallow undercutting sweep-tillage in the interrow areas.
c). Broadcast of preemergence herbicides over the entire field surface.
d). Postemergence-directed spraying of herbicides under the crop rows.
e). Postemergence-directed spraying of herbicides in the interrow areas.
f). Over-the-top postemergence application of selective herbicides.
g). Broadcasting herbicides between cropping seasons.

The appropriate timing, materials, and rates for weed control will be somewhat site specific, following an Integrated Pest Management (IPM) plan. All of the optional procedures being used in various conservation tillage and no-tillage systems can be readily incorporated into row-zone tillage systems.

Row-Zone Tillage "Alternatives". Row-zones may range in width from as narrow as 10 cm to as wide as 25 cm for row spacings of 40 to 100 cm, respectively. The tillage conducted in these zones is most easily characterized by depth and width of operation. Alternatives will typically be one of the following:

a). Shallow planting-depth at 3 to 5 cm.
b). Cultivation depth at 7 to 10 cm.
c). Chiseling depth at 15 to 20 cm.
d). Subsoiling depth at 25 to 40 cm.

Degree of soil loosening, structure change, and mixing may vary among soils and soil conditions, as well as among different tillage tools and speeds of operation (M'Hedhbi, 1989).

Several of the above Alternatives are already established procedures, and are used as integral parts of the planting/seeding operations under various terminologies. If row-zone tillage is separated from the planting operation, then there are some additional management alternatives to take advantage of changing soil properties during the period between crops. For instance:

1). Shallow tillage [Alternative (a)] one day prior to planting to loosen, dry, and warm the soil to the planting depth.
2). Residue clearing of the row-zone to increase solar insolation to warm cold soils for planting.

3). Cultivation depth tillage [Alternative (b)] several weeks or months before planting to loosen soil deeper than would be desirable at planting, but relying on subsequent rainfall and consolidation to firm the seedbed.
4). Shallow tillage [Alternative (a)] to incorporate herbicides into the row-zone prior to planting.
5). Chisel depth tillage [Alternative (c)] at the time of the year when the soil is driest, to fracture any consolidated and compacted layers which might impede crop rooting.
6). Chisel or subsoiler depth tillage [Alternative (c) or (d)] to deep place fertilizer below the crop rows, days, weeks, or months before planting.
7). Multiple passes of tillage within row-zones, before or including tillage during the planting/seeding operation.

Implements For Tillage Alternatives. Crop production with row-zone tillage systems could substantially reduce the number and total cost of implements, as compared to conventional or minimum tillage. For example, the machinery inventory could be limited to the following implements:

a). Conventional pesticide sprayer with nozzle booms,
b). Conventional row-crop planter/seeder,
c). Row-zone tiller.

For this example, the fertilizer would be applied with the row-crop planter and/or with the row-zone tiller. No intercultivation would be done during the season. Additional implements might include:

a). Postemergence-directed pesticide sprayer,
b). Low-disturbance type shallow interrow cultivator,
c). Cutter-shredder for cutting standing residue-stubble.

Tractors, harvesters, grain carts, etc. would be common in all systems.

Row-zone tillage implements are either attachments for planters or separate implements to be used prior to planting. The planter attachments are most often mounted on additional toolbars to position the tillers ahead of each planter unit. Currently available options include the following examples of implements and attachments:

a). Subsoiler followed by a rolling soil crumbler (Brown-Harden "SuperSeeder"; Bush Hog "Ro-Till"; KMC "In-Row Tillage System").
b). Double or triple fluted rolling coulters which are spring-loaded for flotation, but not depth control (Rawson "Coulter Till"; Progressive "Twin Coulter").
c). Cultivating sweep and depth control wheel (Fleischer Mfg. "Buffalo Cultivator"; Brown Mfg. Co. "ChiselVator"),
d). In-row deep fertilizer placement knives (DMI "Indexing"; Valmar Airflo Inc. "Deep Bander").

Separate row-zone implements are now under development. These implements promise to be multipurpose machines which can have tools attached to perform Alternatives (a), (b), and/or (c). (Subsoiling [Alternative (d)] would require a substantially stronger implement). Toolbars will be used for the main frames, so that individual units may be positioned to correspond to various crop row spacings. This flexibility will also allow the units to be positioned between crop rows for use as interrow cultivators or as side-dress fertilizer applicators when equipped with appropriate tools. Standard features of individual units will be:

a). Unit flotation,
b). Depth control,
c). Adjustable or controllable vertical force for soil penetration,
d). One or more rolling coulter blades to cut residue and soil.

Attachment options will include:

a). Residue-clearing tools to clear a narrow path,
b). Shallow sweep tool,
c). Cultivating-depth sweep tool,
d). Narrow chisel tool,
e). Sweep-type chisel tool,
f). Wide shallow sweep for interrow cultivating,
g). Nozzle for applying herbicides to be incorporated in the row-zone,
h). Nozzle or tube for applying liquid or granular fertilizer.

Row-zone implement designs will be new combinations of standard components to operate in residue-covered soils under management systems that are adapted to particular soils, crops, and climates.

## REVIEW OF DATA FROM CANADA AND USA

Information has only recently been reported at meetings and published on row-zone systems. Karlen et al. (1991) reported the use of [Alternative (d)] in-row subsoiling to a depth of 40 cm in a loamy sand soil which normally consolidates to impede plant root growth. They measured drawbar power requirements in the range of 18 kW per row unit in dry soil, which is excessive and possibly not economical. Edwards et al. (1988) used strip-tillage subsoiling to a depth of 30 cm ahead of a planter in Alabama on a Hartsell fine sandy loam (fine loamy, siliceous, thermic Typic Hapludults). They found that strip-tillage and no-till in combination with a corn-soybean (*Zea mays L.-Glycine max L.*) rotation gave the most consistent yield increases during a four year study. Row-zone tillage has been used for some specialty crops. For instance, Halvorson and Hartman (1984) reported that in some areas of sugarbeet (*Beta vulgaris L.*) production, as much as 20% of the acreage is produced by the use of shallow powered row-zone tillers [Alternative (a)] operating 7-10 cm deep. In their studies on irrigated Savage silty clay loam soil (Typic Argiboroll), they found no effects on spring soil temperature, plant stand, root yield, or sucrose (sugar) yield among conventional, 18-cm wide row-zones, and no-till tillage systems. Sugarbeet tillage systems were also compared by Smith et al. (1995) in Nebraska on a Tripp very fine sandy loam (Typic Hapustoll). Their study of energy requirements showed that both minimum-tillage and powered tiller row-zone systems reduced total tillage energy requirements by 60% over conventional moldboard plow systems.

In Ontario, Canada, Raimbault et al. (1991) grew corn in herbicide-killed rye (*Secale cereale L.*) cover crop. They were working on a Maryland loam (Typic Hapludalf) and used powered rotary tiller units to produce shallow 12-cm wide and 10-cm deep row-zones [Alternative (a)]. Their corn yields were the same for conventional moldboard plowing and row-zone tillage, when the rye was killed at least two weeks prior to planting. In the central Corn Belt states, Iqbal et al. (1995) studied in-row soil disturbance effects from the use of no-till, a single coulter, and triple coulter blades. The triple coulter produced a zone of lowest bulk density and penetration resistance, but corn plant emergence and growth rate was the slowest. Their results are an example of a situation where the planting method was not compatible with the row-zone treatment. Detailed studies by Hares and Novak (1992) in Vancouver, Canada on Bose loamy sand (Typic Haplorthad), revealed that there is a complicated thermal regime in the bare soil strips of row-zone tillage. It seems that due to radiation from interrow residues and heat transfer between the bare strips and residue-covered interrows, soil temperature is increased in the middle of the bare strips. Kaspar et al. (1990) studied the effect of removing residue cover from 8, 16, and 32-cm wide row zones in the Corn Belt. They found that seed-row residue removal reduced time for both 50% corn plant emergence and tasseling, increased plant height, and increased yield. The responses to width of row-zones were best described as logarithmic functions, improving with wider zones. For continuous wheat (*Tritcum aestivum L.*) production in Oregon, Bolton and Booster (1981) used powered rotary tiller units to produce row-zones that were 18-cm deep and 10-cm wide in wheat stubble. Their row-zone wheat yields consistently exceeded yields from no-till, because of improved plant stand establishment.

## EXPERIMENTAL METHODS

In 1995, cotton (*Gossypium hirsutum L.*) tests followed preliminary studies with comparisons of cotton growth between conventional chisel tillage and no-tillage systems. Row-zone treatments were added, using thin knife-chisels to prepare soil for planting. The treatments were conventional fall chisel plowing with tandem disking, fall and spring row-zone knife-chiseling, and no-tillage. In-row soil properties were measured with a cone penetrometer, and core sampling for water content and bulk density. Cotton plant growth and yield performance were monitored on Houston black clay soil (fine, montmorillonitic, thermic Udic Pellusert) in a randomized complete block design with four replications. Cotton treatments in 1996 were a repeat of the 1995 treatments, but conducted in undisturbed corn stubble residue. The design was a split plot with whole plots composed of either long-term no-till or chisel-till systems (Morrison et al. 1990).

Corn tests in 1996 were conducted in shredded corn residue from a 1995 conventional tillage crop. Two soils were used; Houston Black clay and Austin silty clay (fine-silty, carbonatic, thermic Entic Haplustolls). Tillage treatments were conventional fall chisel plowing with tandem disking, fall and spring row-zone knife-chiseling 20-cm deep, and winter and spring shallow row-zone cultivating with a 20-cm wide sweep operating 4-cm deep. All treatments were planted with a conventional John Deere 7100 MaxiMerge planter without any special attachments. Counter-CR insecticide (American Cyanamid Co.) was applied as a 16-cm band over the planted rows. Plant emergence rates and growth were monitored on three, 3-m long subsamples within each treatment across four replications on each soil type.

## RESULTS

The usual summer drought did not occur during the 1995 growing season (Jost, 1996). Therefore, cotton growth and performance differences seen during preliminary studies in previous years did not prevail in 1995. Soil bulk density to a depth of 40 cm was not different between the four tillage treatments after June 15 (date of usual start of drought period) because of frequent rainfall. Spring knife-chiseling in the row-zones caused significant loss of soil water until corrected by timely rainfall. In-row cone penetrometer resistance was greater at the 5 to 10-cm depth for no-till, but there were no differences below a depth of 20 cm during the growing season. Cotton plant stand establishment was increased by both the chisel-till and spring in-row chisel-knifing over no-till plant stands, indicating superior seedbed conditions. Due to sufficient rainfall in 1995, there were no differences among tillage treatments for cotton growth height, biomass development, or yields.

In 1996, corn emergence favored shallow row-zone tillage conducted one day before planting (Table 1). Plant growth was superior for shallow row-zone tillage treatments over deep knifing and conventional chisel plowing. Deep knifing treatments dried the soil prior to planting and thus reduced both emergence and growth.

Cotton plots in 1996 had similar emergence, plant heights, and biomass (Table 2). A trend toward more plant height for the no-till treatment may have been due to increased stored water under the no-till residue in a dry season.

## CONCLUSIONS

Use of row-zone tillage procedures will provide more management options than no-till, while still providing environmental protection and crop production.

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## TABLES

Table 1. Corn emergence and growth height for five tillage treatments.

| Treatment | Mean * Emergence (plants/3m) | Final † Emergence (plants/3m) | Leaf Collar Height (cm) ‡ |
|---|---|---|---|
| Conventional | 9.4ab | 10.3a | 20.9d |
| Fall Deep Knife | 9.3b | 10.9a | 32.5c |
| Spring Deep K' | 9.2b | 10.5a | 31.6c |
| Winter Shallow | 9.5ab | 10.1a | 38.4a |
| Spring Shallow | 10.0a | 10.9a | 34.8b |

* Mean emergence over 14 observation days; letters indicate similar means in a column at the 5% level of significance by Duncan Multiple Range test.
† Final emergence on day 24 after planting.
‡ Heigth of collar of highest developed leaf on day 51 after planting.

Table 2. Cotton emergence and biomass development in 1996.

| Treatment | Mean Emergence (plants/m) | Plant Height on Day=55 (cm) | Plant Height on Day=62 (cm) | Biomass on Day=62 (g/m) |
|---|---|---|---|---|
| Conventional | 14.7a* | 24.6ab | 33.3a | 69.3a |
| Fall Knife | 14.8a | 22.2b | 31.5a | 61.6a |
| Spring Knife | 14.3a | 25.9a | 35.0a | 70.4a |
| No-Till | 13.5a | 26.0a | 34.2a | 62.5a |

* Letters indicate similar means in a column at the 5% level of significance by the LSD test.

ILLUSTRATIONS

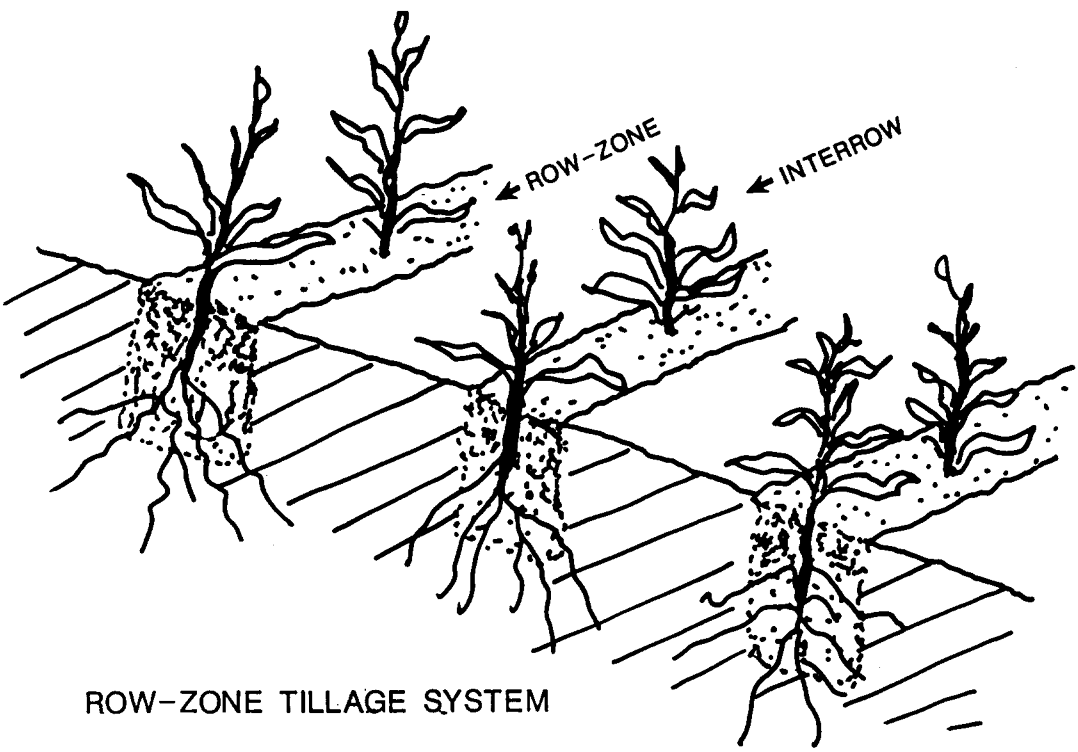


Figure 1. Row-Zone systems are conservation cropping systems wherein at least 75% of the field surface is not tilled and remains covered with protective residues.