Reduced or zero-tillage systems are often found to generate higher yields, reduce production costs, and reduce erosion and other forms of land degradation, with corresponding benefits for the natural resource base. They improve environmental quality owing to less greenhouse gas emissions and air pollution made possible by the reduced use of diesel fuel and stoppage of burning of residues (when planting could be done into surface mulch). It also ensures 25% saving in water. Many developed countries use these systems along with a whole system of mechanization to ensure good crop establishment, proper placement of fertilizer, and handling of crop residues. This is accompanied by a set of crop protection practices for handling weed, disease and pest problems.

In South Asia, reduced and zero-tillage practices for wheat after rice have been developed, though progress in the elaboration of complementary crop management practices is not as advanced as in developed countries. Nevertheless, farmers have already started to use some of these technologies. Zero-tillage for wheat after rice generally results in yields that are better than or equal to yields obtained using conventional practices.

**Surface Seeding**

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### Reduced and Zero-Tillage Options

- Surface seeding
- Reduced tillage with two- and four-wheel tractors
- Zero-tillage with four-wheel tractor
- Bed planting systems, particularly permanent beds
The key to success with this system is having the correct level of soil moisture. Too little moisture will result in poor germination, and too much moisture will cause seed to rot. A saturated soil is best. The seed germinates into the moist soil and the roots follow the saturation fringe as it drains down the soil profile. High soil moisture reduces soil strength and thus eliminates the need for tillage, but at the same time the moisture level must not be too high, as oxygen is needed for healthy root growth.

An early, light irrigation may be required. Some farmers who relay wheat into the standing rice crop place the cut rice bundles on the ground after harvest. This practice allows the rice to dry and also act as a mulch, keeping the soil surface moist and ensuring good wheat rooting. Young seedlings are also protected from birds. However, relay planting can be done only if the soil moisture is enough for planting at this stage.

Surface seeding gives significantly higher yield than that in the farmers’ practice, and because the cost of land preparation is zero, surface seeding also generates higher net benefits.

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As with surface-seeding practices, soil moisture was found to be critical in this reduced tillage system. The rotovator fluffs up the soil, which then dries out faster than when conventional land preparation technologies are used. The seeding coulter does not place the seed very deeply, so soil moisture must be high during seeding to ensure germination and root extension before the soil dries appreciably. This problem could be overcome by modifying the seed coulter to place the seed a little deeper.
One benefit of the two-wheel tractor is that it comes with many options for other farm operations; it includes a reaper, a rotary tiller, and a moldboard plow and it can also drive a mechanical thresher, winnowing fan, or pump. However, most farmers are attracted to the tractor because it can be hitched up to a trailer and used for transportation.

The main drawback of this technology at the moment is that the tractor and the various implements are not available in sufficient numbers.

In India, a four-wheel version of the two-wheel tractor is available. Engineers at Punjab Agricultural University, Ludhiana, India, have developed a "strip-till drill," which uses the same rotary land preparation and seeder combination described earlier but differs by tilling the soil in a strip into which the seed is planted, rather than tilling the whole area. The results have been encouraging.

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At Pantnagar University, India, engineers have modified the seed drill used to plant rabi (winter) wheat by replacing the old seed coulters with the new inverted-T openers that had been tested in Pakistan. This seeder is now being produced locally in India at a fraction of the cost of a similar, imported New Zealand drill.

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- Stubble can be burnt, as is presently done in most conventional systems. However, this creates environmental problems of air pollution and also results in a loss of organic matter.

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Research in the heavy clay soils of northern Australia has shown that most damage in the 10-30 cm depth zone occurs the first time a wheel passes over the soil. The damaging effects last for 2-4 years even in these self-mulching soils, which recover their structure during wetting and drying. The major effects of this damage are:

- Runoff from wheeled areas increases dramatically, increasing erosion and loss of nutrients.
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- Plants can extract ~50% less water from wheeled soil.
- Wheeling kills more earthworms and other beneficial soil organisms than most tillage operations.
- Planting or tillage of wheeled soil requires much greater tractor power.

Lower tyre pressure might help to reduce soil damage, but lower pressures usually require wider tyres, which affect a greater area. The best solution is controlled traffic farming, where all heavy wheels are restricted to permanent laneways, and all crops grown on permanent beds. This is most easily done where the permanent laneways are in the furrows. In controlled traffic fields, 25% or more of field area is lost to permanent laneways, but farmer experience has usually been an overall yield increase of >10%, combined with a significant reduction in costs.

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**Need for Controlled Traffic**

While there are biophysical and insect/disease conditions which can restrict zero-tillage, the major single constraint is the simple issue of planting. Effective zero-tillage planters available in Australia and North America are all complex, large and heavy, and their high cost and power requirement has been a major impediment to the adoption of improved systems even
in capital-intensive agriculture. They are quite unsuitable for use in developing country systems, where tractor power and lifting capacity are limited (Murray and Tullberg, 2002, Zero-tillage planting: Project proposal, unpublished).

The cost and complexity of the machinery is a direct consequence of the need to plant through residue into a soil surface that is hard and sometimes uneven. There are many residue soil interactions, but soil surface issues can be overcome by permanent bed or controlled traffic cropping systems. Crop residues left in the field can be reduced by avoiding interrow planting, baling, or cutting; these activities are influenced by residue type, quantity, and condition. Some multinational farm machinery companies have ceased research on zero-tillage equipment in response to limited adoption. Controlled traffic avoids the contradictions inherent in most mechanized farming systems to provide substantial, demonstrable, and consistent improvement in the economics and sustainability of cropping.

**Beneficial Effects of Controlled Traffic**

**Permanent Bed System**
Permanent bed system allows soil conditions in the beds to be optimized for crop production, and the lanes optimized for traction. The advantages of controlled traffic include an indirect energy economy which occurs because there is less need for deep tillage. The direct effect occurs because non-compacted soil requires less tillage energy than compacted soil, and traction is more efficient when tyres are working on compacted permanent tracks (Tullberg, 2001).

Thus, permanent bed systems provide all the advantages of controlled traffic in terms of reduced energy input and improved soil condition (structure, hydrology, soil life, and crop yield). Bed or controlled traffic systems avoid the problems of leveling and planting tractor wheel tracks, but the permanent wheel tracks also provide a place for the temporary storage of excess residues, and an alternative to residue burning. Permanent bed systems also provide major advantages in direct costing and timeliness in rice production, where the cost of reforming beds for every crop is high and the operation may not be possible if the rains have started.

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In controlled traffic systems, all field traffic is restricted to permanent, defined traffic lanes. Traffic lanes are normally untilled and not planted to optimize traction and trafficability. Soil in the intervening beds is managed to optimize crop performance, uncompromised by traffic.

Controlled traffic farming avoids the situation where a large proportion of tractor power is dissipated in soil degradation. It is a system in which the management of different soil zones is optimized to provide maximum benefit in terms of:
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References


Contributed by:
Jeff N. Tullberg
Interactions of Tillage and Crop Establishment with Other Management Practices

Tillage and crop establishment practices interact strongly with other management practices. Variety selection, seeding date, seed rate, fertilizer and water management, weed, pest and disease control are all affected by zero-tillage and surface seeding. For example, fertilizer cannot be incorporated in surface seeding but research shows it is better to delay nitrogen fertilizer application until the first top-dressing. Planting date can be closer to the optimal in zero-till and surface seeding leading to higher yield and efficiencies. Water use is less and needs different timings.

Residue management is important in rice-wheat systems because large quantities of crop residues are produced, especially where combines are used for harvest or where taller, local, or basmati rice is grown. Incorporation of straw into soil after harvest is possible in conventional tillage, but studies have shown that incorporation of crop residues leads to a decrease in yield of the next crop because of nitrogen immobilization.

Other studies have shown that retaining crop residues on the soil surface, rather than burning them or incorporating them by tillage, increases organic carbon and total soil nitrogen in the top 5-15 cm of soil.
Management of Residues

Management of residues has become a major problem for farmers. Many farmers dispose of residues by burning, especially in fields that are combine harvested. Burning can result in up to 80% loss of tissue nitrogen by volatilization and can also be a significant source of air pollution.

Rice residues harbor rice stem borers, and if residues are not plowed, the larvae potentially have a greater chance of surviving to deplete the next rice crop. When a crop of wheat is grown in rice stubble with irrigation and fertilizer, the stubble decomposes and the larvae dies before spring, when they would have hatched out. Recent data show that in zero-tillage, where the rice residues are left on the surface as anchored straw and not burnt, more biodiversity of beneficial insects occurs that helps control stem borers and other deleterious insects.

Diseases such as leaf blight (Helminthosporium spp.) are also more likely to proliferate on crop residues and to be more of a problem in zero-tillage systems. Here, wheat varieties with greater resistance to leaf blight may become more important than previously thought.
Some varieties of wheat do much better under zero-tillage than others. The difference in performance may be related to rooting. There is also an interaction between wheat variety and performance on beds, where taller, less upright varieties yield better. Variety also plays a role in insect, disease, and weed control and is a necessary component for a successful crop establishment under reduced tillage.

Most rice in the rice-wheat tract is transplanted, but as labor becomes more expensive and water becomes less available, farmers have to switch to other methods of rice establishment, such as direct seeding, both wet and dry.

Dry seeding of rice can benefit the subsequent wheat crop. If puddling is not done for rice production, the deleterious effect of this practice on soil disaggregation and wheat establishment can be prevented.

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Wheeling and Tillage Effects on Soil Health: Worms Don’t Enjoy Traffic or Tillage!

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Earthworms in top 15cm/m²

0 25 50 75 100 125

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Farmers Control Field Traffic
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Residue management is important in rice-wheat systems because large quantities of crop residues are produced, especially where combines are used for harvest or where taller, local, or basmati rice is grown. Incorporation of straw into soil after harvest is possible in conventional tillage, but studies have shown that incorporation of crop residues leads to a decrease in yield of the next crop because of nitrogen immobilization.

Other studies have shown that retaining crop residues on the soil surface, rather than burning them or incorporating them by tillage, increases organic carbon and total soil nitrogen in the top 5-15 cm of soil.
Rice residues harbor rice stem borers, and if residues are not plowed, the larvae potentially have a greater chance of surviving to deplete the next rice crop. When a crop of wheat is grown in rice stubble with irrigation and fertilizer, the stubble decomposes and the larvae dies before spring, when they would have hatched out. Recent data show that in zero-tillage, where the rice residues are left on the surface as anchored straw and not burnt, more biodiversity of beneficial insects occurs that helps control stem borers and other deleterious insects.

Diseases such as leaf blight (*Helminthosporium* spp.) are also more likely to proliferate on crop residues and to be more of a problem in zero-tillage systems. Here, wheat varieties with greater resistance to leaf blight may become more important than previously thought.
Some varieties of wheat do much better under zero-tillage than others. The difference in performance may be related to rooting. There is also an interaction between wheat variety and performance on beds, where taller, less upright varieties yield better. Variety also plays a role in insect, disease, and weed control and is a necessary component for a successful crop establishment under reduced tillage.

Most rice in the rice-wheat tract is transplanted, but as labor becomes more expensive and water becomes less available, farmers have to switch to other methods of rice establishment, such as direct seeding, both wet and dry.

Dry seeding of rice can benefit the subsequent wheat crop. If puddling is not done for rice production, the deleterious effect of this practice on soil disaggregation and wheat establishment can be prevented.

Adapted from:

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Zero-tillage Technology: Troubleshooting Tips

Zero-tillage is a resource-conserving technology that is presently gaining popularity amongst farmers in the Indo-Gangetic Plains (IGP) of India, Pakistan, Nepal and Bangladesh for establishing wheat after rice harvest. The widespread adoption of the technology is hampered because of insufficient training and dissemination of information on the proper use of the machinery and technique. Availability of drills also limits coverage. Training and suitable materials are needed to ensure all operators follow the correct procedures for successful zero-tillage.

The main problems faced by farmers using zero-tillage are:

- clogging of the drill by loose stubbles after combine harvesting rice;
- increase in rodent activity in some fields; and
- infestation by carryover weeds (e.g., *Cynodon dactylon*) from rice to wheat, particularly on high, well-drained soils in warm areas.

The first problem needs to be resolved by engineers and manufacturers by developing a suitable drill that allows planting into the loose crop residue. The anchored residue is not a problem. The second problem requires some rodent control measures to be taken by farmers and also perhaps community action. Use of reduced tillage and herbicides or better weed control in rice can solve the problem of weed infestation in wheat. Farmers should follow these principles of good zero-tillage practices.

Do zero-tillage the right way.

Do not spend money on extra plowing.
Checking the Machinery

The zero-tillage drill should be properly serviced and maintained. It should be checked before use to ensure that all the nuts and bolts are tightened and that all the parts are in good condition. For example, if the openers are worn out, they should be replaced. The fertilizer and seed boxes should also be in good condition to allow free flow of seed and fertilizer. Chains should be adjusted and oiled. After use at the end of each day, the drill should be checked, the seed and fertilizer boxes cleaned, and the moving parts oiled. After the planting season, the drill should be properly stored.

Calibration of the Drill

After ascertaining that the drill is in good working condition, it should be calibrated. Calibration values are sometimes placed on the drill by the manufacturer. However, it is very important to ensure that the drill is supplying the correct amount of seed or fertilizer at the time of use. A plastic or paper bag is placed over the spout to collect the seed or fertilizer dropped by the drill over a specific length or area. The material is collected and weighed. The width and length of the area covered are measured and area calculated. The amount of seed or fertilizer applied per unit area is then calculated and compared with the recommended value. Adjustments are made, if needed, and the machine re-calibrated until the operator is satisfied that the value is within the required range.

Seed Germination and Sowing Rate

While calibrating the drill, seed germination percentage should be considered. If seed germinates 50%, then twice as much seed needs to be sown. To check germination, place 100 seeds onto a wet newspaper, roll it up, and then carefully close the ends. Keep the roll moist and at moderate temperature for three to five days. Open the roll and count the number of seeds that have germinated and then calculate germination percentage.
The seed rate for sowing is based on seed germination. Accordingly, the drill is adjusted and the recommended seed rate is used. In zero-till, the seed is placed uniformly at the correct soil depth. The recommended seed rate for wheat is 100 to 120 kg per ha. If seed rate is increased, wheat plants will be spindly and therefore, will lodge resulting in low yield. However, wheat can compensate for low seed rate by tillering and adjusting head size and grains per head.

Some varieties respond better than others to zero-till. Wheat varieties that have vigorous early growth and tillering are good for zero-till. The best variety available in the region or the variety that has performed well with conventional planting should be used.

**Adjustment of the Drill**

The three point hitch adjustments where the drill fixes to the tractor should be adjusted. The drill should be level from side to side and have just enough forward and backward adjustment to enter the soil at the proper angle.

**Fertilizer Mixing and Use**

Once the drill is calibrated for fertilizer, the chemical should be placed in the fertilizer box. Di-ammonium phosphate (DAP) should be applied at sowing and urea at the first irrigation and second irrigation by topdressing.

Do not adjust the drill too steep as planting will be too deep. Do not adjust the drill too shallow as the seed will drop on the surface.

Do not mix DAP and urea and leave the mixture in the fertilizer box for prolonged period because the two products react and form a cake. Thus, there is no free flow of fertilizer to the ground. Do not apply urea at sowing because it burns young wheat roots and reduces seedling emergence.

Do not use zero-till when the soil is too wet or too dry.

**Soil Factors**

Zero-tilled fields should be more wet than conventionally plowed fields at planting. This additional moisture reduces soil strength and allows the emerging roots to penetrate the soil. If the soil is too dry, the soil strength is high and roots may not be able to penetrate the soil. If it is too wet, the roots may experience aeration stress and rot. The correct soil moisture depends on soil texture and is best determined by the farmer. On heavy clay or silty clay soils, it is difficult to operate the zero-till machine due to excess water and poor drainage in the field. In sandy soils, the soils dry out quickly and soil strength increases fast. The field should be irrigated soon after planting with zero-till drill to facilitate root penetration into the sandy soil.
**Irrigation**
For zero-tilled wheat, rooting depends on high soil moisture that softens the soil and allows easy root penetration. The timing of the first irrigation depends on the soil moisture at planting and soil texture. Light textured and sandy soils should be irrigated earlier in zero-tilled fields than plowed fields to ensure good rooting and subsequent tillering.

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**Weed Control**
Zero-tillage disturbs the soil less than plowing. Therefore, few weed seeds reach the surface soil and germinate. The weed population, especially *Phalaris minor*, is low in zero-tilled wheat fields compared to plowed fields. But if the weed population is above the economic threshold, herbicides should be applied at the proper rate and time with proper equipment (e.g., T-jet nozzle). Glyphosate can be sprayed a few days before or soon after planting to control Bermuda grass.

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**Insect and Rodent Problems**
Rice stem borer is often cited as one of the major issues that limits the use of zero-tillage for wheat after rice. But data shows that this is not a problem. In fact, if the anchored residues as well as the loose residues are left in the field and not burnt, beneficial insects proliferate. These act as predators and thus reduce the population of the stem borer.

Rodent menace is more in zero-tilled fields than plowed fields as their habitat is less disturbed. Appropriate control measures should be followed.

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