Reduced and Zero-Tillage Options

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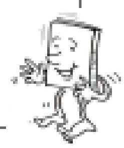
- Surface seeding
- Reduced tillage with two- and four-wheel tractors
- Zero-tillage with four-wheel tractor
- Bed planting systems, particularly permanent beds



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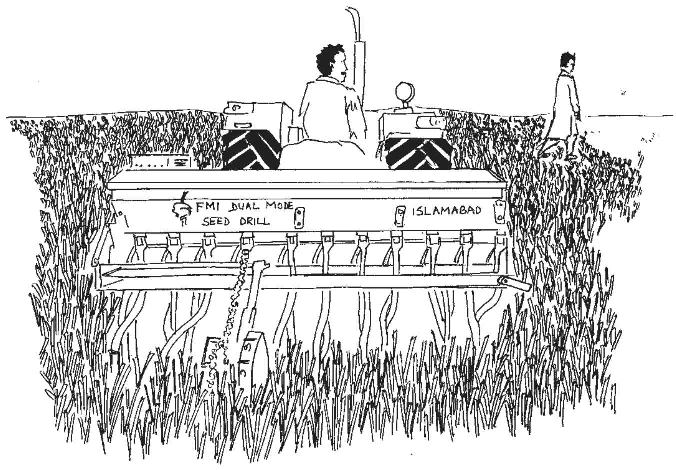

As with surface-seeding practices, soil moisture was found to be critical in this reduced tillage system. The rotovator fluffs up the soil, which then dries out faster than when conventional land preparation technologies are used. The seeding coulter does not place the seed very deeply, so soil moisture 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.

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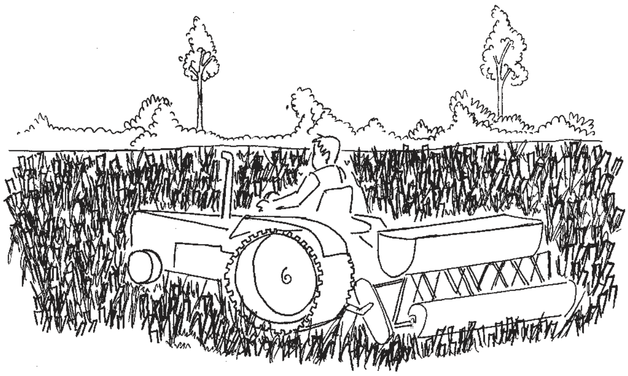

The main drawback of this technology at the moment is that the tractor and the various implements are not available in sufficient numbers.

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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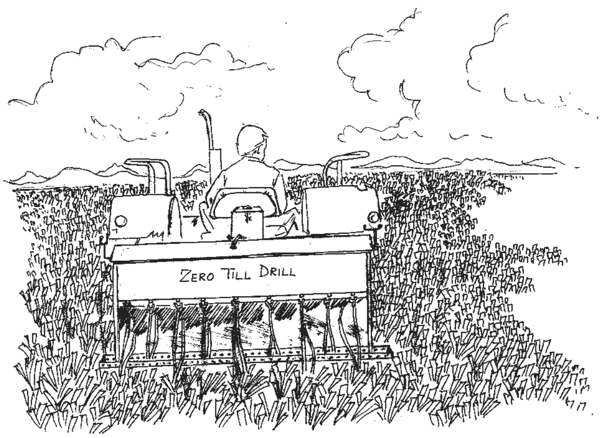

In the late 1980s, 34 zero-tillage trials were conducted on farmers' fields over three years in the rice-growing belt of the Pakistan Punjab. The implement used in these trials was a tractor-pulled seed and fertilizer drill with inverted-T openers. With this equipment, farmers could place the seed directly into the standing rice stubble without any land preparation.

As with the reduced tillage systems discussed previously, earlier planting is the main reason for the additional yields obtained under zero-tillage. In trials in Pakistan, zero-tilled plots were planted as close as possible to 20 November, the optimum date for planting wheat; the longer the farmer delays planting, the lower the yield.

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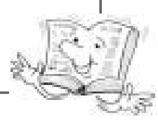
Weed problems typically are more severe under conventional tillage than under zero-tillage. Longer-term research is needed to anticipate how changes in tillage practices may affect weed populations.



Combine harvesting of wheat is becoming popular among farmers in northwestern India and Pakistan. A potential difficulty with this technology is that the inverted-T opener may not work well where combines are used, as the opener acts as a rake for the loose straw. In this case, various options need to be considered:

- 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.

- A suitable trash drill, using some form of disk opener, can be developed. It could either take the form of disk cutters running ahead of the inverted-T openers or a new system of disk planters could be developed and tested. This implement would raise the weight and cost of the seeder, but it might still be within reach of some farmers, particularly those using combination for harvesting. Through the use of custom hiring, a common practice for resource-poor farmers without tractors for plowing, even these farmers can benefit from the new technology.

- The combination should be modified to chop the straw into small pieces before it leaves the machine and also distribute it evenly on the soil. These small pieces of straw would not interfere with the inverted-T openers and would leave a stubble mulch on the soil surface.

Adapted from:

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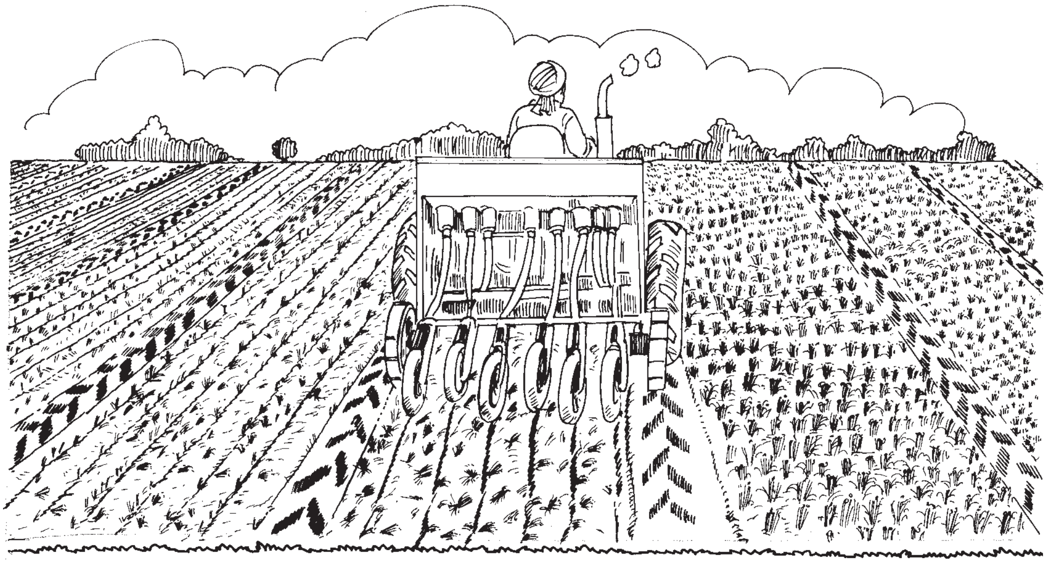
Improving Zero-tillage by Controlled Traffic



Conventional crop production practices of the 1960s were asociated with substantial soil and water erosion. To overcome the problem of runoff and soil erosion, resource conservation technologies were developed. These have replaced the frequent tillage and fallow practices that characterized conventional tillage.

Role of Zero-tillage in Conservation Farming

Conservation tillage refers to various practices that provide better protection for the soil. These practices include stubble mulching (maintenance of residue cover with mechanical weed control), minimum tillage (using a mixture of herbicide and mechanical weed control) and zero-tillage (soil disturbance occurs only at planting). Conservation tillage has been widely adopted over the past 20 years in Australia and also in other countries.

Zero or minimal tillage systems are optimal in terms of productivity and sustainability for most grain cropping. Despite overwhelming evidence in favor of this practice, excessive crop residue levels and soil compaction prevent farmers from maintaining zero-tillage production for more than one or two crops. Continuous zero-tillage farming is still rare, except where soils are highly resistant to compaction, and crop residues are minimal due to low yield, grazing, or burning.

Practice with Care

Zero-tillage is the key to improvement of crop productivity and sustainability. But it will be futile unless crops are planted without plowing, burning crop residues, or soil compaction.

What is Controlled Traffic?

Additional effort is required to disturb soil that has been compacted manually or mechanically during tillage. Traditional agricultural systems such as those described by Chi Renli and Zuo Shuzhen (1988) can sometimes avoid this energy penalty by maintaining separate zones for traffic and crop growth, but this is not easily achieved over the full cycle of operations involved in current crop production systems. The negative effects of traffic on infiltration, tilth, and penetration resistance of clay soils in Australia were first quantified by Arndt and Rose (1966), who advocated the use of improved traffic systems to minimize the problems.

Wheeled traffic is unavoidable in current crop production systems. Soil subjected to normal wheel traffic treatment is referred to as "wheeled" and that managed in controlled traffic as "non-wheeled". Optimum conditions for crop production, i.e., soft, friable, and permeable soil are quite unsuitable for efficient traffic and traction, and vice versa.

Wheel traffic increases soil strength and the draft requirement of subsequent tillage, while tillage reduces soil strength and the efficiency of subsequent traction (Tullberg, 2000). It also leads to degradation of soil physical properties (Yuxia Li *et al.*, 2001). Where field traffic follows a different pathway for each of a series of operations, the processes of tillage and traffic are contradictory. These contradictions are avoided in controlled traffic farming (Taylor, 1983), where all field traffic is confined to permanent lanes, and all crops are grown in permanent beds.

Wheeling Problem and Solution

Tractor and implement wheels drive over a large proportion of the field area every time a crop is produced. This proportion is more than 50%, even in zero-tillage. With one or two tillage operations, the total area wheeled, per crop, is greater than the area of the field. Implements (even zero-tillage planters) disguise the effect of wheels on the soil surface. Most of the damage is subsurface, so one has to dig to see it, but because the whole field area has been wheeled, a difference is seen only if there is a nearby non-wheeled area.

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.
- Infiltration of rainfall into wheeled soil is reduced by 5%-20% (overall); internal drainage is also reduced. Waterlogging is a greater problem.
- 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.

REMEMBER: Plants grow best in soft soil, and wheels work best on hard surfaces.

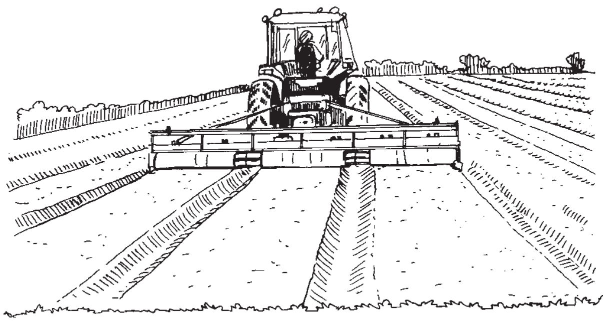
Need for Controlled Traffic

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).

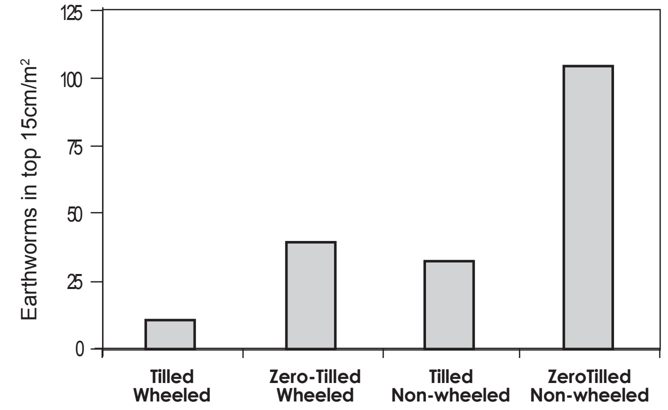
Thus, permanent bed systems provide all the advantages of controlled traffic in terms of reduced energy input and improved soil condition (structure, hydrology, soil life, and crop yield). Bed or controlled traffic systems avoid the problems of leveling and planting tractor wheel tracks, but the permanent 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.

Soil Response to Traffic

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, uncompromized 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:

(1) energy requirements to allow a reduction in fuel use, tractor size, and production cost;
(2) soil structure and health to provide reduced runoff and enhance crop/soil performance; and
(3) spatial precision in the soil/ plant/machine relationship to improve crop management.



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

Farmers Control Field Traffic

Controlled traffic is a prerequisite for zero tillage. Hundreds of Australian farmers using controlled traffic now find they can zero till for many years without the need for expensive deep tillage to undo soil compaction problems. They are saving money, getting better yields, and helping the environment.

Direct Benefit to Farmers

Controlled traffic demands and promotes the use of greater precision in field operations. In northern Australia, farmers practicing controlled traffic have experienced 10% to 20% reduction in time and material input to cropping operations. When permanent wheel tracks are accurately installed, the elimination of double coverage and/or gaps also has a positive effect on yield.

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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.

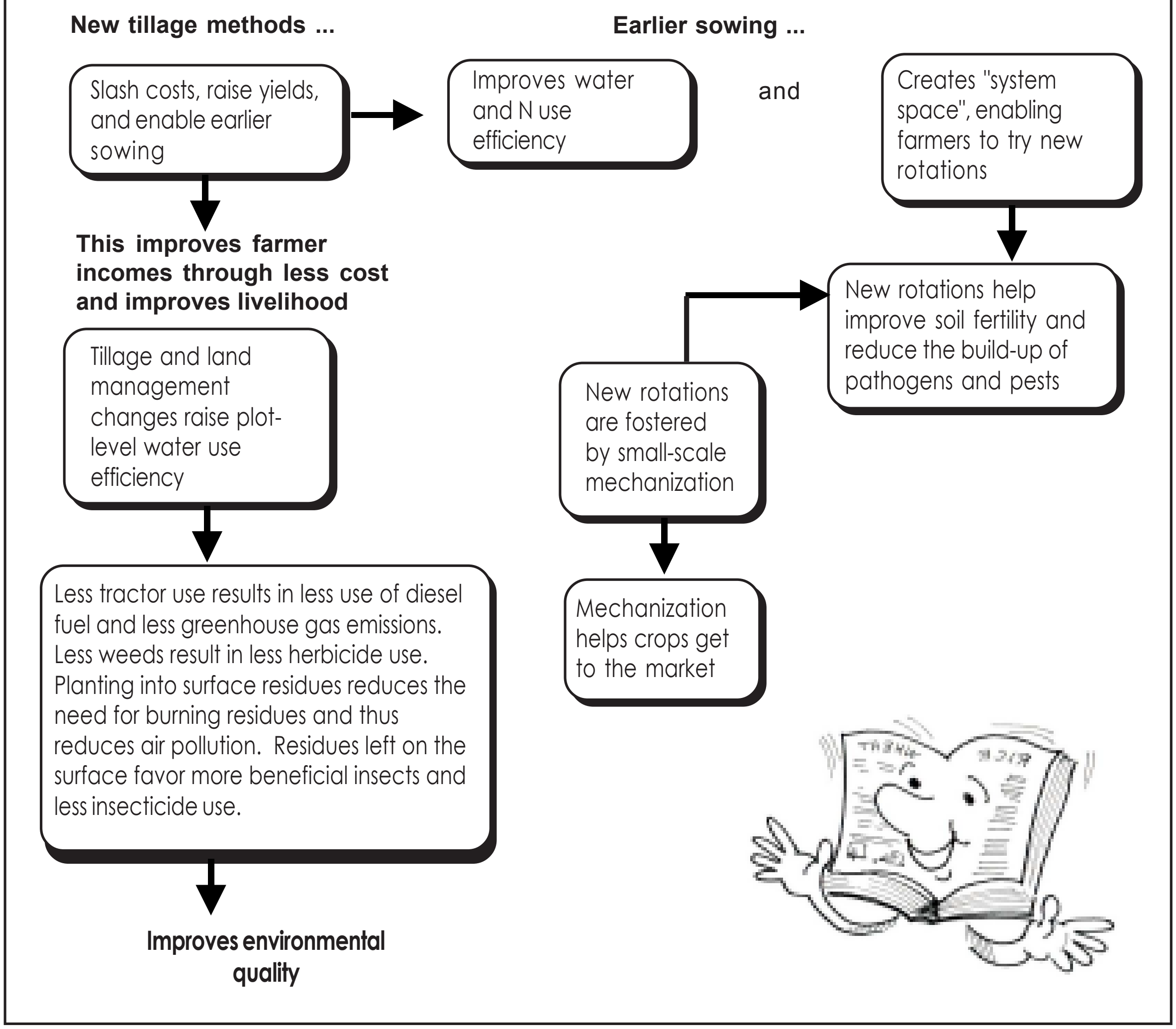
Issues

- Problems of fertilizer application and timing for surface-seeded rice
- Residue/stubble management
- Insect pest and disease management under zero-tillage
- Varietal choice to combat diseases, pests and weeds, and to suit reduced or zero-tillage planting systems
- Problems of labor cost and labor availability
- Deleterious effect of puddling on succeeding wheat

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.

An Example of How Improved Practices Developed and Delivered by the Rice-Wheat Consortium Interact and Help Farmers



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.

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.

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.

The control of weeds in dry-seeded rice is probably the most important constraint for its successful adoption by farmers.

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.

A. good practice

B. bad practice

Stubble Management

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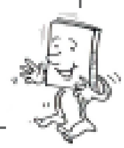

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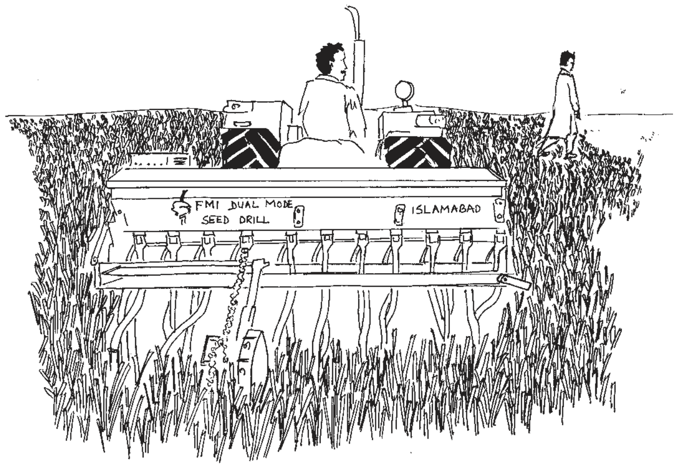

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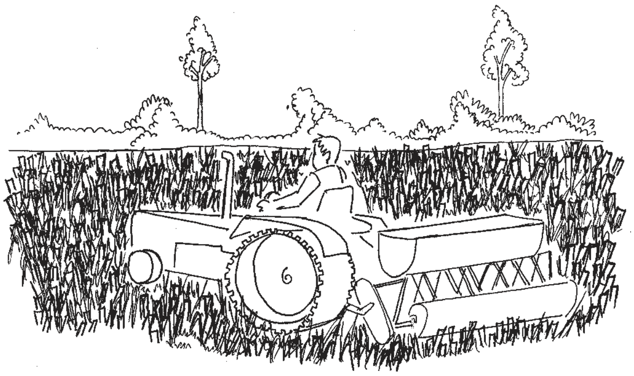

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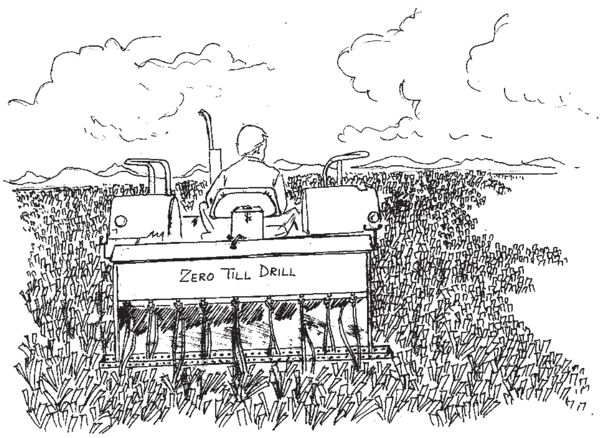

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[a] Number of extra days needed for land preparation before seeding compared to the surface seeding

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.

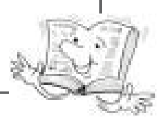
Combine harvesting of wheat is becoming popular among farmers in northwestern India and Pakistan. A potential difficulty with this technology is that the inverted-T opener may not work well where combines are used, as the opener acts as a rake for the loose straw. In this case, various options need to be considered:

- 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.

- A suitable trash drill, using some form of disk opener, can be developed. It could either take the form of disk cutters running ahead of the inverted-T openers or a new system of disk planters could be developed and tested. This implement would raise the weight and cost of the seeder, but it might still be within reach of some farmers, particularly those using combination for harvesting. Through the use of custom hiring, a common practice for resource-poor farmers without tractors for plowing, even these farmers can benefit from the new technology.

- The combination should be modified to chop the straw into small pieces before it leaves the machine and also distribute it evenly on the soil. These small pieces of straw would not interfere with the inverted-T openers and would leave a stubble mulch on the soil surface.

> Weed problems typically are more severe under conventional tillage than under zero-tillage. Longer-term research is needed to anticipate how changes in tillage practices may affect weed populations.



Adapted from:

Hobbs, P. R., G. S. Giri and P. Grace. 1997. Reduced and Zero-Tillage Options for the Establishment of Wheat after Rice in South Asia. Rice-Wheat Consortium Paper Series 2. Rice-Wheat Consortium for the Indo-Gangetic Plains, New Delhi, India.

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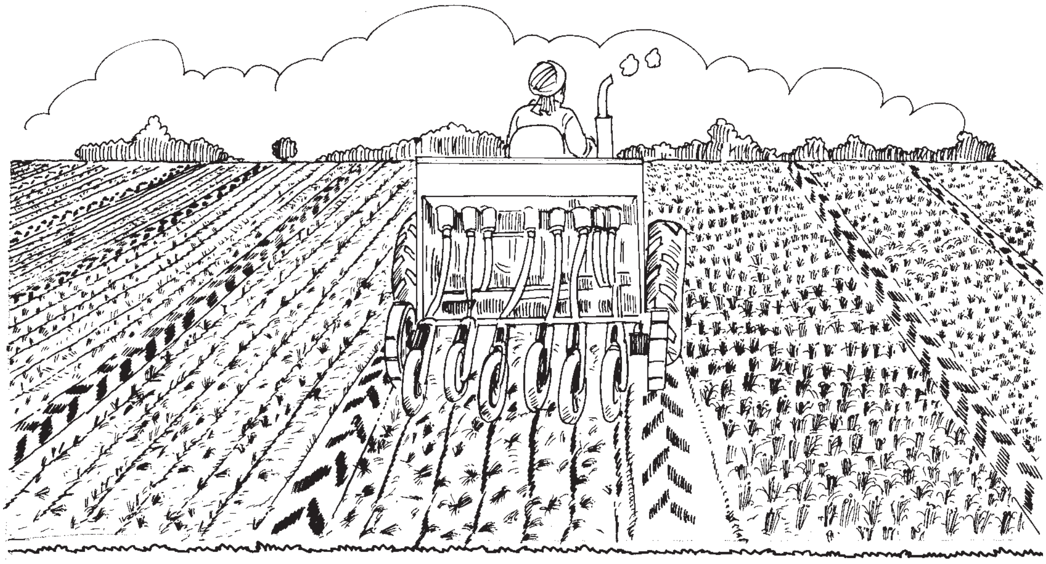
Improving Zero-tillage by Controlled Traffic



Conventional crop production practices of the 1960s were asociated with substantial soil and water erosion. To overcome the problem of runoff and soil erosion, resource conservation technologies were developed. These have replaced the frequent tillage and fallow practices that characterized conventional tillage.

Role of Zero-tillage in Conservation Farming

Conservation tillage refers to various practices that provide better protection for the soil. These practices include stubble mulching (maintenance of residue cover with mechanical weed control), minimum tillage (using a mixture of herbicide and mechanical weed control) and zero-tillage (soil disturbance occurs only at planting). Conservation tillage has been widely adopted over the past 20 years in Australia and also in other countries.

Zero or minimal tillage systems are optimal in terms of productivity and sustainability for most grain cropping. Despite overwhelming evidence in favor of this practice, excessive crop residue levels and soil compaction prevent farmers from maintaining zero-tillage production for more than one or two crops. Continuous zero-tillage farming is still rare, except where soils are highly resistant to compaction, and crop residues are minimal due to low yield, grazing, or burning.

Practice with Care

Zero-tillage is the key to improvement of crop productivity and sustainability. But it will be futile unless crops are planted without plowing, burning crop residues, or soil compaction.

What is Controlled Traffic?

Additional effort is required to disturb soil that has been compacted manually or mechanically during tillage. Traditional agricultural systems such as those described by Chi Renli and Zuo Shuzhen (1988) can sometimes avoid this energy penalty by maintaining separate zones for traffic and crop growth, but this is not easily achieved over the full cycle of operations involved in current crop production systems. The negative effects of traffic on infiltration, tilth, and penetration resistance of clay soils in Australia were first quantified by Arndt and Rose (1966), who advocated the use of improved traffic systems to minimize the problems.

Wheeled traffic is unavoidable in current crop production systems. Soil subjected to normal wheel traffic treatment is referred to as "wheeled" and that managed in controlled traffic as "non-wheeled". Optimum conditions for crop production, i.e., soft, friable, and permeable soil are quite unsuitable for efficient traffic and traction, and vice versa.

Wheel traffic increases soil strength and the draft requirement of subsequent tillage, while tillage reduces soil strength and the efficiency of subsequent traction (Tullberg, 2000). It also leads to degradation of soil physical properties (Yuxia Li *et al.*, 2001). Where field traffic follows a different pathway for each of a series of operations, the processes of tillage and traffic are contradictory. These contradictions are avoided in controlled traffic farming (Taylor, 1983), where all field traffic is confined to permanent lanes, and all crops are grown in permanent beds.

Wheeling Problem and Solution

Tractor and implement wheels drive over a large proportion of the field area every time a crop is produced. This proportion is more than 50%, even in zero-tillage. With one or two tillage operations, the total area wheeled, per crop, is greater than the area of the field. Implements (even zero-tillage planters) disguise the effect of wheels on the soil surface. Most of the damage is subsurface, so one has to dig to see it, but because the whole field area has been wheeled, a difference is seen only if there is a nearby non-wheeled area.

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.
- Infiltration of rainfall into wheeled soil is reduced by 5%-20% (overall); internal drainage is also reduced. Waterlogging is a greater problem.
- 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.

REMEMBER: Plants grow best in soft soil, and wheels work best on hard surfaces.

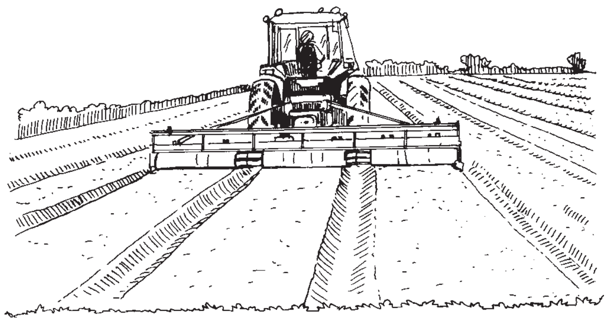
Need for Controlled Traffic

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).

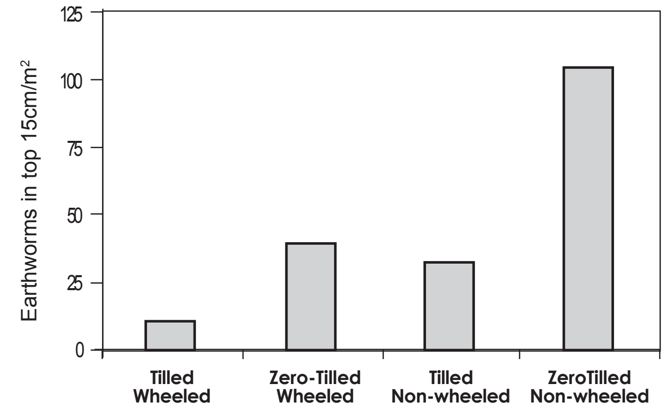
Thus, permanent bed systems provide all the advantages of controlled traffic in terms of reduced energy input and improved soil condition (structure, hydrology, soil life, and crop yield). Bed or controlled traffic systems avoid the problems of leveling and planting tractor wheel tracks, but the permanent 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.

Soil Response to Traffic

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, uncompromized 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:

(1) energy requirements to allow a reduction in fuel use, tractor size, and production cost;
(2) soil structure and health to provide reduced runoff and enhance crop/soil performance; and
(3) spatial precision in the soil/plant/machine relationship to improve crop management.



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

Farmers Control Field Traffic

Controlled traffic is a prerequisite for zero tillage. Hundreds of Australian farmers using controlled traffic now find they can zero till for many years without the need for expensive deep tillage to undo soil compaction problems. They are saving money, getting better yields, and helping the environment.

Direct Benefit to Farmers

Controlled traffic demands and promotes the use of greater precision in field operations. In northern Australia, farmers practicing controlled traffic have experienced 10% to 20% reduction in time and material input to cropping operations. When permanent wheel tracks are accurately installed, the elimination of double coverage and/or gaps also has a positive effect on yield.

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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.

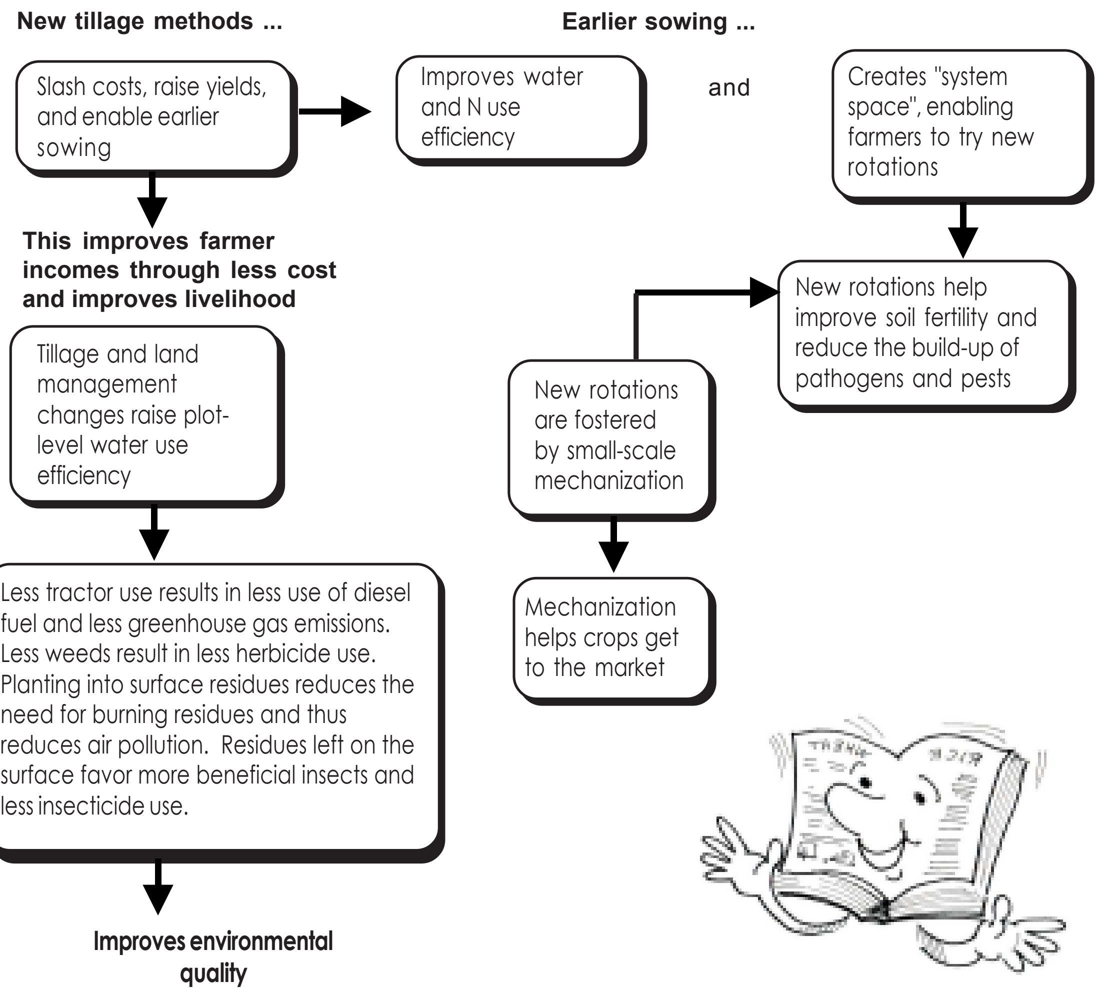
Residue management is important in rice-wheat systems because large quantities of crop residues are produced, especially where combines are used for harvest or where taller, local, or *basmati* rice is grown. Incorporation of straw into soil after harvest is possible in conventional tillage, but studies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

Issues

- Problems of fertilizer application and timing for surface-seeded rice
- Residue/stubble management
- Insect pest and disease management under zero-tillage
- Varietal choice to combat diseases, pests and weeds, and to suit reduced or zero-tillage planting systems
- Problems of labor cost and labor availability
- Deleterious effect of puddling on succeeding wheat

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.

An Example of How Improved Practices Developed and Delivered by the Rice-Wheat Consortium Interact and Help Farmers



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.

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.

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.

The control of weeds in dry-seeded rice is probably the most important constraint for its successful adoption by farmers.

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.

A. good practice

B. bad practice

Stubble Management

Adapted from:

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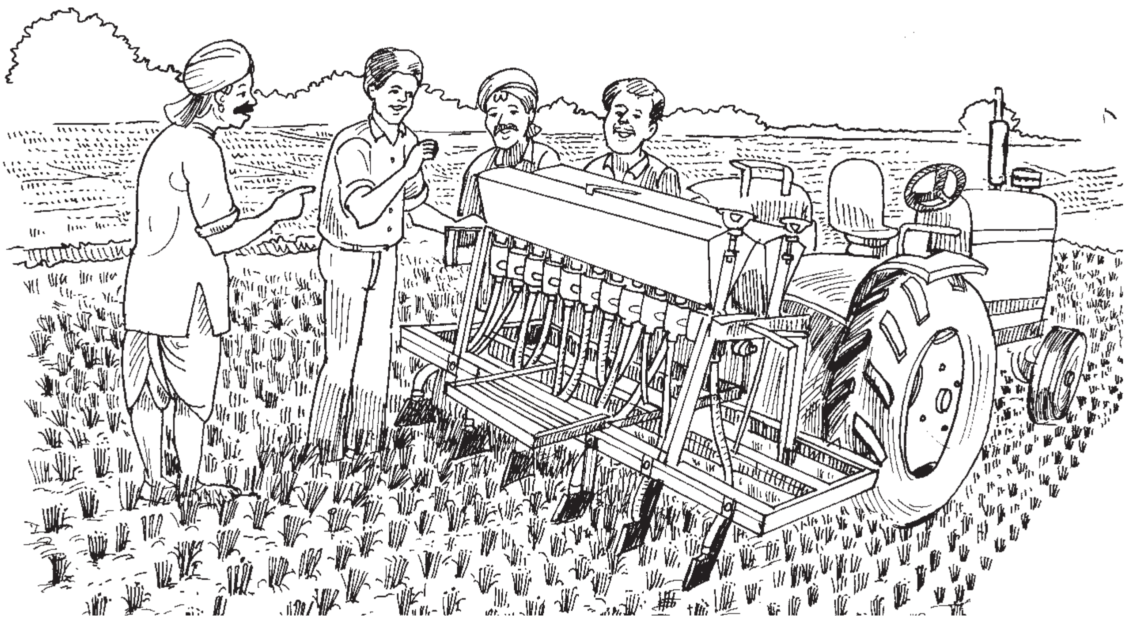
Zero-tillage Technology:
Troubleshooting Tips



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.

✓ Do zero-tillage the right way.

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.

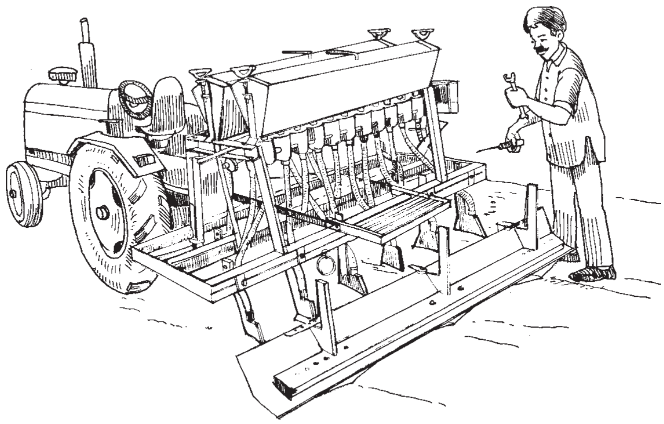
The first problem needs to be resolved by engineers and manufacturers by developing a suitable drill that allows planting into the loose crop residue. The anchored residue is not a problem. The second problem requires some rodent control measures to be taken by farmers and also perhaps community action. 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 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.

✗ Do not leave the fertilizer in the box overnight as it will clog the opening.



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.

✓ Calibration should be done properly at the beginning of the planting season for both seed and fertilizer.

✗ Do not use the machine unless the drill is calibrated.

Seed Germination and Sowing Rate

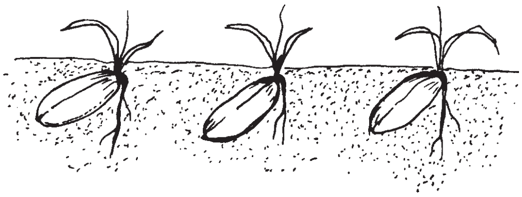
While calibrating the drill, seed germination percentage should be considered. If seed germinates 50%, then twice as much seed needs to be sown. To check germination, place 100 seeds onto a wet newspaper, roll it up, and then carefully close the ends. Keep the roll moist and at moderate temperature for three to five days. Open the roll and count the number of seeds that have germinated and then calculate germination percentage.

✓ Use good quality seed for high 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.

✕ Do not use poor quality seed and high seed rate for sowing because germination and plant growth will be poor.

Some varieties respond better than others to zero-tillage. Wheat varieties that have vigorous early growth and tillering are good for zero-tillage. 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.

✕ 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.

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 mix DAP aDd 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.

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.

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

Irrigation

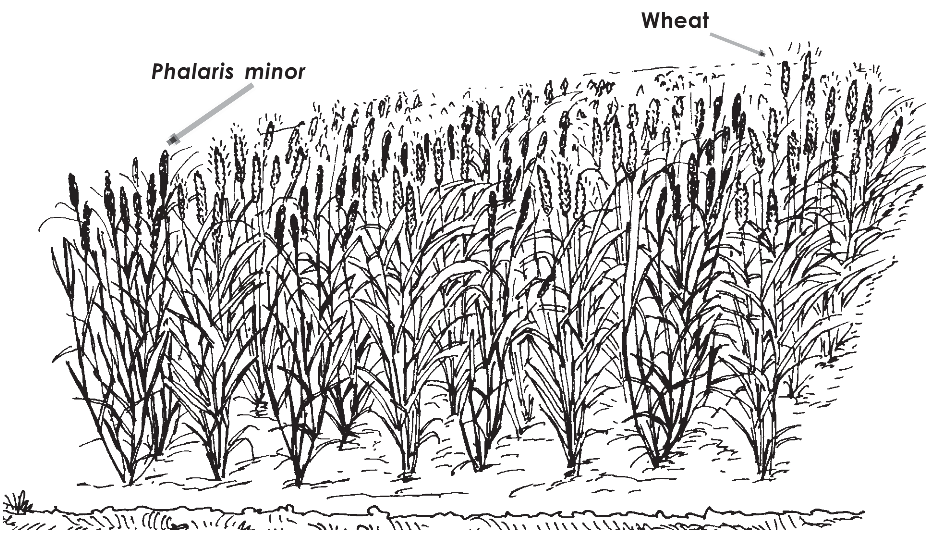
For zero-tilled wheat, rooting depends on high soil moisture that softens the soil and allows easy root penetration. The timing of the first irrigation depends on the soil moisture at planting and soil texture. Light textured and sandy soils should be irrigated earlier in zero-tilled fields than plowed fields to ensure good rooting and subsequent tillering.

✗ Do not irrigate heavy textured soils earlier than recommended unless soil moisture is low.

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.

✓ Use herbicides only after proper training.



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.

✗ Do not use pesticides indiscriminately as the population of beneficial insects will be reduced.

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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