Conservation agriculture

what you should know about ……

tractor equipment and machines

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Land preparation

Soil tillage or land preparation is one of the routine activities in most agricultural systems. Often, land preparation starts with burning fallow vegetation or previous crop residues in order to clear the land or to scare away wild animals or snakes.

Plate 1
This farmer is not only cleaning his field, but also 'cleaning his pockets' by burning the potential fertility of his soil.

Burning is usually followed by soil tillage. Depending on the possibilities of the farmer tillage can range from very extensive to very intensive. But why do farmers plough?

In the first place to prepare an adequate seedbed which permits a good germination of the seeds. They think that a soil well tilled, loose, levelled and with a lot of fine particles favours the contact between the seeds and the soil, which in turn lead to sowing at an adequate depth. In second place, farmers plough in order to control weeds. Other reasons for tillage may include enhancement of soil water storage and retention and warming-up of the soil.

Box 1. Functions of soil tillage

- Prepare seedbed
- Manage crop residues
- Incorporate fertilizers and agro-chemicals
- Control weeds
- Decompact dense layers
- Increase water infiltration
- Shape the soil surface (levelling, ridging)

Unfortunately, the method used to achieve any of the above mentioned objectives of tillage might produce a conflict with the other objectives. Each additional tillage operation for weed control also buries more residues and exposes moist soil to the surface, causing additional water loss. As the number of tillage operations is increased, the aggregation of soil is decreased leaving the soil more vulnerable for soil erosion (Godwin, 1990).

In this way, tillage operations have negative effects on the soil productivity and the economic return of the crops. They are responsible for the destruction of the soil and crop residues. Tillage also affects the availability of water and nutrients in the soil. Among the costs of tillage one should also count:

- increased erosion and loss of fertility
- increased evaporation and moisture loss
- decreased capability of the soil to hold water

Eroded soil can move on to other places, like ditches, lakes and reservoirs, water harvesting tanks or to the neighbour's field, taking with it organic matter, nitrogen, phosphorus and pesticides. Preventive measures, like the construction of terraces, are expensive. It is far more effective and cheaper to refrain from tillage and conserve the residues on the soil surface.

Soil tillage

Generally, tillage is defined by the type of activity carried out (Friedrich, 2000):

- **Inversion**: this type of tillage turns the soil in part that is worked. Surface layers are completely incorporated and deeper soil layers are brought to the surface. The argument that ploughing controls weeds is not valid when done every year, as the same amount of weed seeds is brought to the surface.
- **Mixture**: this operation mixes all materials homogeneously to a certain soil depth, which is usually around 10 cm.
- **Ripping**: this type of tillage breaks the soil open, in order to loosen the soil without moving the clods, for instance in soil decompaction operations (subsoiling).
- **Pulverize**: this operation is to crumble the soil clods in order to form a very fine horizon, i.e. the seedbed. It is executed within a few centimetres from the surface.

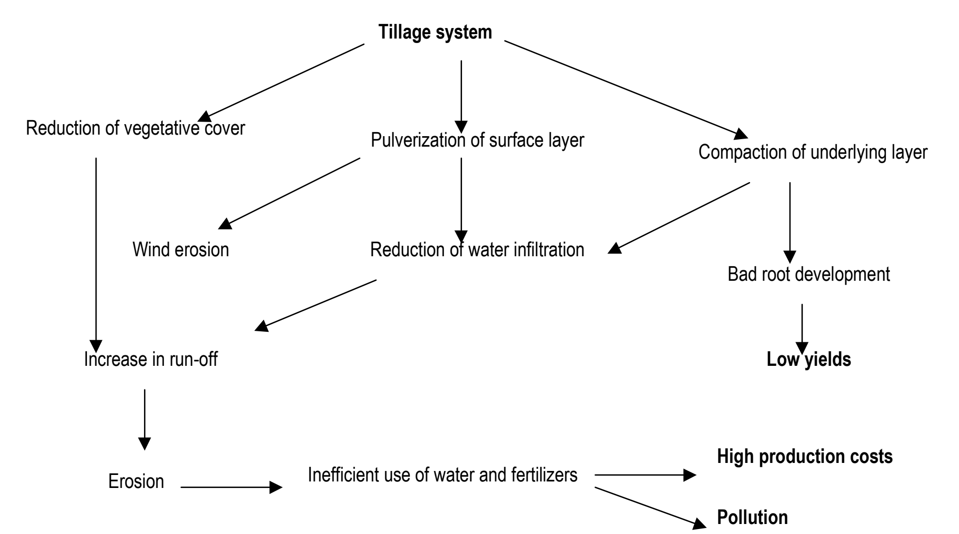
Both inversion and aggressive mixture affect the quantity of residues that are left on the soil surface. Ploughs and discs turn over the soil completely, whereas chisel ploughs break and mix the soil and cultivators only mix. Harrows pulverize the soil in order to prepare a seedbed.

At least four types of tillage operations can be distinguished in a conventional system (Krause *et al*., 1984):

- Clearing of the land and management of residues, including burning of fallow vegetation or residues
- Primary tillage
- Secondary tillage
- Crop management activities, like weeding, ridging, breaking crusts, etc.

But sometimes deep tillage or subsoiling is necessary to break dense and compacted layers deeper in the profile.

Figure 1.
Consequences of badly chosen tillage practices



In tropical and subtropical areas, where the danger of erosion through rainfall is high, the soils are usually poor and eroded and the temperatures are high and thus decomposition is rapid, tillage systems are usually selected with the objective to prepare the topsoil to create a very fine seedbed. And in only attending this objective, tillage systems are applied that bring certain degradation processes with them (Figure 1) (Vieira, 1996).

The type and number of land preparation operations determine the quantity of residues left on the soil surface. For example, ploughing leaves less than 15% on the surface, as a cultivator leaves between 50 and 70% of the residues intact on the surface.

Table 1 Percentage of residues left on the surface with different land preparation activities

Type of land preparation	Resistant residues	Fragile residues
Residues after harvest	80-95	70-80
Plough	0-15	0-10
Plough and chisel	0-10	0-5
Discs (2 operations)	15-20	10-15
Chisel (2 operations)	30-40	20-30
Cultivator (2 operations)	40-50	30-40
Cultivator (1 operation)	50-70	40-60
Direct seeding	80-95	60-80

Box 2. Disadvantages of tillage

- ☹ Loss of soil moisture
- ☹ Limits water infiltration through surface sealing
- ☹ Destroys the soil structure
- ☹ Increases erosion risk
- ☹ Increases operational cost
- ☹ High demand on power, time and equipment

Therefore it is important to choose land preparation practices that protect the natural resources and at the same time improve productivity and reduce production costs. In conservation agriculture systems land preparation practices are reduced to almost no tillage at all.

Zero tillage or no-till practices are those activities in which the seeds are brought into the soil with the least soil disturbance possible. That means planting and sowing into the residues of previous crops and weeds. Therefore, farmers, extensionists and researchers have been developing not only instruments and equipment to seed into the residues, but also tools and implements to manage the crop residues and fallow vegetation.

Ploughs, chisels and subsoilers

The plough as mouldboard or disk plough is probably the most popular land preparation tool that is used in both developing and developed countries. There is no other tool that symbolizes agricultural development, like the plough. Tillage tools might still be necessary for some specialized operations even under Conservation Agriculture. This is why they will be discussed briefly in the training. However, under CA they disappear as commonly used implements.

Plate 2
Primary tillage in order to open the soil, resulting in moisture loss and higher weed infestation.
(*T. Friedrich*)

The plough is mainly used for primary tillage: opening up the soil with the aim of loosening the soil for good root penetration and cutting and burying weeds. Disadvantages of the plough include:

- ☹ repeated ploughing at the same depth can create plough pan or compacted layer
- ☹ turning the soil upside-down will result in loss of soil moisture through evaporation
- ☹ brings weed seeds from deeper soil layers to the soil surface, resulting in more weed infestation in the field.

The design of the mouldboard, like the size and form, determines the quantity of crop residues that is left on the surface and the part that is mixed into the soil. The bigger and more curved the mouldboard the more residues are inverted into the soil and thus fewer residues that are left on the surface. Disk harrows are often considered as tools for in minimum or reduced tillage. However, equal to the disk plough they partly invert, mix and pulverize the soil and over time they build up substantial subsoil compaction. The rather intensive actions on the soil make them unsuitable for conservation tillage. Farmers during the transition to conservation agriculture should, in case some tillage operation is required before adopting a permanent no-till regime, opt for implements with vertical tines like chisels or cultivators leaving a maximum of residues on the surface.

Rippers using chisels can be used to break up severely degraded and unstructured soils in the transition phase before the soil structure is starting to recover. For use under Conservation Agriculture rippers or chisel cultivators should be capable of handling surface residues, either by using cutting disks in front of the chisels or by providing sufficient horizontal and vertical clearance between shanks and frame to allow a free flow of residues through the equipment. Care should also be taken that the chisels do not lift clods to the surface which would then require additional secondary tillage operations to prepare a seedbed. This is achieved by choosing the right soil moisture for operation, when the soil is at the crumbling point, and by preferring implements with the shanks bent sidewards. If at all, for example on seriously degraded, or on wet and cold soils, ripping is often limited to the planting rows as strip-tillage.

Plate
Heavy ripper for deep ripping equipped with cutting disks for residue handling
(*T. Friedrich*)

Plate
Sidewards bent shanks of a paraplough to avoid lifting of clods
(*T. Friedrich*)

Subsoilers are deep rippers used to break up hard or compacted soil layers, with the aim to improve water infiltration and root penetration. The point of the subsoiler is brought right under the compacted layer, which would be typically at soil depths of 25-60cm. Disadvantages include:

☹ very high power requirements
☹ the soil must be at crumbling point or dryer up to the depth of intervention
☹ point can break easily when used incorrectly and worn points reduce the effect
☹ when not used correctly water infiltration rates are not improved a lot

Subsoiling to break compactions should not be considered a periodic work but an absolute exception. After subsoiling measures are to be undertaken to stabilize the loosened structure. Very much care has to be taken not to recompact the subsoiled soil. Driving with heavy machinery on a freshly loosened soil or applying intensive tillage with disk harrows might destroy the effect of the subsoiling and produce even more serious compactions than before subsoiling. Due to the high power requirement of subsoiling biological ripping with plants developing strong and deep roots might be the cheaper option.

Plate
Completely worn out point of a subsoiler
(*T. Friedrich*)

Plate
Subsoiling with a paraplough leaves residues in place and does not disturb the soil surface
(*T. Friedrich*)

Cover crop and weed management

The objective of cover crop, residue and weed management is to prepare the area for planting of seeds of the subsequent commercial crop and to manage the weeds so that they cannot interfere with the crop development. In conservation agriculture systems, this management should facilitate the penetration of direct seeding equipment in the field without obstructing the implement and favour the germination of seeds.

It is desirable that the residues form a good soil cover that protects the soil for quite some time against the impacts of rainfall and that liberates allelopathic chemicals to suppress the germination of eeds. The release of these chemicals should be slow and gradually until the commercial crop is able to compete with the weeds. One of the factors influencing the release of allelopathic chemical is the decomposition of organic matter (Almeida, 1988).

Residue/cover crop management can be done either mechanically or chemically, or a combination of the two, depending on the possibilities of the farmer, the topography (slope or flat land), the degree to which the area is invaded with weeds and the development stage of the cover crop.

Mechanical management

Mechanical residue/cover crop management can be done by using knife rollers, crushers, mowers or choppers etc. or any derived implement.

Knife rollers or chopping rollers

The knife roller is used to bend over and crush the weed or cover crop vegetation prior to planting of the commercial crop, resulting in the death of the cover crop. This operation is best carried out after flowering but before maturity of the seeds of the cover crop. In this way there is no need to apply a herbicide to desiccate the vegetative cover, which will substantially reduce the cost of production. It is important that the knife roller only breaks and crushes but does not cut the cover crop plants so that they dry out and die. If the plants are cut the stubble might stand up again and re-sprout. Mechanical planting is also easier if the residues are not cut but still in contact with the soil. Rolling down the residue or cover crop cover improves also the weed control as compared to the standing residues or cover crops.

The knife roller is a simple and relatively cheap piece of equipment that can be made on the farm. It consists of a cylindrical body that rotates freely over a horizontal axle. The blades are arranged around the cylinder with equal distances apart. The distance between the blades determines the crushing length. Staggered knives and knives set at an angle to the radial of the cylinder improve the action and reduce the impact on the draft animals. The body is placed in a frame which might also provide transport wheels and a protection for the operator. When pulled the cylinder rolls on the knife-edges, bending over and crushing the vegetation (Araújo *et al*., 1993).

A simple knife roller can be made of a tree trunk, adorned with "knives" at a distance of 22-25 cm apart around its circumference. The knives can be made of strips of hardened steel, e.g. the leaf springs of an old motorcar (Bertol and Wagner, 1987).

It needs proper management to avoid regrowth. In case of bending and crushing the vegetation it is important that the cover has a uniform development stage and that no regrowth or seeding occurs after the operation. Therefore it is recommended to use the knife roller in the following growth stages of the cover crop (Calegari, 1992):

- for legumes: between full flowering and formation of the first pods;
- for grass species: during the milky stage;
- for other species, like oil radish: between flowering and maturing of the seeds.

If mixtures of cover crops are used, it is important to choose those species with a more of less uniform growing cycle (Monegat, 1991).

Plate 7
Simple kniferoller made from wood with metal bars.
(*T. Friedrich*)

Plate
Tractor mounted knife roller
(T. Friedrich)

Construction details for a knife roller (according to http://www.rolf-derpsch.com/)
The Knife Roller consists of a hollow steel cylinder, 6mm thick, approx. 115 - 200 cm wide and 60 -70 cm in diameter.
Ends are welded to be filled with water if needed.
Approx. 8 - 12 blunt knives are placed every 19 cm.
The knives are about 7 - 10 cm high and are placed parallel to the cylinder at an angle of 45° or 90°.
Weight of each 200 cm cylinder is aprox. 400 kg empty and 800 kg full of water.
Three cylinders are often placed in such a way that two run in front and one in back allowing for greater working width.
Cylinders are mounted on a frame to allow hydraulic lifting.
(Derpsch, 2003)

Plate
The Knife Roller to flatten and kill green manure cover crops and leave the plant residues on the soil surface is an essential tool for cover crop management.
(R. Derpsch)

Crushers
Based on the principle of the knife roller, several options to bend over and crush the vegetation can be thought out. Basically anything that is round and more or less heavy would qualify as show the following examples of tools used by farmers:

- sledge
- tree trunk without blades
- cement tubes
- old car tyres (Paraguay)
- modified disk harrows

Plate
Modified disk harrow to be used as knife roller
(T. Friedrich)

Plate 9
A culvert used to crush the cover crop previous to the current onion crop.
(*V.H. de Freitas*)

Plate 10
Metal tubes behind a tractor used as cover crop crusher.

Mowers

Mowing cover crops is normally not recommended as it could lead to resprouting of the stubble. In addition the residues would be loose on the surface and not aligned as it is the case when they are rolled down with a knife roller. This could complicate the planting.

Besides mowers, shredders are another type of machines used for mulch management. They consist of knifes, rotating vertically at high speed around a horizontal axle. Usually they reduce the biomass to small pieces. The advantages include a fairly even spreading of the mulch, the control of pests and deseases and might facilitate the work of seeding equipment. However, the biggest disadvantage of shredders is that the chopped residues decompose much quicker which means they would not last as long as non chopped residues on the soil surface. Another serious disadvantage is the high energy consumption. For this reason shredders should only be considered in special cases for residue and cover crop management.

Plate 11
Tractor mower used to cut cotton residues.
(T. Friedrich)

Plate 12
Shredder used to chop cotton residues.
(*T. Friedrich*)

The same principle applies to the cereal straw after combining. It is very important that the straw is equally distributed across the cutting width of the combine. In many cases modern combines are therefore equipped with straw-choppers. The straw chopper must be set in a way that all the straw and chaff is spread uniformly across the cutting width of the combine.

Plate
Combine harvester with straw chopper
(T. Friedrich)

Under Conservation Agriculture it is preferable even in the case of cereal straw not to chop but just to spread the straw behind the combine harvester. This saves energy and fuel, provides a longer lasting soil cover and reduces the danger of hairpinning – straw being push into the seed slot – during planting. Straw spreaders for combine harvesters are commercially available or could be built easily on farm.

Plate
Straw spreader on combine
(MAX - Irmãos Thonnigs Ltda.)

Plate
Farmer's built straw spreader
(T. Friedrich)

Chemical management

Chemical management of fallow vegetation or cover crop is done by spraying herbicides. Herbicides are applied to desiccate or "burn" the vegetative cover and thus facilitates the subsequent planting of the commercial crop. This practice is normally carried out when the green manure/cover crop is not yet in the full flowering or milky growth stage, and it is necessary to sow the next crop, or when the farmer is too late for using the knife roller.

For applying herbicides the standard tractor boom sprayer is the most common equipment. Depending on the size this can be tractor mounted, trailed or self propelled. For row crops shielded sprayers can be used to apply herbicides between the lines without affecting the crop.

Using herbicides requires very much care, knowledge and skills in order to avoid environmental or human health hazards. Spray equipment should conform to established safety standards and be in safe working conditions. There should not be any leaks, the controls should be working properly and the nozzles be checked replaced regularly. Operators should be trained and proficient in using sprayers. A badly done herbicide application increases the production costs and might even endanger the crop.

Plate
Shielded row crop sprayer for herbicide application between the crop rows
(*T. Friedrich*)

Before spraying the sprayer should be properly calibrated to make sure the right dose rate is applied. For herbicide application nozzles should be chosen that provide a good even distribution across a level surface, provide good overlap even at varying boom heights and produce a coarse droplet spectrum to avoid drift. These are usually flat fan or deflector or flood jet nozzles. Depending on the nozzle and the required application rate the pressure should be low to avoid the formation of small droplets (1-2 bar).

Box 4. Different sprayers

- Hydraulic nozzle
- Rotary nozzle/low volume

- Point sprayer (single nozzle)
- Boom sprayer
- Shielded sprayer/row crops

To avoid drift, spray booms can be equipped with drift shields or air-sleeves.

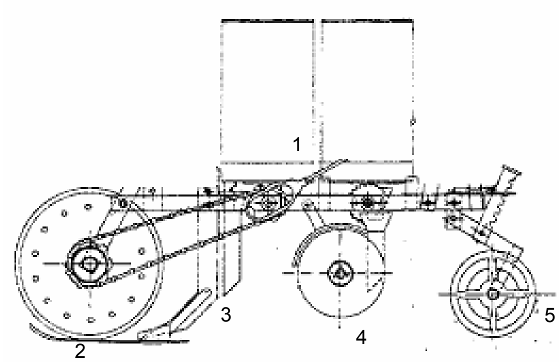
Plate
Tractor mounted boom sprayer with airsleeve (airboom) for reduced drift
(T. Friedrich)

Where old obsolete sprayers are available but not in proper working order, they can be upgraded at low cost by replacing only the liquid carrying technical components. Usually the tank and sprayer frame, often even the boom can still be used. It is advisable to replace pump, hoses, controls, filter units and nozzles with the respective lines.

Plate
Old sprayer upgraded with new pump, controls and spray lines
(T. Friedrich)

Direct seeding

Figure 2
Basic design of a direct seeder (Adapted from Riveira *et al.*)



Legend

1. Measuring and distribution of fertilisers and seeds
2. Cutting disk
3. Furrow opener and fertiliser- tube
4. Furrow opener and seed-tube
5. Depth control and Press wheel

No till planters or seeders have either all or some of the following components:

- Hoppers for seed and, if applicable, for fertilizer with the respective metering mechanisms and delivery tubes
- Row cleaner, if necessary, to remove excess mulch from the plant row
- Cutting disk to cut through residue cover
- Furrow opener for fertilizer
- Furrow opener for seeds
- Seed fixing press wheel

- Furrow closing wheel (often in combination with depth control)
- Press wheel

Row cleaner
Under some circumstances, direct seeders have a row cleaner just before or combined with the cutting disc. Row cleaners make the seeding more efficient under the following conditions:
- heavy or difficult mulch
- delicate seeds
- in cold climates to warm up the soil

Plate 20
Row cleaner combined with cutting disc.
(*T. Friedrich*)

Cutting disk
A cutting disk is usually necessary to make a clean cut through residue cover and avoid residue collection around the planter elements or the pressing of residues into the seed row. They are particularly important with heavy residue covers and with chisel type furrow openers. The efficiency of the disc that cuts the (cover) crop residues depends on various factors:
- soil conditions: texture, resistance to penetration, humidity and porosity
- straw and residue conditions: resistance to be cut, humidity, quantity and management
- seeder: weight and dynamics
- disc: size, shape and profile

For good results it is recommended:
- to work during the warmest hours of the day (after 10 in the morning);
- work when the straw is either green or completely dried, never when it is wilted;
- operate when humidity level reaches the point of soils being friable;
- when using animal traction, never try to seed when more than 5 tons of dry matter per hectare is left on the surface.

Inefficient cutting leads to an accumulation of residues between the different parts of the seeder and results in seed and fertilizer deposition problems, i.e. irregular spacing or complete absence of seeds (Ribeira *et al*., 1999).

Plate 21
Cutting disc.
(*T. Friedrich*)

The soil needs to be firm enough to facilitate the cutting through residues, otherwise those will be pressed into the soil, resulting in hairpinning and bad soil contact of the seed. Blockage of the equipment could also result from not proper cutting of residues on soft soils (Casão and Yamaoka, 1990). The cutting discs are either flat or profiled to improve grip in the soil. Extremely profiled undulated disks are used if more soil movement is desired, for instance when *Fusarium* infestation is expected and a drier soil is needed, or to improve the turning of the disk and avoid blockage.

Furrow opener

A furrow can either be opened by a chisel tine or hoe, single disc at an angle to the furrow, double discs or by punch type injection. Usually the furrow opener is placed just before or on the tip of the tubes that drop the fertilizer and the seeds.

The performance of the furrow opener depends on its geometric characteristics, the speed, the texture and density of the soil, the quantity of residues and the pressure placed on it by the seeder. It can be formed as:

- a chisel tine or hoe: commonly used in soils that have a higher resistance to penetration, but results in more problems with clogging up the implement with residues, and can not be used in areas with stones, trunks or a lot of roots; chisel openers, either exclusively or in combination with disks are usually preferred for lightweight no-till planters used with smaller tractors as they require less weight due to the better penetration characteristics;
- single discs at an angle to the furrow;
- double discs, either the same diameter or not and placed in an angle forming a "V" to each other. The additional effect is that residues not yet very well cut, are cut by these discs resulting in less obstruction of the implement. The implement has less capacity to penetrate the soil, especially in clay soils (Ribeira *et al*., 1999). Disks of different diameter and offset axles have better self cleaning and penetration characteristics than those of similar diameter.
- Other types of openers, like inverted T and cross slot.

There are different opinions about the function of furrow openers in direct planters and seeders. Some believe that the furrow opener should, while placing the seed into the soil, at the same time provide some seedbed preparation in the furrow. The planters for this purpose use often hoe-type furrow openers and create considerable soil movement. This leads to higher draft power requirements, soil moisture losses and the germination of weed seeds might be stimulated. Under CA it is therefore preferred to use furrow openers which are designed to create a minimum of soil movement, regardless whether they are chisel or disk type.

Plate
No till planting with hoe type furrow openers creating considerable soil movement
(T. Friedrich)

Plate
No till planting with double disk furrow openers creating hardly any soil movement (on the right side field planted with hoe-type planter)
(R. Dambros)

Generally, there are four basic slot shapes (Baker *et al*., 1996):

1. V-shaped slots;
2. U-shaped slots;
3. Inverted T-shaped slots;
4. Cross slot.

V-shaped slots are almost always created by two discs which touch in the front and open at an angle at the back. The angle of the V is usually about 10 degrees. Each of the angled discs pushes roughly an equal amount of soil sideways when both discs are at the same angle to the vertical. Biggest advantage of double discs is their ability to handle surface residues, stones and minor obstacles without blockage. The construction is relatively simple and maintenance free.

Plate 23
Double disk furrow opener, here with offset disks for improved penetration (*T. Friedrich*)

When the front edges of the two discs leave a gap open at ground level, this can cause problems with residues entering. This can be avoided through:

☺ placing a third disc ahead of, or in between the two angled discs, which cuts the residues; or,
☺ positioning one of the two discs forward of the other as to present a single cutting edge (offset disks); or
☺ replacing one of the two discs by a smaller one; the larger disc becomes the leading edge to cut the residues.

Plate
Double disk furrow opener with offset disks of different diameter
(T. Friedrich)

Disadvantages of V-shaped slots:

☹ needs high penetration forces
☹ intolerance to sub-optimal soil conditions
☹ tendency to 'tuck' residues into the slot (hairpinning)
☹ tend to concentrate seed and fertilizer at the base of the slot if applied in the same furrow

U-shaped slots have a broader base than V-shaped slots. They are created by a variety of opener designs:

- single angled disc type openers
- hoe openers
- power till openers

All of these designs produce some loose soil on the surface near the slot that can be used to cover the slot again. Angled disc type openers scrape soil away from the centre of the slot; hoe and furrow type openers burst the soil upwards; power till openers chop the soil with a set of rotating blades; and furrow openers scoop the soil out from the slot zone.

Plate 24
Detail of single disc furrow opener.
(*T. Friedrich*)

Box 5 Single disc coulters

Characteristics:

- Produce U-shaped slot
- Simple and robust
- Compact (often used for small grain seed drills)
- Good residue handling

Disadvantages:

- High penetration force required
- Considerable soil movement (depending on the angle)

Hoe type openers refer to any shaped tine or chisel, which is designed to vertically penetrate the soil. Seed is delivered either down the inside of the hollow tine itself or down a tube attached to it, which is usually open at the back. The biggest disadvantage of hoe openers is the fact that they do not handle even modest levels of residues without blockage, unless a leading disc is placed ahead of the hoe opener to cut the residues.

Plate 25
Wide wing hoe type furrow opener.
(*T. Friedrich*)

Advantages of hoe openers:

☺ low cost
☺ they penetrate the soil better requiring less weight of the implement which make them ideal for animal traction
☺ they do not tuck residues into the slot, but 'brush' them side ways
☺ they do not create smear surfaces at the sides of moist planting furrows creating a better seedbed

Disadvantages:

☹ problems with stones and obstacles
☹ requires a good cutting disc for long residues
☹ considerable soil movement depending on shape and width

Plate
Narrow chisel type furrow opener for little soil movement
(T. Friedrich)

The inverted T-shaped slot was developed as a result of inverting the wide-top, narrow-base of the V-shape. The main objective for the development was the possibility of the implement to fold the residue-covered soil back over the slot for moisture conservation. The second objective was to find a design that would be able to handle proper fertilizer placement at the same time as seeding. The implement consists of a vertical shank that curves out at its base to form two wings that are inclined towards their fronts at 5-10°. A disc in front is used to cut the residues. The main advantages include:

☺ no compaction of the soil
☺ self-closure of the slot
☺ maintain a constant seeding depth by following closely the soil surface
☺ capable of seeding very superficially through reduced inclination of the wings.

Plate 26
Inverted T furrow opener
(*T. Friedrich*)

Disadvantages:

☹ considerable wear on sandy soils
☹ no proper furrow opening on loose soils
☹ difficult residue handling (requires a cutting disc)

Box 6. Cross-slot characteristics

☺ Ideal germination conditions for seed
☺ Efficient seperation of seed and fertilizer
☺ Low draft requirement
☺ Good residue handling; no hairpinning problem

☹ Considerable wear on sandy soils
☹ Expensive

The Cross-Slot furrow opener is a further development resulting from the inverted t-opener. It provides close to ideal germination conditions for the seed (see box 6). It consists of a cutting disks, with two small wings attached to it on both sides. The wings open a horizontal cut, in which seed is placed on one side and fertilizer on the other, separated by the vertical cut of the cutting disk.

Plate
Detail of Cross-Slot furrow opener
(T. Friedrich)

The rolling punch injection is another form of furrow opener. The seed is placed between the fingers of two starwheels which are at an angle comparable to a double disk, punched into the soil and release. It handles residues quite well, but tends to clogg when used in sticky soils.

Plate 27
Rolling punch injection planter (starwheel planter).
(*T. Friedrich*)

Plate
Detail of Rolling punch injection planter.
(*T. Friedrich*)

It is recommended for annual crops that fertilizer should be placed about 5 cm besides and under the seeds. In a direct seeder this would mean that the ripping device for fertilizer is placed outside the line of work compared to the seeder. However, in many planters the fertilizer is placed under the seed, but in the same line.

For a long time, scientists have thought that the best cover for seeds was loose soil. Obviously this thinking was derived from situations with tilled seedbeds. However, especially under dry conditions it can be observed that seeds under mulch cover germinate better than those covered by loose soil. Since under tilled conditions (loose soil) the macropore system in the vicinity of the seeds is completely destroyed the soil moisture equilibrium and the capillarity is disturbed. In undisturbed soil, the soil humidity equilibrium is intact providing optimal exchange of moisture between soil particles and pores. This allows the capillary supply of soil water to the soil surface while reducing the evaporation loss with the mulch cover. In conservation agriculture, soil moisture loss takes place in the slot, and depending on the type of slot more or less moisture is lost (table 2 and figure ..).

Figure 3
Moisture loss from different slot shapes and the position of the seed in the different slots (after Carter, 1994).

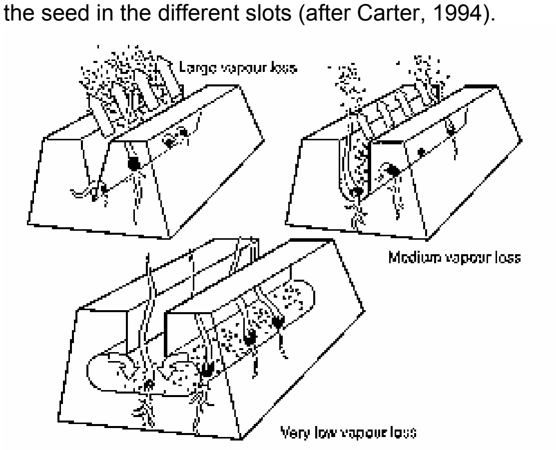


Table 2 Effect of slot shape on slot drying rates (Baker *et al.*, 1996)

	V-shaped slot	U-shaped slot	Inverted T-shaped slot
Daily loss of relative soil humidity (%)	3.7	2.4	1.7

Table 3 Wheat seed and seedling responses to no-tillage openers in a dry soil and soil of adequate moisture (Baker *et al.*, 1996)

	V-shaped slot		U-shaped slot		Inverted T-shaped slot	
	Moist	Dry	Moist	Dry	Moist	Dry
% seedling emergence	42%	10%	70%	31%	68%	59%
Germinated seeds that had failed to emerge	58%	72%	30%	22%	32%	23%
Ungerminated seeds	0%	18%	0%	47%	0%	18%

The inverted T-slot traps water vapour within the slot, which germinates the seed. Pressing on the seeds in V- and U-shaped slots before covering the seeds improves their performance, especially in dry soils.

The wheels at the back of the implement serve to press humid soil or crop residues on the slot in order to place the seed into close contact with the soil. Some seeders lack this wheel and in that case it is the operator of the planter who puts the seeds into contact with the soil, as s/he walks on the slot.

Surface residues are an important resource for promoting seedling emergence from dry soils and it is possible to obtain more effective seedling emergence from a dry soil by direct seeding than by tillage, provided the correct technique and equipment are used.

Different crops and seeds require different ways of seeding or planting. The two major types are

1. Drill seed: the seed is seeded in a continous band into the seedrow. This method is usually used for small grain crops like cereals. The seed is metered with feed rollers of different design, either positioned one for each seedline and gravity fed or centrally with pneumatic distribution of the seed to the lines. The machines for this type of seeding are usually called seeddrill or seeder.
2. Precision planting: single seeds or a predetermined number of seeds is placed at equal predetermined distance within the row. This method is usually used for row crops like maize, beans, cotton, sunflower etc.. The number of seeds per planting hole and the distance of each planting location is determined by seedplates which have holes or chambers to meter the seed. The metering can either be mechanical or pneumatic, where the air is either as vacuum or as pressurized air used to single out the number of seeds per position.

Plate
A mechanical no-till seed drill
(T. Friedrich)

Plate
Pneumatic no-till seed drill with two central metering and distribution units
(T. Friedrich)

Plate
Small row crop precision planter
(T. Friedrich)

There are some modern no-till planters which incorporate both options in one machine, the seeddrill and the row-crop precision planter. The farmer only equips the seed-drill-cum-planter with the desired number of furrow openers and connects them to the respective metering mechanism.

Plate
Seeddrill-cum-precision planter: on top the feed rollers of the metering system for drill seed, below the boxes for the precision planting seedplates
(T. Friedrich)

Plate 28
Detail of the inside of the seed container of a precision planter with seed plates to distribute the seeds.
(*V.H. de Freitas*)

Seedplates inside the containers are controlling the plant density in the field. They are activated to turn by the movement of one of the wheels either with a chain or gear. The distance between the soil and the tube defines the preciseness of planting: if the distance is bigger, the chance that the seeds deviate from the optimal planting distance is bigger.

Upgrading of old seeders/planters into no-till seeders/planters

No-till seeders and planters often are much more expensive than conventional ones. Therefore the investment into a no-till seeder or planter might create a serious obstacle for the transition process towards Conservation Agriculture. In many cases the old conventional seed-drills or planters can be converted at low cost into no-till seeders or planters, either by the farmer him/herself or by mechanical workshops. For the conversion the metering systems remains the same, the planter frame might have to be reinforced and the soil engaging parts, namely the furrow openers, are replaced by new no-till units.

Plate
Modifying a conventional precision planter for no-till use: adding a cutting disk in front and replacing the furrow openers for fertilizer and seed.
(T. Friedrich)

Plate
Modifying a conventional seeddrill for no-till use: adding new cutting disks and furrow openers and modifying the frame.
(T. Friedrich)

Plate
The above seeddrill after the finished modification. The upgrading was done by a farmer using modification kits.
(T. Friedrich)

Other information on direct seeders

Already a lot of manufacturers of zero tillage equipment have posted their products together with information on the Internet. FAO Agricultural Service tries to bring as much information together as possible in their on-line database on Conservation Agriculture Technology, which is accessible through: http://www.fao.org/ag/catd/index.jsp

The database provides information on different models of conservation agriculture equipment for manual use, animal and mechanized traction. Technical, agronomic and commercial information for direct planters and seed drills, rippers, equipment for residue handling and specially developed sprayers can be viewed from this site. Complete addresses are provided, including links directly to webpages of the manufacturers.

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