Frequently asked questions about Cross Slot® no-tillage

(Revised, February 2013)

FOREWORD

This booklet records the questions and answers about Cross Slot® no-tillage that numerous people have posed over the years. It does not attempt to reference each answer; nor to cover the topics in great detail. More complete referenced explanations can be found in two additional books written by the authors and on our web site (see question 1). It is no accident that the people responsible for Cross Slot no-tillage were the scientists and engineers who undertook a 30-year published science project to determine why other no-tillage technologies and systems had not always worked reliably. As a result they became acknowledged international experts in this field and have addressed numerous international conferences on the topic as guest speakers.

Cross Slot adopts a different approach than other no-tillage systems. Reducing the risk of impaired crop performance has been the number one goal. The answers to the questions are unashamedly based on the authors' own science as well as that of other scientists and reveal a number of new scientific principles and management techniques not known or well understood prior to this research.

The questions asked by farmers, scientists, consultants and environmentalists over the years illustrate the complexity of the factors that must come together to make the practice of no-tillage both feasible and sustainable. Cross Slot no-tillage technologies have now been in the market place in 17 countries since 1995 and in that time have seeded millions of hectares. In so doing, they have amply demonstrated that what the science said would happen in practice has indeed done so.

ADDITIONAL INFORMATION

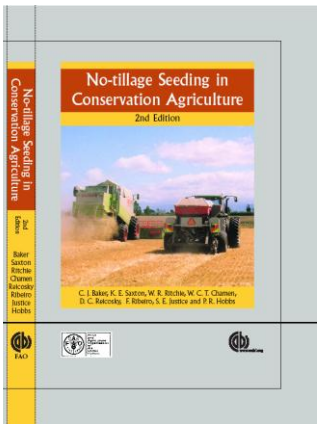
1. **Where could I find additional and more detailed information?**

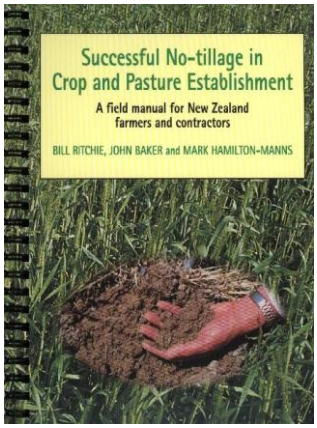
   Our web site is www.CrossSlot.com . Amongst other things, it contains summaries of some of the key scientific experiments.

   The Food and Agriculture Organization (FAO) of The United Nations commissioned the inventors of Cross Slot no-tillage systems and machines to write and edit a book explaining in layperson's terms, the science behind the answers given below. The 2006 book, entitled ***No-Tillage Seeding in Conservation Agriculture*** (Baker, Saxton, Ritchie, Chamen, Reicosky, Ribeiro, Justice and Hobbs) is published by CABI, Oxford, England, and is a sequel to the first edition (1996), which was entitled ***No-Tillage Seeding: Science and Practice*** (Baker, Saxton and Ritchie).

   Available from FAO, Rome, Italy; Baker No-Tillage Ltd, P.O. Box 181, Feilding 4740, New Zealand; and the publishers.

   The management steps needed to undertake successful no-tillage as a practice are described in a book entitled ***Successful No-tillage in Crop and Pasture Establishment*** (Ritchie, Baker and Hamilton-Manns) which is available from Baker No-Tillage Ltd, P.O. Box 181, Feilding 4740, New Zealand.





CROP YIELD

2. We read that long term trials are casting doubt on whether or not no-tillage is really improving crop yields and soil health. Does this apply to all no-tillage?

No! The reason is that very few people in the world are actually doing true no-tillage. Many are doing some form of minimum tillage using a seeding machine instead of separate tillage machines. Over the years, so-called “no-tillage” openers have become increasingly aggressive and many practitioners have lost site of the fact that no-tillage is more about residue management than ceasing to till the soil to full depth.

3. Does this apply to strip tillage too?

Yes. Within the tilled strips the soil remains as disturbed, pulverised and destroyed as full tillage has always done (which is bad). Between the strips it is left totally undisturbed (which is good). The average over the whole field though, is likely to be little different than if the whole field had been minimum-tilled.

4. Are strip tillage and minimum any use at all?

Yes, they are useful interim steps that help a farmer make the adjustments from full tillage towards true no-tillage. In many cases they also allow farmers to keep using the same seeding openers they have been using with full tillage, thus reducing cost and the need to learn new skills.

But they are only half-way measures at best and should never become the end goals themselves.

5. How does Cross Slot no-tillage stack up?

Almost without exception, Cross Slot no-tillage has increased crop yields where it has been applied. In some cases the increases have been spectacular (up to 50%) but more importantly, it is very rare indeed to find examples of Cross Slot no-tillage having reduced crop yields, even in the all-important first year out of tillage.

Just as important, has been reducing the variability of crop yields that are often seen in successive years with conventional tillage.

THE IMPORTANCE OF SOIL CARBON

6. In what ways do minimum tillage, strip tillage and aggressive “no-tillage” practices fall short?

In two main respects. Firstly, they simply do not utilize the surface residues to advantage. Residues are treated as being something of a nuisance rather than an asset. And secondly, they continue to at least partly-pulverise the soil, which destroys soil structure, soil organisms, and oxidizes soil carbon.

7. Which of these is the most important shortcoming?

Not using the residues is the most important mistake. Residue from the previous crop is the single biggest asset that true no-tillage possesses, which is why no-tillage openers should focus on utilizing, rather than avoiding residues through partially burying them, removing them or pushing them aside.

The worst practice of all is to burn the residues. Yet there are still consultants who recommend burning residue-loads greater than 4 tonnes/hectare (4,000lb/acre). This simply reflects ignorance on their part of technologies like Cross Slot that can happily handle 15 tonne/hectare residue loads.

8. Please explain

Decomposition of surface residues is nature’s way of re-stocking the soil with carbon that has otherwise found its way into the atmosphere. Re-stocking the soil with carbon is the single most important thing that can be done to make world food production truly sustainable.

9. How so?

The products of the decomposition of crop residues (organic matter) are largely carbon-based (often referred to as humus). The Western Australian Department of Agriculture has found that 1 kg (or pound) of humus holds as much water in the soil as 9 kg (or pounds) of clay. So the first effect is simply to increase the water holding capacity of soils, which usually translates directly into crop yield.

The second effect is that this humus feeds the millions of soil microbes that hold the soil together and make it into a living entity rather than the sterile “dirt beneath our feet”. Some microbes (such as abuscular mycorrhizal fungi - AMF) form symbiotic relationships with plant roots that helps them take up nutrients. Soil biologists now claim that the presence of AMF can raise crop yields by as much as 15%. Other microbes seek out plant pathogens and destroy them. And the exudates of most microbes help hold the soil together.

Scientists now claim that one teaspoon of a healthy soil can contain about 6 billion microbes – many of them are so small that they can only be identified by their DNA.

10. But doesn’t any of this happen in tilled soils too?

It is drastically reduced in tilled soils, which is why tillage is such a destructive practice, especially repetitive tillage! When the soil is tilled it becomes aerated and this aeration oxidizes much of the labile (readily available) soil carbon into carbon dioxide, which escapes into the atmosphere (scientists now estimate that up to 15% of the atmospheric CO_2 comes from the world’s annual tillage of its soils). There are other forms of less-available carbon that are not easily oxidized, such as are found in so-called “Biochar” (a form of charcoal).

But that is not the most important issue. If any one soil is tilled annually for long enough the soil organic matter level will gradually ramp downwards, starving the all-important soil microbes until they die and the soil becomes almost inert like talcum powder. The dust storms of the USA Midwest in the 1930s attested to this occurrence. It is now know that the dust storms were largely a result of repeat tillage of the prairie soils, which had stripped them of their natural (pre-ploughing) organic matter.

11. Don’t we just need to plough some straw back into the soil to keep the biological system topped up?

Unfortunately no. The soil disturbance caused by the very act of ploughing usually oxidizes as much (or more) existing soil carbon into CO_2 than is gained from the buried straw. And it kills invertebrates like earthworms, which are otherwise the most obvious indicators of soil health. The only way to get a net increase in soil carbon is either to cart in humus from elsewhere (e.g. compost) or to adopt true no-tillage that allows the residues and straw to decompose on the surface of the ground and become incorporated into the soil by the earthworms and soil microbes. This is why minimum soil disturbance and maximum residue retention are the cornerstones of true no-tillage.

12. Does this mean that organic farming methods are a good option?

Sadly, no. True no-tillage is a more organic process than so-called “organic farming”; at least as it applies to the growing of annual crops (90% of the world’s food comes from annual crops). Because “organic farming” of annual crops does not allow the use of synthesised herbicides to kill weeds, it usually relies on tillage to do this and (as described above) tillage is about the most inorganic thing that can be done to any soil.

Therefore, regardless of whether or not organic food is better for human consumption, where “organic farming” of annual crops depends on tillage for weed control it is certainly not a sustainable or environmentally responsible practice at the farm level. On the other hand, where weeds can be controlled by non-herbicide methods (other than tillage) organic farming is every bit as environmentally sustainable and responsible as true no-tillage.

13. Can you illustrate the effects?

The three photographs below show three spade-slices of the same soil in Ukraine. The left hand photo shows the soil in its natural state that has not been disturbed in any way for the past 50 years. The soil (of glacial origin) is very healthy with a lot of buried organic. A healthy crumb structure has formed that in turn has created pore spaces between the individual (crumbs). This soil is as healthy as you will see anywhere in the world.

The centre photo shows the same soil after 50 years of continuous tillage, which has oxidized much of the organic matter, resulting in loss of structure and development of compaction with little porosity. The visible cracks have resulted from digging the soil up and would not have been present in the undisturbed soil. Crop yields would have declined cumulatively.

The right hand photo shows the same previously-tilled soil after 9 years of minimum tillage. There is a clear horizontal break about half way down the profile (shown by the arrow). Deeper than this break-line the soil has not been tilled for 9 years and its recovery towards its natural state is well advanced. Crumb structure has re-formed. But at depths shallower than the break line the soil is still being tilled and is no better that in the poorly-structured soil in the central photograph.

The message is clear and simple:

9 years of minimum (shallow) tillage has done wonders for half of the soil, **but not all of it**. Total recovery of this soil will not be achieved until genuine low-disturbance no-tillage is applied to the full soil profile. Minimum tillage has improved the situation, but has only gone half way.

14. What would be your management advice for a new owner of a Cross Slot no-tillage machine?

a. For all crops, learn how important soil carbon and organic matter are to crop yield and sustainability.
b. For all crops, aim for maximum residue retention and minimum soil disturbance.
c. Remember that lying straw decomposes faster than standing stubble.
d. For annual crops, leave short rather than long standing stubble (standing stubble takes longer to decompose but may be helpful for short periods as a wind protection for seedlings and for trellising of subsequent legume crops).
e. Row spacing should primarily reflect the available soil water and this will likely increase as soil organic matter increases. With Cross Slot openers, it is not necessary to have wide rows for residue handling purposes, but of course they keep the machinery costs down.

15. Is Cross Slot no-tillage suitable for fallowed land such as "CRP" in the USA and "set aside" elsewhere?

Absolutely! It is not only suitable, it is highly desirable! The purpose of fallowing such land has been to rebuild its organic matter content by interrupting the destructive tillage cycle for 10 years or more. As a result, the soil will likely be as healthy as it has ever been. The worst thing that could then happen to it is to disturb it more than absolutely necessary. Any form of tillage (or even minimum tillage) would be a disaster and most other no-tillage options will simply not cope with the amount of residues present nor their tangled nature.

Cross Slot no-tillage openers will handle the tangled residues with ease as well as preserve all of the good soil biology and structure that has accumulated.

Firstly, make sure that any lingering pests and weeds are dealt with.

Then just spray it and drill it. It is as simple and fail-safe as that.

THE INFLUENCE OF CROSS SLOT NO-TILLAGE MACHINES ON CROP YIELD

16. It is difficult to believe that seeding machines can influence crop yield. Surely it's the weather, genetics, fertilizers, diseases, pests and crop husbandry that do that?

A significant amount of recent scientific research has been devoted to finding out exactly what influence a no-tillage drill can have on (1) stand establishment and (2) crop yield. In summary:

(a) Drill openers have a big influence on the micro-environment that seeds and seedlings experience in untilled soils (tillage tools, rather than drills, have most influence on the seed's micro-environment in tilled soils).

(b) This micro-environmental influence is itself largely determined by surface residues, particularly where they finish up relative to the slot (since there are no surface residues in tillage, they play virtually no role in tilled seedbeds).

(c) Drill openers have a major influence on how seeds derive water for germination (imbibition). In no-tillage, vapour-phase water (or soil humidity) becomes an important germination resource whereas in tilled soils humidity usually plays a very minor role because of general soil loosening and loss of humidity to the atmosphere. Liquid-phase water is the main resource in tilled soils.

(d) Similarly no-tillage drill openers have an important influence on aeration around seed and seedling roots in wet soils (tillage does this instead in conventional seedbeds).

(e) The seed micro-environment is also influenced by depth of seeding. Consistency of depth is more important and difficult to maintain in no-tillage than in tillage and drill design has a major influence on how well this is achieved (in tillage, because the soil is made uniformly soft and smooth, drills have a much simpler job to do).

(f) Drill openers influence compaction around the seed. Compaction, in turn, can influence how well or poorly seedling roots develop (tillage eliminates most of the influence of openers on compaction by uniformly loosening the soil).

(g) Drill openers influence how well drilled slots are closed in untilled soils (covering is harder to achieve than in tilled soils because the soil is less friable). Covering influences slot drying together with bird and insect damage.

(h) Seed drill openers determine if and where fertilizer is placed during the drilling process (fertilizer placement is not nearly as important in tillage as it is in no-tillage where it can have a major influence on crop yield).

(i)Finally, as explained above, openers have a profound effect on what happens to the surface residues during the drilling process. Those that leave the residues where they found them will encourage microbial activity in the seed zone. Those that push them aside will (1) cause soil disturbance in the “pushing aside” action, and (2) remove the microbial activity to where the residues end up.

Of course weather, genetic makeup, fertilizers, husbandry, and pests and diseases are the major primary determinants of yield. But even these fundamental resources are useless unless drills position seeds, seedlings and growing plants to take full advantage of them. Another way of looking at it is that a poor drill design can negate the positive things that good weather, genetics, fertilizers, and husbandry may offer.

17. Is there scientific evidence of superior crop yields in the field?

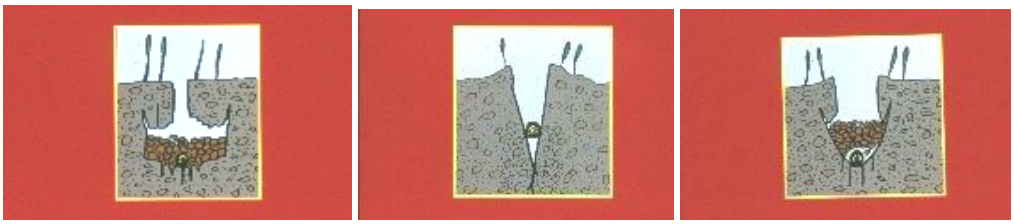
We hear repeatedly from farmers all over the world who have changed to Cross Slot no-tillage, that they are now getting their best-ever crop yields. But anecdotal evidence like this is difficult to quantify. So we have summarized some of the more noteworthy published longer term yield comparisons between Cross Slot no-tillage (CSTNT) and other methodologies:

Locality	*Comparison :*	*Crop*	*Term of experiment*	*Yield increase by Cross Slot*
US Dept. Agr., Pullman, WA, USA	**CSTNT vs double disc no-tillage**	**Winter wheat**	**7 years**	**13%**
NSW Dept. Agr., Grafton, NSW, Australia	**CSTNT vs conventional tillage**	**Soybean**	**13 years**	**30%**
Foundation for Arable Research (FAR) Canterbury, New Zealand	**CSTNT vs triple disc no-tillage**	**Winter crop rotations**	**Last 5 years of a 10 year experiment**	**23%**
Foundation for Arable Research (FAR) Canterbury, New Zealand	**CSTNT vs conventional tillage**	**Winter crop rotations**	**Last 5 years of a 10 year. experiment**	**13%**
Combined Rural Traders Ltd., Marlborough, New Zealand	**CSTNT vs triple disc no-tillage**	**Forage brassicas**	**11 randomly picked fields**	**51%**

SLOT SHAPE

18. What is different about Cross Slot® openers?

Cross Slot openers create horizontal soil slots (for seed and fertilizer) whereas most other openers create either vertical or slanted slots and many are for seed only.



Cross Slot *Double disc* *Hoe or shank*

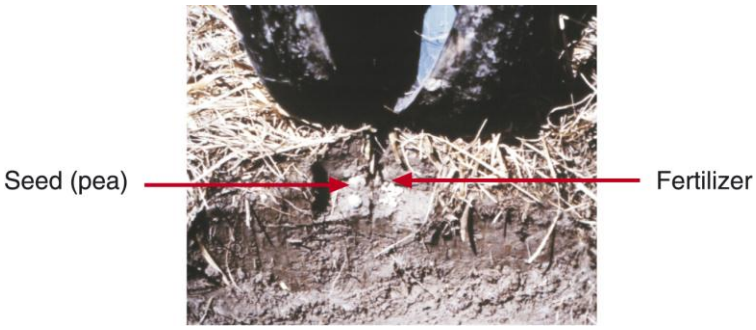
19. What is the significance of Cross Slot creating horizontal slots?

Vertical and even slanted slots are very difficult to close, especially in damp soils. With horizontal slots the seed is tucked under a horizontal flap of soil at the time that the slot is created, ensuring the seed is always covered.

SLOT MICRO-ENVIRONMENT IN DRY SOILS

20. Do horizontal slots have any other advantages?

Yes, several. They ensure that the seed micro-environment can be controlled almost regardless of soil conditions, and they permit fertilizer to be placed in bands that are separated horizontally from the seed.



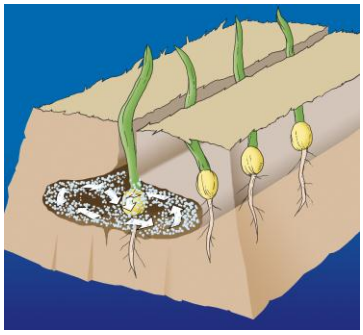
A cut-away of a typical Cross Slot slot in soil

21. What is so special about controlling the seed micro-environment? Isn't getting good seed-soil contact enough?

In short, no! Seed-soil contact is often not enough under no-tillage and is why no-tillage often fails compared with tillage. On the other hand it is also why no-tillage, undertaken with Cross Slot openers can be more failsafe than tillage.

22. Please explain.

Soil that is not tilled has an atmosphere within its pore spaces of 100% relative humidity. Germination of seeds is greatly assisted by this humid soil atmosphere. In some cases the humidity alone is capable of germinating seeds by itself without any soil-seed contact at all. But the relative humidity level needs to be at least 90% to do this.



Humidity entrapment in a Cross Slot slot

23. Does this mean soil-seed contact plays no part at all with no-tillage?

On the contrary! Seeds will take up water in both liquid and vapour (humidity) forms. Seed-soil contact is still important to maximize the liquid uptake, but the availability of vapour moisture in Cross Slot slots gives no-tilled soils an added resource to germinate seeds, which is why germination and emergence failures with Cross Slot openers are very rare events indeed.

24. Does this mean that seeds sown with Cross Slot openers do not actually have to be in contact with wet soil?

Yes! It means exactly that. Provided there is a good mulch cover of surface residues it is not necessary to actually place the seed in damp soil. Close to it will be sufficient for the humidity to do the rest.

25. In such circumstances will germination be as fast as if the seed had been in damp soil?

No! Relying on humidity alone (or even as the predominant mechanism) for germination will certainly delay germination a few days since uptake of vapour water by seeds is slower than uptake of liquid water. But it will occur nonetheless.

26. Don't tilled soils also have such soil humidity?

No! The tillage process aerates the soil so much that soil humidity escapes to the atmosphere and finds a new lower level that seldom approaches even 90% (let alone 100%) except when it rains. Seeds sown into tilled soils therefore mostly rely on absorbing liquid water from the soil and this is influenced greatly by soil-seed contact.

Further, tillage destroys the natural capillary channels in soil that facilitate upward movement of liquid water as the soil surface dries.

27. If that is the case why is no-tillage not always better than tillage?

Because not all no-tillage openers (and the soil slots they create) are capable of harnessing the soil's humidity. Nor are many of them capable of even creating good soil-seed contact. Many no-tillage openers aim to disturb the soil in the slot zone on the assumption that disturbance is good. Although disturbance may assist seed-to-soil contact it breaks the capillary channels close to the seed and ensures that soil humidity escapes from the slot zone.

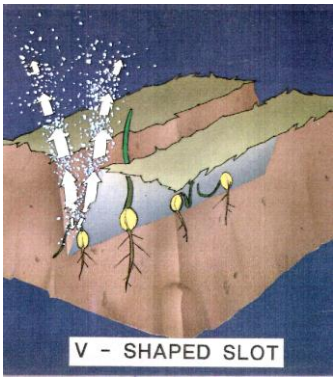
28. Please explain the role of openers in relation to retaining soil humidity.

Although undisturbed soil, especially if it is covered with crop residue (which is the cornerstone of no-tillage) is always at 100% relative humidity, there is one disturbed zone in each otherwise undisturbed soil that is capable of loosing humidity. This is the slot zone created by the openers as they pass through the ground sowing seed and perhaps fertilizer. Therefore it is important that no-tillage openers create their slots in a manner that minimizes loss of humidity from the slot zone itself while at the same time ensuring the seed gets good contact with the soil.

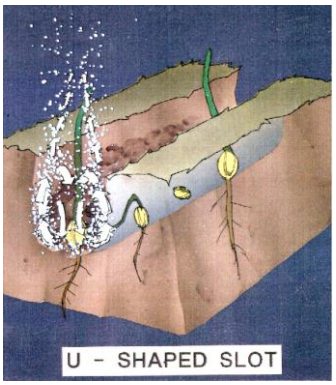
29. In what ways do different no-tillage openers vary in their abilities to retain soil humidity?

The biggest issue is how the slot is closed. With horizontal slots (Cross Slot) two flaps of soil are raised by the wings of the opener as it travels along, creating two horizontal shelves, one on each side of a central disc. Seed and fertilizer are placed separately on each of these two shelves and the flaps of soil are then folded back over the seed and fertilizer. If the flaps of soil are also covered with crop residue this traps the humidity under the flaps.

With vertical slots there are no horizontal soil flaps to be folded back over the seed. The best that can be done is to try to squeeze the sidewalls back together so as to wedge the seed between these walls. But even then the best that will happen is that this will assist soil-seed contact and ensure water is taken up in its liquid form. Vapour water plays no part in germination in vertical no-tillage slots.



V-shaped slots are often difficult to close, allowing water vapour to escape easily.



It is easier to get some loose soil back into U-shaped slots but loose soil is a poor barrier against water vapour loss compared with surface residues.

With slanted slots there may be a partial slanted soil flap created. If so this will trap some vapour water but it is not nearly as effective as horizontal slots in this respect.

30. How do we know this is not just all sales talk?

Because it is has been the subject of numerous scientific studies that are reported in the international scientific literature that were subjected to peer-review by other international scientists over a period of 30 years. No-one has ever challenged these findings, which are also the subject of an international textbook on the interactions between soils, seeds and no-tillage openers. Indeed, other scientists have supported them.

31. Even although it would seem to be impractical, could you get the same effect from vertical slots by placing strips of say, plastic, over them?

Scientists tried this. Even although they found that the slot atmosphere did indeed remain at around 100% relative humidity, they also found fungal growth in the anaerobic atmosphere of the plastic-covered slots. From this they concluded that by ensuring soil gets covered with dead plant residues, nature has always provided a medium that retains moisture vapour but also lets the soil breath. Plastic cannot duplicate both functions. Cross Slot slots simply duplicate what nature has always done, so it is no surprise that seeds and plants respond favourably.

It is not an accident that most deciduous trees flower, set seed and then drop their seeds on the ground before they shed their leaves. The leaves then land on top of the seeds and create conditions similar to that created by Cross Slot no-tillage openers. All we are doing is duplicating nature except that we are choosing the seed type we want and putting it in rows.

32. What happens to the slot micro-environment if dry soil comes into contact with the seed?

With some angled disc openers dry soil can fall into the slot before the seed, which effectively embeds the seed in dry soil. This cannot happen with Cross Slot openers since the seed travels down the inside of the blades, which prevent other soil from falling into the slot until after the seed has been placed. Even if some dry soil did eventually fall into Cross Slot slots the high humidity still ensures that germination will take place.

With other openers the dry soil cushion prevents the seed from getting access to liquid-phase water.

SLOT SHRINKAGE

33. What happens if the soil shrinks after seeding and the slot opens up as a result?

Shrinkage of this nature is unavoidable on occasions with almost all no-tillage openers. But even although the vertical portion of a Cross Slot slot may open just as all other slots do, a small humidity probe is placed down the vertical part of the slot and then into the horizontal part (as scientists have done) it will likely show a low humidity zone in the vertical slit but a high humidity zone under the soil/residue flaps in the horizontal shelves. Because the seeds are located in this horizontal zone they remain in a high humidity zone whereas with all other openers it is difficult to avoid seeds being placed in the low-humidity vertical zone.

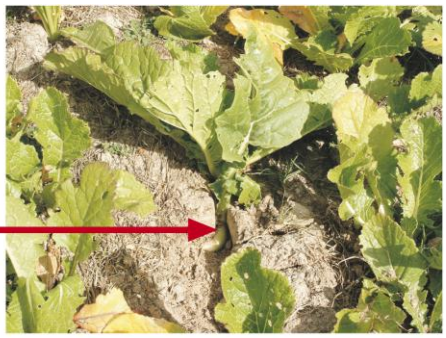
Of course if the soil has adequate liquid moisture anyway, placing seeds in a low humidity zone may not then affect germination because the seeds can still get from contact with the sidewalls of the slot, regardless of whether these are vertical or horizontal. The main differences show up as soil conditions move from being damp (optimum) to dry (sub-optimum). They do not need to move far from optimum to show differences.

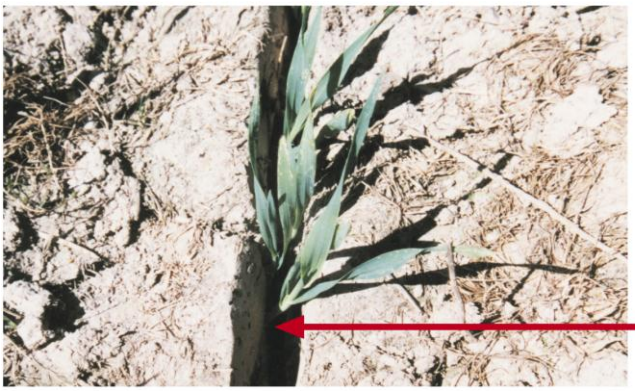
34. But if the seeds are tucked off to one side under a flap of soil, how do they emerge?

In friable soils, the emerging shoots simply push straight up and emerge through the soil flaps to one side of the central disc slit.

But in circumstances where the central slit of a Cross Slot slot shrinks open and the seeds are under a flap to one side that is not friable, the seedlings initially grow sideways towards the light in the open slit, and then they grow vertically. There are many examples and photographs (see below) showing that this is what happens. The end result is a perfectly healthy plant that would otherwise have died in other no-tilled slots.

Healthy brassica plants. A flap of soil has been removed to show where the seed was positioned to the left hand side of the slot. The stem of the centre-most plant firstly travelled horizontally from under the soil flap, and then turned through a right angle towards the light and emerged and grew normally.





Barley seedlings emerging from under a soil flap in otherwise hostile soil conditions, which cause most other no-tillage openers to fail.

35. But what happens if the soil is loose and friable?

Firstly if the soil is like this it will probably not shrink much anyway, so the central slit will not open up. In these circumstances most seeds will simply travel up through the overlying soil and emerge directly above where they were sown rather than take a pathway up through the central slit.

36. How much difference in seedling emergence rates are we talking about?

The differences in seedling emergence counts between openers get bigger as the soil conditions get more hostile. For example differences of 1,000 to 1,400% between Cross Slot openers and double disc openers have been reported in the scientific literature with dry soils. Differences of 20-50% are very common, even when soil conditions are only slightly sub-optimal. In wet soils, differences up to 400% in favour of Cross Slot openers have been reported for different reasons.

GERMINATION AND EMERGENCE

37. Does it follow then, that so long as seeds can get an adequate supply of liquid water there will be no differences between the various no-tillage slots?

Unfortunately no! There is more to it than that. Experiments have shown that even if a seed germinates in a vertical slot made in a dry soil (because it has good contact with the sidewalls of the slot and is therefore able to take up liquid water) the ability of that seedling to survive until it emerges from the soil is an even greater problem in getting a reliable stand under no-tillage.

38. If seeds can germinate in a no-tillage slot, why would they not also be able to emerge?

Because there is a critical period between germination and emergence (which lasts several days) during which seedlings must start collecting water from the soil with their new root systems in order to (1) remain alive, and (2) give them the resources to push through the soil and finally emerge. Sub-surface survival (or mortality) of seedlings is a major determinant of the success or failure of no-tillage crops.

39. Why do some sub-surface seedlings live while others die in no-tillage?

Seedlings die when their roots cannot get through the walls of the slot to collect water from the surrounding undisturbed soil. Unlike tilled soils, in no-tillage slots there is a disturbed slot zone and an undisturbed soil zone alongside. The interface between the two zones in a no-tillage slot is usually the slot wall and is very distinct. In some damp soils, this slot wall may become smeared. When the smear dries it presents an additional cemented barrier. In tilled soils there is no such interface because all of the soil has been disturbed beforehand and the openers do not create any major differences between the two areas.

The problem in no-tillage is worst when the slot wall is nearly vertical, and worse still when it is compacted or smeared such as when it is created by wedging a neat “V” with a double (or triple) disc opener. It is still a problem with “U” shaped slots created by hoe-type openers and slanted slots, but is no problem at all with inverted “T” shaped slots created by Cross Slot openers. In the latter case, because the sub-surface seedlings are held in an atmosphere of near 100% relative humidity, they do not become stressed while the roots negotiate the interface between the slot zone and the undisturbed soil alongside, which is non-compacted and mainly horizontal anyway and therefore more in line with where the roots want to go (i.e. downwards).

40. How long can sub-surface seedlings survive in an inverted “T” shaped slot before emerging?

Scientists had measured survival times of up to three weeks in very dry laboratory conditions. But field experience has recorded survival times up to eight weeks in a dry soil before rain eventually fell and provided an abundance of water.

41. Is there a limit to the dryness of the soil from which seeds sown by Cross Slot no-tillage will fail to emerge?

Yes! But it is remarkable just how dry a soil they will tolerate. Scientists have recorded 50% emergence of wheat seedlings from a no-tillage soil sown by Cross Slot openers at –12 bar moisture tension. Moisture tension is a measure of how tightly moisture is held by the soil particles. A high negative moisture tension means that the soil is drier than at a low moisture tension. Minus 15 bar moisture tension usually defines “permanent wilting point”, which is where the soil is so dry that growing plants will wilt and not recover even if water is re-applied. Minus 12 bar is therefore close to “permanent wilting point”.

42. Does that mean then that untilled soils have more potential to stimulate germination and seedling emergence than they have to sustain plant growth?

Yes! It means exactly that. Even at “permanent wilting point” an untilled soil will provide an equilibrium relative humidity of 99.8% in its pore space and this is the key to seed germination and seedling survival in such soils provided the no-tillage openers are designed to harness that potential. But a growing plant cannot harvest water at such a high tension. Experiments have shown that while you can get wheat seedlings to emerge from a soil at –12 bar the plants died soon after emerging.

Because tilled soils almost never have an equilibrium relative humidity approaching 100% (except when it is actually raining), germination must wait until there is sufficient liquid water for the seeds to absorb and this also ensures there is sufficient water for the seedling roots to sustain the plant both before and after emergence.

43. Is there therefore a danger that Cross Slot openers will force germination from soils that are too dry for the plants to grow in?

Theoretically yes but we have never seen it happen in practice. If it was the case then the solution would be to redesign Cross Slot openers so they were less capable of germinating seeds and that would seem to be even more illogical. In reality it is very seldom that crops fail when sown with Cross Slot openers into untilled, residue-covered soils. In fact their ability to tolerate a much wider range of conditions than other openers is one of the main things that make them superior to all other no-tillage openers and gives them such a high fail-safeness rating (99%).

DUST MULCHES AND NON-WETTING SANDS

44. Is Cross Slot no-tillage usable in dust mulches?

Most dust mulches are deliberately created in arid and semi-arid soils by repeat tillage of a thin layer of surface soil with the aim of creating a thin super-dry dust layer that interrupts the capillary rise of soil water to the surface from deeper (wetter) layers. The objective is to sacrifice a small amount of soil water near the surface in the interests of preserving a greater loss of water from deeper depths over time. The problem is how best to seed into this precious resource of stored water beneath the dust mulch.

The conventional approach has been to use tillage openers that sweep the dust aside, place the seeds in the deeper wet zone and then return the dust over the sown seed, all of which involves considerable soil movement. So long as the dust layer is not too thick, an alternative approach is to use Cross Slot no-tillage openers with long blades that will reach down through the dust and deposit the seed in the wet zone without sweeping the dust aside, even temporarily. There is a limit to how thick a dust layer the Cross Slot blades can reach through before at least some of it will need to be swept aside so as to get the seed into the wet zone. And because there is seldom any residue present, it is unlikely that the dust zone will contain enough vapour-phase soil water on its own to allow seeds to be placed directly in the dust zone and expect germination and emergence to take place. But testing is continuing.

45. Is Cross Slot no-tillage compatible with non-wetting sands?

Cross Slot openers are very well suited to non-wetting sands, provided that some surface residues are present. There are a variety of additives that are currently used to break the surface tension of non-wetting sands so as to allow infiltration of rain water or irrigation. It may be necessary to use one of these initially to get a cereal crop established in the first place. But once that crop has grown and been harvested Cross Slot no-tillage should do the rest. The secret is to value the crop residues even more highly than usual since retaining a mulch (or even a partial-mulch) on the soil surface is the best way of gradually (but permanently) reversing the non-wetting properties of these sands.

Over time, the problem will often disappear altogether with continued use of Cross Slot no-tillage and heavy-residue-producing crops. The absence of non-wetting problems under the heavy residues on undisturbed roadside soils illustrates what is possible.

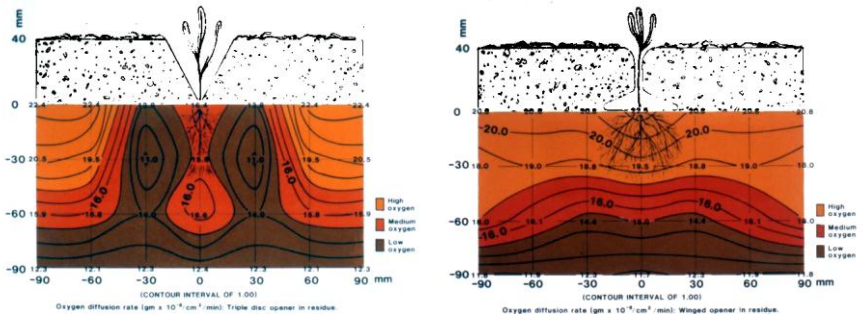
SLOT MICRO-ENVIRONMENT IN WET SOILS

46. Are there advantages of Cross Slot openers in wet soils?

Yes! They are equally tolerant of wet soils for entirely different reasons. And there are further advantages too (see below).

47. In what way are Cross Slot openers superior to other openers in wet soils?

Scientists have shown that when an inverted “T” (or horizontal) shaped slot is created in a wet soil, the placement of crop residue over the slot provides a ready source of food for earthworms, which actively colonise the slot zone. This in turn leads to an increased oxygen supply to the seeds because of their tunnelling. Further the tunnelling also increases the rate of infiltration of rain (or irrigation) water into deeper layers of the soil.



The brown colouration is low-oxygen soil
The red colouration is medium-oxygen soil
The orange colouration is high-oxygen soil

Double and triple disc openers create a compacted zone of low oxygen soil around the seed.

Cross Slot openers retain high oxygen soil close to the seed.

48. What opener types are worst in wet soils?

Double (or triple) disc type openers, because of their wedging action, produce sidewall compaction, which discourages earthworms from colonizing the slot zone. Further, by compacting the soil they exclude oxygen and push residue down into the slot allowing seeds to become lodged in this residue.

The latter problem is known as hairpinning (because the straw gets bent over like a hairpin) and is explained below.

HAIRPINNING AND SHADING BY RESIDUES

49. What is the disadvantage of seed becoming lodged in residue (a hairpin) that is pushed down into a no-tilled slot in a wet soil?

The residue decomposes and in so doing creates acetic acid, which burns the seeds or seedlings, thus reducing emergence counts.

50. Does this not happen with Cross Slot openers too?

The central disc of Cross Slot openers will push residue down into the vertical slit under certain circumstance. There is no known disc opener that does not do this. The difference though, is that with Cross Slot openers the seed is placed off to one side of the vertical slit on a horizontal shelf. Seeds are never in contact with the residue. The acetic acid that is produced by decomposition of the residue is very rapidly broken down itself by soil microbes. Even a small amount of physical separation (as little as 10 mm) between the residue and the seed is effective in preventing seed burn. Only Cross Slot openers achieve this.

With all other openers (including slanted discs that produce angled slots) the seed is deposited right into the residue that is tucked into the slot. So seed burn is inevitable in those circumstance when and if acetic acid is produced as a result of decomposition.

51. Are there any circumstances in which seed burn will not occur when residue is pushed into the slot of other openers?

Yes! When the soil is dry and the residue therefore does not readily decompose. But then the seed may be prevented from having good seed-soil contact because the residue insulates it from contact with the slot walls.

Even when such soils wet up, the hairpinned residues may absorb the moisture more quickly than the soil and begin decomposing about the same time the seeds are germinating.

So one way or another, unless the seed can be tucked off to one side of a slot created through heavy residue levels in no-tillage, it could be at risk in both dry and wet soils. The only time the risk does not exist with other openers is when soil moisture conditions are optimal and there is plenty of in-slot oxygen available, but no-one can guarantee that happening at any time, let alone all of the time.

52. Does that mean that in optimal soil conditions one would not expect to see major differences between Cross Slot and other no-tillage openers?

Sometimes, yes. But seedlings that emerge from Cross Slot slots, even in optimum conditions, are thought by seed physiologists to be advantaged because of the relatively small amount of energy they expend and the lack of stress they encounter in getting to the soil surface. The high-humidity of Cross Slot slots is thought to have an important effect in cocooning the seedlings in a favourable atmosphere prior to emergence, and thereby influencing crop yield potential even before the seedlings have emerged from the soil, even when plant counts between Cross Slot and other openers are the same due to favourable conditions. But then seedling emergence is only one part of the equation anyway.

53. Do surface residues cool the soil down?

Yes. This can be both an advantage and a disadvantage. It is good in the autumn when the soil is drying and the climate is hot because it reduces the surface temperature of the soil and protects the soil from drying. It also reduces diurnal (day and night) fluctuations. It can also be a disadvantage in spring because it slows down the rate at which the soil heats up again after a cold winter.

54. Does the shading effect in spring create problems for Cross Slot, which replaces the residues over the slot?

Yes and no. Certainly, by replacing residues over the slot, soil temperatures are likely to rise more slowly in spring. A common remedy, regardless of opener type, is to use row cleaners (or “residue managers”) ahead of the openers to scrape the residues to one side (or both sides) of the row. This can be done as effectively with Cross Slot openers as with any other openers. But by doing so you loose the benefits of residues as the cover over the slot, which is unique to Cross Slot. But since moisture is seldom limiting in spring this is of no major consequence.

On the other hand, because the control of Cross Slot seeding depth and moisture retention is so good, seeding with Cross Slot openers can often take place at shallower depths than with other openers. The soil temperature at, say, 25 mm seeding depth under residues (as for Cross Slot operating without residue managers) is likely to be little different from the soil temperature at, say, 40 mm operating with residue managers.

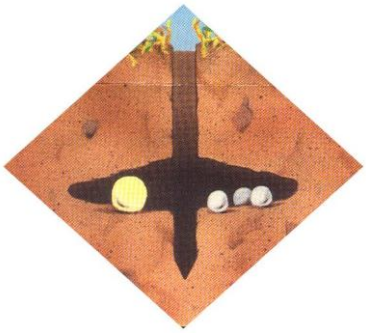
To some extent therefore, the “jury is still out” on this issue.

FERTILIZER PLACEMENT (BANDING)

55. What other things influence crop yield potential?

Another major determinant of crop yield is how well the plants are fed and this is influenced by fertilizer placement at the time of sowing.

In a survey of no-tillage experts in the USA in the early 1990’s, all agreed that the single most important feature they would like to see on no-tillage openers at that time, was the ability to place (band) fertilizer separately at the time of seeding. Cross Slot openers provide a facility in this respect that no other design has yet emulated, let alone surpassed.



Cross Slot openers are unique in their ability to band fertilizer horizontally with the same opener that sows the seed

56. Don't other no-tillage openers also provide the capability of separately banding fertilizer at the same time as seed?

Some do. With some designs two openers are married together so one places seed and the other bands fertilizer, but the combined opener occupies so much space that this seriously limits how close the sown rows can be to one another on a drill. In other cases manufacturers provide two rows of seed and every third row is for fertilizer alone (known as "skip row"). This has a negative effect on crop yield but is better than broadcasting the fertilizer instead.

In still other designs (mainly hoe or shank-type openers and sweeps) separate fertilizer banding is achieved by creating a large disturbed zone with a tine and splitting the flow of seed and fertilizer before they reach the ground. But the amount of soil disturbance such openers create largely negates their claim to being no-tillage openers. They also have only a limited ability to avoid blockage with surface residues, which further prevents them from being used repeatedly in a true no-tillage environment.

The photograph below shows the disturbance created by a typical shank-type opener. This much soil disturbance is more correctly described as minimum tillage, even although it has been caused by a seeding machine.

57. Is there anything else special about how Cross Slot openers band fertilizer?

Yes! Scientists in USA have shown that horizontal banding of seed and fertilizer under no-tillage produces superior crop yields compared with vertical banding. Cross Slot openers specialize in horizontal banding. But, in addition, by using optional short and long side blades on either side of the disc Cross Slot openers can also be made to produce diagonal (i.e. partly horizontal and partly vertical) banding for those who have come to believe that "deep banding" is the only way.

58. What is wrong with "deep banding" anyway?

One of the biggest mistakes no-tillage growers and machinery designers can make is to assume that what works in tillage will also work in no-tillage. Just because "deep banding" (placing fertilizer up to 75 mm or 3 inches below the seed) seemed to work in tillage does not mean it works in an untilled soil. In fact there is strong evidence that such is not the case.

59. How do we know that "deep banding" is not appropriate in no-tillage?

Because the US Department of Agriculture conducted extensive independent trials over a three year period comparing Cross Slot openers (horizontal banding of seed and fertilizer) with Yielder double disc openers ("deep banding" with vertical separation of seed and fertilizer in a skip-row configuration). In none of the seven separate experiments was the crop yield from the Yielder openers equal to (let alone superior to) that from Cross Slot openers. The average wheat yield advantage over 3 years in favour of Cross Slot openers was 13%.

Up until that time Yielder openers had produced the best crop yields of any no-tillage openers then available in the USA.

60. How far away from the seed is the horizontal band of fertilizer with Cross Slot openers?

Approximately 20 mm or ¾ inch.

61. Isn't that too close?

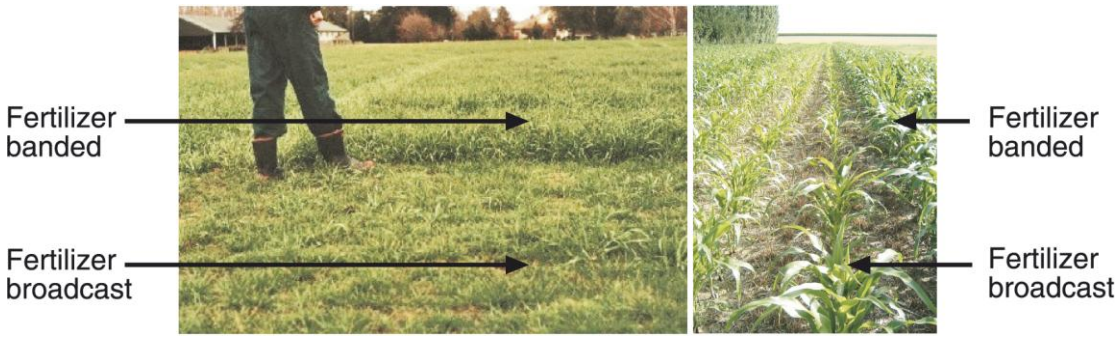
It is certainly closer than the deep banding that is recommended for tilled soils. But we are not dealing with tilled soils. We are dealing with untilled soils, which are different in many important ways. Scientists in Illinois, for example, showed that under no-tillage, corn yields started to decline for separation distances greater than 1 inch (25 mm) and after 2 inches (50 mm) the fertilizer had very little benefit at all.

They also showed that horizontal separation was superior to vertical separation in both avoiding seed "burn" and getting maximum yield responses.

62. Why can't farmers simply broadcast the fertilizer under no-tillage in the same way that they often do with tillage?

Because no-tilled soils behave differently than tilled soils when fertilizer is applied. Untilled soils contain earthworm and old root channels that the soluble nutrients run preferentially into, which means that much of the nutrients get diverted away from the small root zones of new plants sown in rows. In a tilled soil these channels are broken up by the tillage process and replaced by an evenly-dispersed artificial pore system. So fertilizer filters down more or less evenly in a tilled soil.

Thus it is more important to band fertilizer in no-tillage than in tillage. Very poor crop responses have been recorded from broadcasting fertilizer on the surface under no-tillage whereas good responses are commonly obtained doing the same thing on tilled soils. The differences have been greater in spring than autumn.



Typical differences with newly-sown pasture (left) and maize (right) attributable to banded fertilizer compared with broadcast fertilizer.

63. If this is so then how is it that pastures, for example, respond to broadcast fertilizer?

Because pastures contain a labyrinth of mature roots that intercept all fertilizer that is placed on the ground surface and is washed into the soil by rain, regardless of the presence or absence of earthworm and old root channels.

64. Given that you can place fertilizer in separate bands with Cross Slot openers, should growers be using more or less fertilizer when they no-till with these openers?

With phosphate, potassium, sulphur and micronutrients, use the same amounts that would be used in tillage. Feel confident about using micronutrients such as boron and elemental sulphur that can burn the seed if mixed with it. It will be separated from (and not burn) the seed with Cross Slot openers.

With nitrogen it is usual to increase the amount applied at sowing under no-tillage anyway, compared with tillage. This has nothing to do with opener design (except that it is not possible to apply any nitrogen at all with many other no-tillage openers). It is because under no-tillage generally, the soil microbes use a lot of nitrogen in decomposing the sprayed weeds and surface residues prior to seeding. This can result in the young crop becoming nitrogen deficient for a period. Banding nitrogen fertilizer at seeding overcomes the short-term deficiency, which ironically corrects itself later in the growth cycle anyway when the microbes themselves die and release the nitrogen again.

With tillage, nitrogen is mineralized by the tillage process, which (1) creates a convenient source of nitrogen for the young plants, but (2) is achieved by oxidizing some of the organic matter in the soil and eventually leads to reduced organic matter levels, which in turn leads to erosion and lower crop yields.

65. Other manufacturers claim to be able to band fertilizer with their openers (called "double shooting"). Is this just sales talk?

Sometimes yes! Other machines may be able to dispense fertilizer at the same time as seed but it is what happens to it in the soil that matters. Unless the openers are doubled up (as described above) some of this seed and fertilizer may become mixed together either before or as they enter the soil. Other openers (including Cross Slot) keep the two separate, including in the soil. This is called "double shooting". The tell-tale design difference is that if openers have separate product tubes for seed and fertilizer they will likely be capable of double shooting. But if they have only one tube going to the opener they will likely not be applying fertilizer at all or the two are being mixed together prior to entering the soil

A small amount of mixing is acceptable if the fertilizer rates are low and special slow-release forms are used (such as low rates of DAP), but normal fertilizer rates cannot be safely applied without the risk of "seed burn" by the fertilizer.

The mixing problem is exacerbated by the absence of loose soil in many no-tillage slots, compared with tillage. Loose soil otherwise dilutes the fertilizer somewhat. It is also worse in dry soils than wet soils because in dry soils the fertilizer-solutions (as they dissolve) remain more concentrated and create an osmotic effect that draws water away from the seed rather than allows water to enter the seed.

66. Does the fertilizer banding function of Cross Slot openers operate in all conditions?

Yes! One of the main features of the horizontal separation action is that it is equally effective in wet, dry and optimum soils and is unaffected by the presence or absence of surface residues or stones, and at forward speeds up to 10 miles/hour (16 kph).

67. Is the fertilizer banding function of Cross Slot openers limited to dry fertilizer?

No! Both ammonia as a gas and liquid fertilizers can be sown with Cross Slot openers at the same time as the seed with no detriment. In fact liquid or gaseous fertilizers can even be sown at the same time as dry fertilizers using Cross Slot openers.

To keep the wet or gaseous fertilizer from contacting the central disc (a wet disc is undesirable) the delivery tubes are angled away from the disc under the soil while dry fertilizer slides down beside the disc.

68. How about anhydrous ammonia application with Cross Slot openers?

The liquid application tubes on Cross Slot openers are small diameter (3/16" and ¼"). So long as a pressure of 30 psi can be maintained, the fertilizer will remain as a gas until it exits the tubes under the ground. No frosting of the tubes occurs and any frosting that occurs at the exit point of the tubes, is broken off by the soil passing by.

69. On the flip side of the gas and liquid issue, is there enough soil "throw" by Cross Slot openers to allow use of triflurolin herbicides?

This is largely self-regulating. When there is little residue present, there is appreciable soil throw by Cross Slot openers and this is also speed dependent. Certainly, experience has shown that there is enough soil throw for application of triflurolin herbicide.

Where more residues are present, there is less soil throw but the mulching effect of the residues reduces the weed burden anyway and the need for a pre-plant-soil-incorporated herbicide therefore decreases.

SLOT CLOSURE

70. What other functions are unique to Cross Slot openers?

Several. Another important function is controlling closure of the slot and also seeding depth. With Cross Slot openers both of these functions are undertaken simultaneously by the press wheels. They are located close to the seeding zone so they ensure the openers rise and fall (up to 45 cm or 18 inches if necessary) in harmony with changes in the soil surface.

But they also fold the soil flaps back over the seed so as to retain the integrity of a truly horizontal (inverted "T" shaped) slot with all of its advantages discussed above.

90%+ retention of residues with Cross Slot

71. What use are press wheels on no-tillage openers in general?

Tests comparing pressing on the top of the soil after covering, with pressing in the base of the slot before covering using hoe and double disc no-tillage openers showed a clear advantage for the latter. The only function that pressing after covering seemed to achieve was to control depth better than where no press wheels at all were used.

With Cross Slot openers, neither of the above pressing options had any effect. So long as the slot was covered, germination and emergence had been so good anyway that there was little if any room for improvement by pressing.

72. So why do Cross slot openers have press wheels?

Strictly speaking, they are not press wheels so much as folding wheels. Their two main purposes are (a) to fold the flaps of soil and residue back over the horizontal shelves on each side of the slot, and (b) to control seeding depth. Any pressing action is incidental.

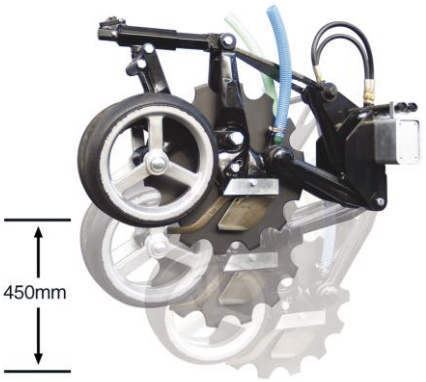
SEEDING DEPTH CONTROL

73. Do Cross Slot openers do anything special as far as depth of seeding is concerned?

Yes! A further unique function of Cross Slot openers is that the downforce is controlled very carefully. In this regard the designers of Cross Slot openers realised at an early stage that when springs are used to push openers into the ground the downforces alter as the springs lengthen and shorten. There is no way of completely overcoming this mechanical shortcoming.

The problem is exacerbated because no-tillage openers are required to travel up and down much more than openers used in tilled soils because tillage smooths the soil prior to drilling.

Cross Slot openers are therefore pushed into the ground with individual hydraulic cylinders that act against one another and are cushioned by a common source of compressed nitrogen. The main advantage is that the downforces remain the same regardless of the position of the opener. So engineers were able to design in an extraordinary amount of vertical travel (45 cm or 18 inches) for each opener, which no other known no-tillage opener achieves.



Each Cross Slot opener has 450 mm of vertical travel and maintains the same down force throughout the entire range

(← direction of travel of the opener)

An illustration of the extra-ordinary surface-following ability of Cross Slot openers through a hollow

74. Hydraulic cylinders on each opener sound very complicated and expensive.

They are neither. The hydraulic cylinders are also used to lift the openers off the ground for transportation, which eliminates the complication and expense of designing lifting mechanisms into frames and creates more space flexibility within a frame and facilitates close row spacing. Each Cross Slot opener is, in fact a self-contained modular unit requiring only to be connected to a tool bar of fixed height plus hydraulic, seed and fertilizer supply hoses.

75. Are there any other features of hydraulic downforce cylinders that are an advantage?

Yes! Because they are all connected to the same source of oil supply, when one opener rises almost inevitably another opener will be going down. Thus openers exchange oil between themselves most of the time, which means that the overall oil pressure does not change much as the machine proceeds. In any case the overall oil pressure can be changed by the operator on-the-move, which gives the operator continuous control over downforces in response to changes in soil hardness across a field.

Mechanical springs simply cannot do any of these things.

76. Does the system go further than that?

Yes! Individual hydraulic cylinders on all openers also allow the oil pressure (and thus the downforce) to be constantly monitored and altered. Cross Slot machines have an electronic monitoring system (called Auto-Downforce or ADF) that measures the force required to push the openers into the soil to a given depth. The system automatically adjusts this force as the soil gets harder or softer, as happens constantly across any no-tilled field.

If the soil gets harder, for example, the force required for correct penetration of the openers will increase. Conversely if the soil gets softer, the force required will decrease. With tilled soils, the tillage process itself ensures the penetration forces are lower and vary little across the field. So there is no need for any form of automatic downforce control in tilled soils.

But in no-tillage, without an ADF system, it is impossible to accurately maintain a consistent depth of seeding. Therefore, with less sophisticated technologies a certain amount of hit-and-miss occurs as far as seeding depth is concerned, and this usually gets worse the longer the field is under no-tillage.

The Cross Slot ADF system monitors the ground hardness 10 times a second and adjusts the hydraulic pressure three times a second on the move. This equates to readjusting the downforce pressure about every metre or yard of forward travel.

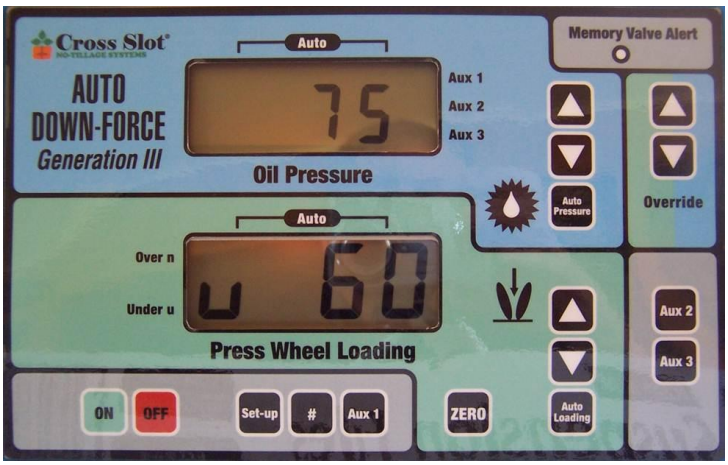
77. Does the operator have to rely on the automatic system alone?

No. The system can be over-ridden at any time.

In manual mode the system allows the operator to change the oil pressure manually on-the-move using the tractor's spool valves in the cab.

In automatic mode the control system tells the tractor hydraulic system to make the necessary alterations to the downforce pressure that the operator would have been making manually in manual mode. This removes yet another opportunity for operator error and is a major aid to helping maintain consistent seeding depth under no-tillage.

No other system achieves this degree of accuracy and automation.



A control unit for the Cross Slot automatic downforce (ADF) control system

78. The system sounds like it is electronically controlled. Is there a fail-safe back-up in case of failure of the electronics?

Yes! The operator can return to manual at any time, or in the case of electrical failure, manual is the default setting.

79. It sounds like a clever system. Does any other manufacturer have the same?

Yes, several other manufactures now offer a similar system but Cross Slot's system is the original system and was first disclosed in 1993, at least 13 years before any competing systems.

RESIDUE HANDLING

80. We are told that surface residues are an integral part of how a Cross Slot opener operates. Will it function in the absence of residues?

Without residues the function of retaining soil humidity suffers somewhat because it is the residues covering the soil flap that are responsible for retaining much of the soil humidity. But the sophisticated control of seeding depth, enhanced soil-seed contact, and fertilizer banding functions still give the opener a distinct advantage over other no-tillage openers.

81. Are Cross Slot openers of any advantage in tilled soils?

Yes! Their superior seed placement and closing functions together with fertilizer banding ensure they function very well in tilled seedbeds so long as the seedbed is firm. They do not function well in tilled seedbeds that are loose and fluffy. It is not suggested that operators who drill only tilled soils should equip themselves with Cross Slot openers. They are probably an “over-kill” for tilled soils.
On the other hand they have no disadvantages in firm tilled soils either, so they certainly suit operators who work in both tilled and untilled seedbeds with the same drill.

82. How well do Cross Slot openers handle heavy residues?

So long as the openers are functioning correctly it is virtually impossible to block them in heavy residues. They have a unique method of clearing residues while still retaining the ability to micro-manage those residues so they finish up back over the slot zone. They have no problem handling 10-15 tonne/hectare (140 bushel/acre) cereal crops, for example. They have even been known to pass unblocked along the bunched (unspread) windrow left by a combine when harvesting such a crop.

Cross Slot openers regularly cope with this much maize (left), grass (centre) and legume residue (right).

83. What is so special about how Cross Slot openers handle residues?

Cross Slot openers are believed to be the only openers in the world where the central disc remains vertical at all times and also travels straight ahead. With most other disc openers there are sometimes multiple discs involved and most are angled horizontally or vertically, or both. With these other openers, the disc(s) almost always perform dual functions - clearing residues and opening the seed slots. These two functions are often in conflict with one another. Adjusting the opener to optimise one function often compromises the other function and requires considerable skill on the part of the operator to keep them functioning properly.

By contrast, the disc on Cross Slot openers has one function only - handling residues. It is the two side blades that open horizontal seed and fertilizer slots. In order to ensure that the two side blades also clear residues, the front edge of each rubs on the two vertical faces of the disc (left and right hand). Because there are two side blades (one on each side of the disc) this also provides effective horizontal separation (banding) of seed and fertilizer, which is one of the most essential functions that a no-tillage opener can perform and which most other disc openers are simply incapable of achieving at all.

As if that is not enough, Cross Slot openers also micromanage the residues that it passes through.

84. What is meant by micro-managing the residues?

Most people know that residues spread over a field are one of the main attributes of no-tillage in general. This is macro-management of the residues. But most competing openers either push the residue aside at the slot zone or push a portion of it down into the slot where it contacts the seed, simply as a by-product of trying to handle it without blocking.

Cross Slot openers do neither. They raise it up with the soil flap and then replace it back where it came from after the seed is deposited, as a means of trapping soil humidity. Cross Slot openers use residues as an important tool in their superior biological functioning. This is micro-management of the residues. Other openers treat residues as an impediment to their functions. That is a key difference between Cross Slot openers and competing designs.

Operators must choose how much value they place on residues when choosing a no-tillage opener. With Cross Slot, the more residues the better (within reason) as thicker residues trap more moisture for longer than light residues.

85. We have heard Cross Slot's residue handling ability described as "low-disturbance". What is "ultra-low disturbance"?

It is when no disturbed soil at all is visible after passage of a set of openers. The photo below shows a 20 tonne/hectare wheat residue through which 5 Cross Slot openers have passed (indicated by the 5 arrows). This amount of residue was created by the unspread windrow behind a combine harvester that had harvested a normal 6 t/ha wheat crop. The audience at a demonstration in Ukraine wanted to know what the upper limit of residue was that Cross Slot openers could handle. So the operator drilled along the unspread windrow. Such a large amount of residue may be too much for some seedlings to emerge through and we would always recommend spreading the residues as evenly as possible over the field as a sensible management practice, but the demonstration answered the audience's question.

Of course if the operator had just allowed the discs to run along on top of the ground the result may have looked similar. You will just have to take our word for it that in this case the seed and fertilizer was sown perfectly beneath the residue.

86. Are there any residues that Cross Slot handles better or worse than others?

Not that we are aware of. It handles them all pretty much the same. For example it does not matter if the residues are long, cut and tangled or alternatively, short root-anchored stubble. Similarly, it deals with wet and stringy residues (including baling twine) about the same as it deals with crisp dry wheat straw. Nor is the height of standing residue an issue. It will handle standing maize (corn) without blocking, for example.

87. Does this have any implications for sowing on the rows of the previous crop, between the rows or across the rows?

Yes. Cross Slot openers can undertake any of those options equally well. Because Cross Slot openers are strongly directional (due to the disc always pointing straight ahead) operators can seed very close to an existing row if they choose, without the machine wandering away from the chosen path. Nutrients and root residues are concentrated in the old rows and utilizing them to advantage is often a choice that Cross Slot operators make.

88. What management implications does that have?

It means that the choice of row spacing need not be influenced by residue-clearance issues. There is no longer any need to choose wide rows simply to avoid blockages. Row spacing can then be chosen on the basis of what is agronomically best for the crop. Nor are their limitations about what crops can be grown (including cover crops) that have hitherto been dictated by the machine's ability to sow the next crop.

In short, it re-openers many otherwise-discarded agronomic and crop management options.

89. Isn't there a danger in some climates that continuously-retained residues will not break down fast enough before the next crop is harvested and therefore get thicker and thicker over time until they become unmanageable?

That was certainly a fear amongst some operators in cold climates. But in reality it has never happened in arable cropping. Certainly maize stover can take up to two years to fully decompose in cold winter climates but crop rotations take care of that problem by avoiding growing continuous maize. In other situations (with heavy (10-15 t/ha) small grained cereal residues, for example) the soil micro-organisms and fauna increase very rapidly with the change to Cross Slot no-tillage and this accelerates the decomposition process.

Thick residues create their own microclimate as a function of their thickness and continual wetness. This increases the temperature of the mass and further accelerates the decomposition process.

As an example of how the system balances itself, an experiment was carried out in New Zealand where 0, 5 and 11 tonnes per hectare of barley straw were spread on three fields of bare untilled ground in autumn. By the end of the three-month winter (where air temperatures seldom remained below 0^0C) all of the straw had disappeared, even on the 11 t/ha fields. Most interestingly, the weight of earthworms per hectare in each of the fields almost exactly equalled the weight of residues that had been placed on those fields, indicating that the earthworm numbers and biomass had responded directly to the amount of food available.

90. But does the system ever get overloaded?

We have seen layers of accumulated undecomposed organic matter in non-arable soils in the highlands of Scotland and New Zealand where daytime temperatures had remained low even in summer. Some of these soils still benefitted from no-tillage of improved pasture species. With Cross Slot drills the best method is to spray out the native grass species and no-till in one or more successive forage crops (usually forage brassicas) and feed them in situ to cattle so that hoof action and urine cycling will break up the mat of undecomposed sod before no-tilling a more permanent improved pasture species. Unlike most other no-tillage openers, Cross Slot openers relish these conditions because the side blade wings undercut the dying turf mat and use it as a perfect mulch cover for the sown seeds.

In other cases powered rotary-type openers have been used to chop up the mat at the same time as drilling takes place. But most tined or simple disc openers simply cannot cope with these conditions.

ENGINEERING DESIGN

91. It is one thing to have good biological design but what about engineering design?

Cross Slot openers and machines have a 10,000- 20,000 hour design life, which is similar to tractors. The designers of Cross Slot reasoned that if a farmer ends up owning only a tractor, sprayer and Cross Slot seeder (as many already do) it makes sense for the seeder to last as long as the tractor and the sprayer, both of which are likely to be designed with 10,000-20,000 hour lives. This is more particularly so with expensive no-tillage machines. The economics of owning a sophisticated no-tillage seeder make much more sense if the replacement period is 10+ years rather than 3 years.

92. But doesn't every manufacturer claim their machines are "robust and long-lasting"?

Unfortunately yes! But at successive No-Tillage Conferences it is clear that this is simply not the case in practice with most no-tillage machines. No-tillage machines have much larger stresses applied to them than conventional seeders because the soil has not been pre-loosened. Even some machines from reputable manufacturers are lasting less than three years because they have been designed more as enlarged versions of conventional machines than as specialist no-tillage machines. The shortest time we have known a rival no-tillage drill to wear out in was three months.

93. What wears out on other no-tillage machines?

Just about everything, but especially pivoting joints and bearings. Of course the soil-engaging components (shanks, discs, blades and scrapers) are expected to wear out anyway, but when the above-ground components of other openers become loose, openers become misaligned, row spacing suffers, residue handling suffers, seed placement suffers, different openers on the same machine behave differently, and downforce application becomes inconsistent.

94. Doesn't that favour designs with smaller numbers of moving parts?

Some people certainly argue that way. But since a disc is a moving part and handling heavy residues in narrow rows is not possible without a disc of some description, and no-tillage is all about retaining crop residues, there is a limit to the trade-off between simplicity and achieving biological reliability, erosion control, sustainability, and profitability.

Cross Slot places biological performance as the single most important issue and has designed innovative mechanical systems to ensure this remains so over an unusually long service life. This undoubtedly adds to the cost of Cross Slot machines, but we have yet to meet anyone who wants us to reduce either the longevity or biological reliability of Cross Slot machines.

95. How are Cross Slot machines different in relation to wear?

All major pivoting joints use pre-packed ball or roller bearings similar to how tractors (and cars) are constructed. Special triple-lipped seals running on stainless steel backing plates are employed that ensure bearings continue to stay clean even in the dustiest conditions. There are only three grease points per opener that require regular (and then only monthly) attention. All other pivots (including disc and press wheel axles) only require checking once per season.

Blades are tipped with tungsten carbide ensuring that their useful lives are comparable with other openers.

96. But the work done in one season for one operator might be very different from the work done by another operator?

True. Operators in New Zealand probably demand more from their equipment than operators in most other countries. Cross Slot seeders in New Zealand operate for up to 9 months of the year and invariably sow two or more crops per year. Much of this drilling in New Zealand is done on steep hillsides and fences surround all fields with relatively narrow (3.5 - 4.5 m wide) gateways. Most New Zealand no-tillage seeders and planters are therefore relatively narrow machines and drill more repeat rounds when sowing a given field than where wider machines can be utilized. They therefore travel substantial distances each year in drilling mode.

In Australia and North America it is common to get 5,000+ acres from a set of Cross Slot blades and about half this area from a set of Cross Slot discs.

97. What is the minimum row spacing of Cross Slot openers?

150 mm (6 inches) is common. Of course there is no upper limit to row spacing.

98. How does this compare with other machines?

There are several other no-tillage openers capable of operating at 150 mm (and even closer) spacing but none that apply fertilizer simultaneously with the seed. Most others that apply fertilizer have a minimum row spacing of 180 mm (7 inches) or wider because of the complexity of their designs, which consist mainly of two openers, joined together.

POWER REQUIREMENT

99. What tractor power is required to operate Cross Slot machines?

This is a commonly asked question. On flat-to gently rolling ground and light soils Cross Slot openers require about 7 -9 engine horsepower per opener. Hillsides and heavier land may require 8-12 hp per opener.

100. Is this power requirement affected by speed?

Yes. Not only is it reduced at slower speeds, it is often reduced (almost halved) with the time a given field has been under no-tillage.

101. We are told that no-tilled soils increase their abilities to stand vehicle and hoof traffic with time. If this is so, how can they become easier to drill with time too?

The easiest way to understand what happens is to imagine that the soil is like a lot of loose bricks. When they are scattered randomly you cannot walk across them because they move continuously. And if you were to pull a vertical tine through them it would meet little resistance as the bricks would part easily.

But if you then stacked them properly they will withstand enormous vertical loads without movement. But a vertical tine would still pass easily through them in a sideways direction because they would still part easily.

This is exactly what happens to the structural units of soil. They build themselves like well-fitting, but un-cemented bricks.

102. Even so, the power requirement for Cross Slot openers seems to be relatively high compared with the 5 hp per opener often quoted by other manufacturers.

The penalty is not as much as you might imagine because Cross Slot openers are usually (and in fact, thrive on being) pulled faster than most other openers (up to 16 km/hr or 10 mph) which consumes power. In any case, it is the price operators pay to get superior biological results, especially the certainty of reliable crop stands and the likelihood of superior crop yields. If an operator sees no-tillage only as a cheap option, then that operator will never achieve crop yields approaching what is possible with tillage or with Cross Slot no-tillage.

The process of tillage makes drilling the seed a relatively easy and cheap procedure. When tillage is eliminated, no tillage then becomes a very demanding operation. Nonetheless the total energy you put into sowing each hectare is much less under no-tillage (by about 75%) than under tillage. The problem is that it is all applied in one pass, compared with several passes with tillage. This means one large tractor has to be used with no-tillage. And no-one has yet found a way of achieving consistent success with no-tillage without using a sophisticated seeding machine.

103. But isn't this just sales talk?

The only way to see the value of Cross Slot machines in their true perspective is to talk with current owners. A survey of New Zealand owners was carried out in 2001. It covered some 40,000 hectares (100,000 acres) drilled with Cross Slot machines over a period of 4 years (8 seasons) in some 6,000 separate fields, sowing a very wide range of crop and pasture species into an equally wide range of soil and residue conditions. Operators were asked to rank the percentage of their crops that turned out equal to or above the district average yields, and those that were below district average yields. In the latter case they were also asked to identify the causes of impaired crops. There was no gain for operators answering in any way but honestly.

90% of crops had been at or above district average yields. Some crops topped national yields and many topped district yields.

9% of crops had been below district average yields due to poor management (inadequate weed or pest control, too early planting, driver error etc – i.e. non-drill problems).

1% of impaired crops were identified as machine problems, and one of those problems (tire tracks of drills causing seedling emergence problems) has already been eliminated.

In other words the Cross Slot machines proved to be 99% failsafe!

We are not aware of any comparable surveys of other no-tillage machines anywhere in the world, nor of the failsafeness of tillage itself, but we doubt if any would come up to this standard. Who, for example would claim that tillage has ever been 99% failsafe over the years?

104. Are you saying that in no-tillage, big and expensive is always better than small and cheaper?

No! There are examples of big and expensive no-tillage machines that turned out to have added very little to the failsafeness of no-tillage. And some smaller cheaper machines that achieved success in specific conditions. But it is hard to find operators of small cheap machines who are confident of achieving success all of the time with no-tillage machines.

We are saying that sophistication (not to be confused with size or complication) is always cost-effective.

105. Please explain the difference between sophistication and complication.

There have been no-tillage openers from reputable manufacturers that required up to 14 adjustments per opener to cope with different soil and residue conditions. Such openers required a high level of operator skill to be successful. There are also well-known no-tillage openers for which operators can buy some 13 different after-market attachments designed to improve their performance. These are examples of complication. Just read some of the questions on the Internet chat session sponsored by No-Tillage Farmer magazine (USA) for evidence of the knowledge and skills being exchanged between operators in this regard as they constantly seek to improve the performance of their machines.

Cross Slot no-tillage openers have only three adjustments, and one of these is made from the tractor cab and is automated anyway. The only adjustment usually needed when going from one soil condition to another is the downforce applied to the openers. No opener modifications are ever necessary to cope with different types or levels of surface residue, wet or dry. Seeding depth may have to be adjusted when going from one crop to another, but fertilizer and seed separation occurs regardless of soil or surface conditions or forward speed.

This is sophistication.

APPLICATIONS

106. Is there an argument regarding no-tillage machines for adopting the "horses for courses" approach?

Some people have argued that way. In the horse racing industry it is well known that certain horses run better on wet tracks and others are superior on dry tracks. And the same applies to some no-tillage machines – but it shouldn't.

Most farms contain several different soil types, especially with the trend towards amalgamation of farms. And in some cases these soil types may change their characteristics with moisture content. Some may even change with overnight rain. It is non-sensical therefore to expect a farmer to have several different no-tillage drills on hand to cope with the different conditions as they occur. In any case this would increase the capital expenditure and negate the purpose of buying a cheap drill in the first place.

It is better to invest in a single sophisticated machine that will handle all conditions, such as Cross Slot.

107. Can an operator really rely on a Cross Slot machine to be truly universal?

There are very few (if any) conditions that Cross Slot machines cannot cope with. That is partly why they have taken so long to develop. The designers and scientists needed to know that a farmer could truly rely on no-tillage full time with such a machine, which would ultimately give that operator the confidence to literally sell the plough and rely 100% on no-tillage.

Operators in 17 countries have done exactly that and never looked back.

108. What about stony soils?

Cross Slot openers cope very well with stones. They do not hook stones out of the soil as most tine or shank openers do. They ride over them. In fact they hammer orange-sized stones progressively deeper into the soil with each successive pass. They simply ride over larger stones and half-buried boulders, and because of their robustness, breakages are very rare indeed. In fact many farmers find they can bring stony soils into production much better with Cross Slot no-tillage than by any other means including tillage.

The central disc can be moved up (relative to the blades) in stony soils, making penetration in tightly packed stones easier than when the disc is lower.

Typical stony soils in which Cross Slot openers thrive. Note how in both cases the stones are already being hammered into the ground with successive passes of a Cross Slot drill. In the left hand photograph a Cross Slot machine has drilled across the immediate foreground, showing the hammering effect of even a single pass.

109. And sticky soils?

"Self-mulching" montmorillinite clays are the most difficult soils to deal with (in terms of stickiness when wet) but a special Cross Slot sticky soil blade is under development that is expected to extend the use of Cross Slot no-tillage to these sticky soils as well as virtually any other soil type.

110. And sandy soils?

Sandy soils are no problem at all. In fact, because Cross Slot retains the maximum amount of residues on the soil surface, such soils quickly gain organic matter and become increasingly productive under Cross Slot no-tillage. Dry surface soil does not fall into the slot (as with angled disc type openers) where it can otherwise interfere with germination.

Some sandy soils also become "non-wetting" and of course are highly erodible when dry. The best and fastest way to improve this situation is to maximize the amount of organic matter in the surface layers. This means retaining the maximum amount of crop residues, which in turn implies using openers that can handle such residues. Cross Slot has no equal in this respect and has already won environmental awards in several countries because of this.

A Cross Slot opener operating in pure beach sand (note the absence of inversion)

111. Why are Cross Slot openers harder to pull than other openers?

For three reasons:

Firstly, they do a lot more work on loosening the sub-surface soil in the root zone than other openers. Most other openers at best loosen the soil at the surface where it is not required to be loosened or simply do not loosen the soil at all. Some in fact compact the soil rather than loosen it.

Secondly, the way in which Cross Slot openers are designed to handle surface residues (by rubbing two blades on the side of the central disc) produces a disc-braking effect that creates drag. But since this function is fundamental to the superior residue handling and biological performance of these openers it is simply one of the costs that must be paid to get superior crops.

Thirdly because they can be (and often are) operated at greater speeds than other openers.

112. Are Cross Slot openers any harder to push into the soil than other openers?

It is easy to get that impression because Cross Slot openers are capable of applying downforces up to twice those of their competitors. But measurements have shown that a single Cross Slot opener requires about the same downforce to attain a given seeding depth as an equivalent diameter double disc opener. The difference is that Cross Slot openers will promote seedling emergence from soils that are far too dry to even contemplate sowing into with double disc and most other openers. Therefore Cross Slot openers get used in drier ground than other openers and thus require higher downforces to cope with this.

113. What is the range of downforces that Cross Slot openers can achieve?

0 to 500 kg (1,000 lbs) per opener.

114. Doesn't it require a very heavy drill to achieve 500kg downforce?

Yes but that amount of downforce is only required when the soil is very dry and hard. So many Cross Slot seeding machines are designed so that weight can be easily added and removed. Most have a basic weight of 300 kg per opener and this can be increased to 500 kg per opener when needed by adding ballast weights.

115. Can Cross Slot openers be attached to other no-tillage machines?

Yes, but some modifications of the basic frame may be necessary in order to get sufficient weight and strength into it to handle Cross Slot openers. This applies to drills, tool bars and planters.

ECONOMICS

116. Is it really economic to invest in a sophisticated (and no-doubt more expensive) no-tillage machine compared with cheaper alternatives?

Only if the more sophisticated machine gives you a better crop. Operators must put values on two things:

a. The cost of crop failure, or alternatively the cost of having to re-drill or re-plant a crop.

b. The cost of loosing 1%, 5%, 10%, 15% and 20% in crop yield.

With no-tillage, a change of mind-set is required to understand the economic implications of choosing between a sophisticated and a cheap seeder. Few operators of conventional drills think about the possible effects the seeder might have on crop yield because in conventionally tilled soils it is the tillage implements that affect yield not the drill.

But in no-tillage it is the seeding machine that has the biggest effect on crop yield.

Therefore operators need to start thinking about yield at the time of drilling. Then the advantages of a sophisticated machine like Cross Slot come into focus.

117. Can you give examples?

At current world prices for arable crops it is easy to compare the costs of operating a Cross Slot seeder versus a cheaper alternative and then to calculate how much change in crop yield you would need to get to make the cheaper alternative uneconomic.

It may be surprising (but nonetheless true) that you may only need a 1 - 3% difference in crop yield to make cheaper alternative drills uneconomic compared with Cross Slot, which has never been beaten on yield. Gains of up to 50% in crop yield from Cross Slot seeders have been recorded.

Even more surprising, is that even if the cost of operating an alternative seeding machine became zero (such as when a seeding machine is inherited for no cost) it would only take about a 5 - 8% reduction in yield from the zero-cost drill to make it uneconomic against a fully-paid-for Cross Slot drill.

118. That sounds incredible. How can I make such comparisons for myself?

We can supply a simple spread-sheet (on Microsoft Excel) that allows you to insert any figures you choose for the operating costs (of Cross Slot and competing drills) together with the expected returns from a given crop, the crop yield range of your choosing, and the currency of choice. It will calculate for you (the algorithms are shown so you can see how the calculations are done) how much crop yield difference you would need to get in order to make the cheaper drill uneconomic compared with Cross Slot.

The results will surprise you.

We are happy to email the spread sheet to any enquirer at no cost.

RISK ASSESSMENT

119. Doesn't all this boil down to risk assessment?

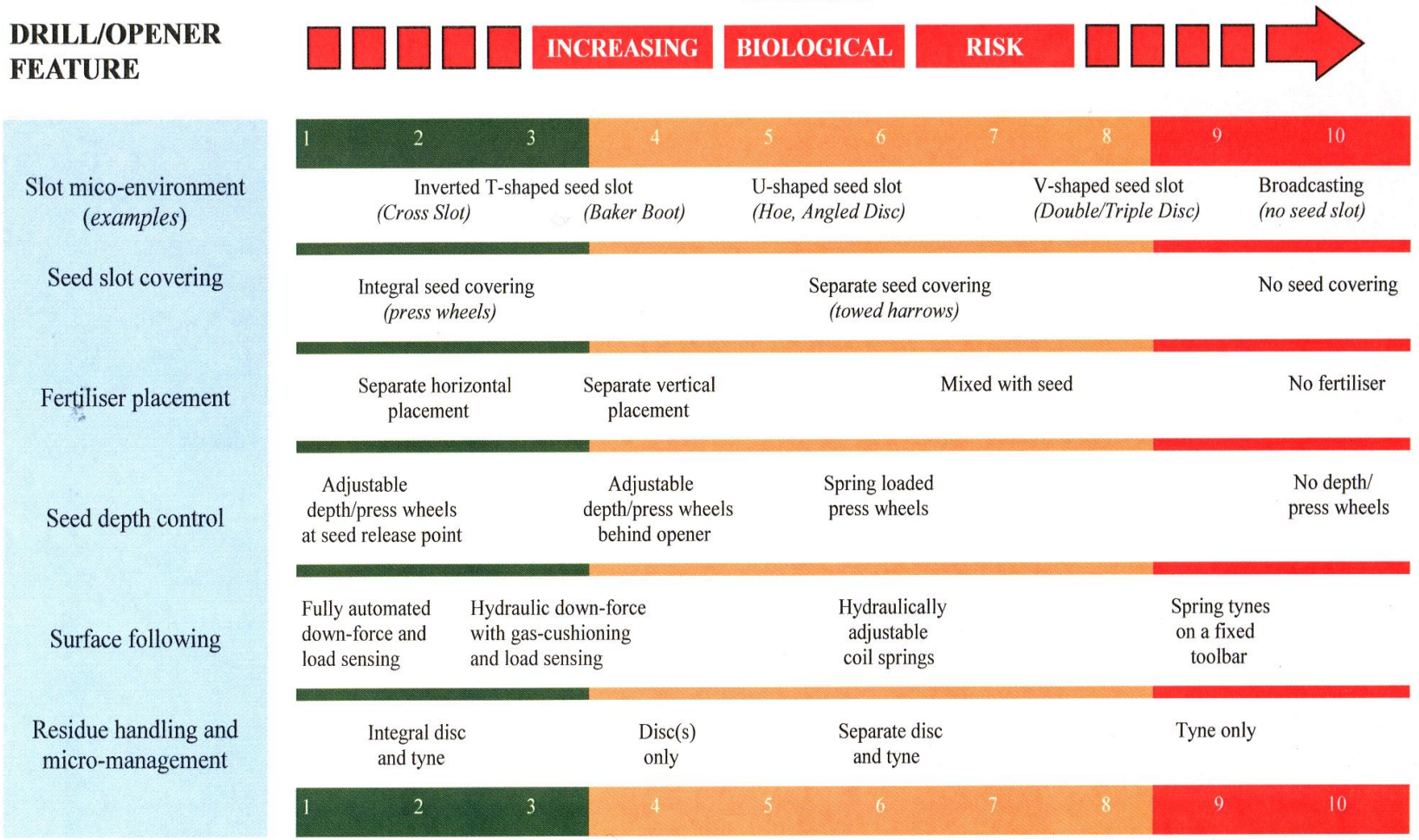
Yes it does. The saying "You pays your money and takes your chances" is never more easily demonstrated than with no-tillage. Put another way – lower risk systems almost invariably cost more than higher risk systems. What each operator must work out for themselves is how the cost of risks balances out against the cost of the inputs they are prepared to put into the system.

120. How does one do that?

We have compiled a risk-assessment chart (see below) which identifies the six most important drill or opener functions that determine the risks associated with the use of any one type of no-tillage drill or opener. It ascribes values (1 – 10) to the risks associated with using different mechanical designs to perform each of these six functions, according to published scientific data. 1 is low risk. 10 is high risk. When you add all of the risk values together and express this as a percentage of the maximum attainable (60) you get a percentage-risk figure. The highest possible risk is 60/60 or 100%. The lowest possible risk is 6/60 or 10%. There is no such thing as zero risk in agriculture.

The percentage risk figure is an estimate of how many times you would expect to see an impaired crop in every 100 no-tillage crops sown with the machine in question. The figures produced by this chart have proven to be remarkably similar to field experience, so their relevance is high.

A METHOD FOR RANKING NO-TILLAGE SEED DRILLS



How to use this chart: Assess each of the six drill/opener features listed down the left-hand side of the chart. Assign a score from the colour bars that relates to the option the drill or opener exhibits. A high total score indicates a higher level of risk. (Example: A hypothetical drill may have inverted-T openers (3), require towed harrows (6), have no fertiliser capability (10), no press/depth wheels (10), hydraulically adjustable coil springs (6) and separate disc and tyne (6) = Total 41/60

121. So how do some common machine types rank?

The table below lists some of the more common machine and opener types with risk assessments ascribed to them. The data are based on scientific experiments reported in the two books identified in Question 1. You may agree or disagree with them but unless you have actual scientific data that refutes them it would be unwise to change them markedly.

Examples of how some common no-tillage openers rank in terms of biological risk

	Disc version of winged opener	Vertical angled disc	Slanted angled disc	Shank & sweep openers	Vertical double disc	Simple winged tine
Slot micro-environment	1	4	4	3	7	2
Slot covering	1	3	2	2	7	4
Fertilizer placement	1	3	3	2	7	7
Seed depth control	2	1	1	9	3	8
Surface following	1	4	4	9	5	9
Residue handling	1	3	3	7	3	10
Total out of max. 60	**7**	**18**	**17**	**32**	**32**	**40**
% chance of impaired biological performance	**11%**	**30%**	**28%**	**53%**	**53%**	**67%**

Notes:

1. The “Simple winged tine” (known as “Baker Boot”) and “Disc version of winged opener” (Cross Slot®) were both invented by the authors and yet they find themselves at opposite ends of the risk assessment chart. In fact, the Cross Slot opener was invented to overcome the shortcomings of the “Baker Boot” opener since although the latter scored well for “Slot micro-environment” it scored poorly in most other respects.

2. The “Baker Boot” was designed to be used predominantly in smooth pasture. Comparing this opener with other openers designed for arable no-tillage penalizes it unfairly but it is nevertheless included here without bias to illustrate how the table exposes the limitations of such an opener when used for arable no-tillage.

3. The figures represent the chances of obtaining an impaired biological performance from using any of these openers. For example, the table suggests that use of Cross Slot openers will result in an 11% chance of a poor crop, whereas use of shank and sweep openers will result in a 53% chance of a poor crop unless there is little residue present and the fields are smooth and flat.

   Put another way , the table suggests that in heavy residues on less-than-smooth ground there would be about 5 times as much chance of getting an impaired crop using shank or sweep type openers compared with Cross Slot openers.

122. But what about functions that do not appear on the chart such as the ability to handle stones, sticky soils etc?

The six key functions that appear in the chart are things every no-tillage opener or machine has to cope with every time it is used, or at least most times it is used in the case of “residue handling”.

Table 2 lists some 29 desirable functions from 7 different no-tillage opener types that are ranked 1 -.5 according to how well each performs each function. In this table, it is clear that Cross Slot openers (“Combo winged tine & disc”) are far superior to any other type of openers in existence.

	TABLE 2: Comparisons of no-tillage opener types by function (1 = poor; 5 = excellent)	Narrow hoe	Wide hoe	Sweep	Double disc	Single disc	Slanted disc	Combo winged tine & disc
1	Ability to mechanically handle heavy residues without blockage	2	1	1	4	4	4	5
2	Leave 70+% of the original residues in place after passage of the rill	3	2	2	5	4	4	5
3	Minimize in-slot soil disturbance	4	2	1	5	4	3	5
4	Trap moisture vapour in the slot in dry soils using residues as slot cover	3	2	3	1	2	4	5
5	Avoid placing seeds in hairpins	5	5	5	1	2	2	5
6	Ability to maximize in-slot aeration in wet soils*	3	4	3	1	3	3	5
7	Avoid in-slot soil compaction or smearing in damp soils*	1	1	3	1	5	5	5
8	Maximize soil-seed contact, even in greasy ("plastic") conditions	4	3	4	3	3	4	5
9	Self-close the slots	2	1	3	2	3	4	5
10	Mitigate slot shrinkage when soils dry after drilling*	3	5	5	1	2	4	5
11	Ability of individual openers to faithfully follow ground surface variations	2	1	2	2	4	2	5
12	A greater-than-normal range of vertical opener travel of individual openers	2	1	1	2	2	1	5
13	Ability to maintain consistent downforce on openers throughout this range	3	1	1	2	3	3	5
14	Ability of openers to seed accurately a shallow depths*	2	1	1	2	2	1	5
15	Ability of opener downforce to auto-adjust to changing soil hardness	1	1	1	1	1	1	5
16	Simultaneously band fertilizer with (but separate from) the seed	5	5	5	1	2	3	5
17	Ensure fertilizer banding is effective with high analysis fertilizers	5	5	5	1	1	2	5
18	Ability to handle sticky soils*	5	5	4	1	3	3	2
19	Ability to handle stony soils*	4	3	1	4	4	2	4
20	Avoid bringing stones to the surface*	1	1	1	5	5	3	5
21	Functions are unaffected by hillsides*	5	5	4	5	2	1	5
22	Minimal adjustments required when moving between conditions	3	3	3	4	1	1	5
23	Ability to maintain most critical functions at high speeds	3	1	1	4	3	3	5
24	Wear components are self-adjusting	5	5	5	3	2	2	5
25	Design life of whole machine matches the tractors that pull it	4	4	4	2	2	2	5
26	Low wear rate of soil-engaging components	5	4	4	2	3	3	3
27	Wear components (including bearings) are cheap and easily replaced	5	5	4	2	2	2	4
28	Requires minimal draft from tractor	4	3	2	5	4	3	3
29	Proven positive impact on crop yield	3	2	2	1	3	4	5
	TOTAL SCORE	97	82	81	73	81	79	136
	SCORE AS A PERCENTAGE OF POSSIBLE (145)	**67**	**57**	**56**	**50**	**56**	**54**	**94**

123. Isn't no-tillage a short-cut and therefore operators must accept higher risks?

No-tillage could be looked on as a short-cut. But it is only when you attempt to shortcut the short cut that risks get out of control.

OPERATION

124. What is the maximum speed that Cross Slot machines can drill at?

Cross Slot openers will operate quite satisfactorily at up to 16 km/hr (10 mph). Such a speed is usually not comfortable for the operator so a lot of drilling is done at 12-14 km/hr. With planters, speed is usually limited by the maximum allowable speed of the seed metering devices (singulators) which is usually in the 8-10 km/hr range.

125. What are the advantages of going fast anyway?

A wide machine going slowly might drill or plant at the same rate as a smaller machine going fast. But the smaller machine will cost less even although both might use the same sized tractor.

On the other hand shank-type and angled disc-type no-tillage openers displace soil to the side. Speed has a profound effect on how these openers operate because the sideways-displacement action is very speed-dependent and generally limits how fast they can be driven. Some openers throw soil to one side only. With these, the speed effect is exacerbated on hillsides.

126. Can Cross Slot machines be used on steep hillsides?

The only limit to how steep a hill a Cross Slot drill can be operated on is the stability of the tractor and ability of the tractor to pull the heavy machine up and down hills. Generally it is better to pull Cross Slot drills across hillsides because they are heavy and require a lot of traction to pull them straight up a hill, for example.

We know of operators who use their Cross Slot drills on 52% (47 degree) slopes in the USA.

127. Is there any difference between how well Cross Slot openers work on gravity or air drills?

No! Cross Slot openers work just as well with both methods of seed dispensing.

128. 100. Is there a preferred method of seed dispensing?

Most Cross Slot drills operate with air seeders mounted on the drill frame or where separate air carts are towed behind Cross Slot tool bars. But gravity machines work just as well.

AVAILABLE MACHINES

129. What machines are Cross Slot openers available on?

Currently the following machines are available:

- **Rigid-frame end-wheel air drills** from 1.8 m (6') to 6 m (20') sowing width.

A 3 m (10') Cross Slot rigid-frame air drill. 3m seeding width and 3m transport width (note the folding front openers for transport).

A 3.6 m (12') Cross Slot rigid-frame air drill being loaded for delivery. 4,000L seed and fertiliser hoppers and on-board hydraulic crane for bulk-bag handling.

A 6 m (20') Cross Slot rigid-frame air drill operating in Alaska, USA.

- **Folding end-wheel air drills** from 4.5 m (15’) to 9 m (30’) sowing width.

A 4.5 m (15') folding Cross Slot air drill at 150mm (6") row spacing.
Seed and fertiliser hoppers with air delivery.
Mounted hydraulic crane for handling bulk bags and granule hopper and spreader.

A 6m (20') folding Cross Slot air drill during assembly. Row-spacing is 200mm (8").

A 7.5 m (24') folding Cross Slot air drill at 250mm (10") row spacing operating in Kansas, USA.

A 9m (30') folding Cross Slot drill operating in South Australia. Row-spacing is 300mm (12").

- **Wide line folding toolbar air seeders** from 9 m (30') to 18 m (60').

A 14 m (45') Cross Slot folding toolbar in North Dakota, USA with tow-behind commodity cart.

An 18 m (60') Cross Slot 5-plex folding toolbar with tow-between commodity cart.

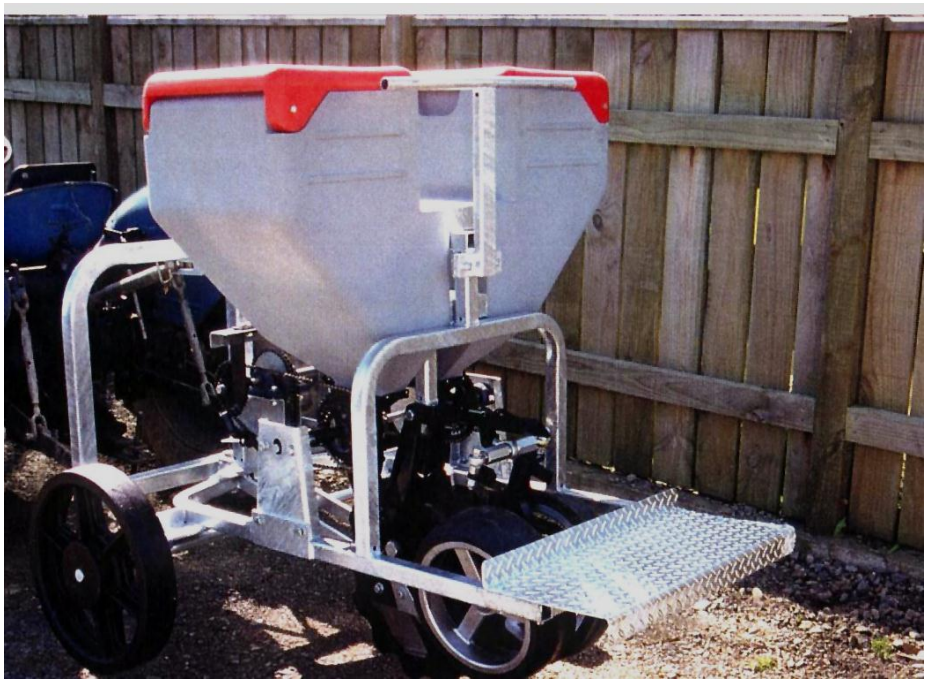
- Retrofit kits for attaching Cross Slot openers to existing toolbars.

A 30' Flexicoil 6000 toolbar retrofitted with Cross Slot openers in USA

- Precision planters for wide row crops.

A small 4-row prototype Cross Slot precision maize planter in New Zealand

- Single-row drills for animal power or small tractors.



A single row Cross Slot drill for animal or small tractor operation in China

The Benefits of Cross Slot® no-tillage

Compared with tillage and minimum-tillage:-

- Yield depressions are rare - even in the first year
- Yield increases are very likely - as new management skills are mastered
- Reduces fuel use - by 50-75% (25-50% compared with minimum tillage)
- Reduces labour - by up to 60%
- Reduces time in the tractor seat – by up to 50%
- Reduces costs - by up to 50%
- More hectares can be farmed with the same resources = more profit
- Alternatively, more time is available for management or leisure
- Machinery replacement and maintenance are less frequent
- Reduces soil erosion – wind and water
- Stones are not brought to the surface – they are progressively buried
- Equipment breakages in stony soils are rare – during tillage they are frequent
- Reduces soil moisture loss - each tillage operation can loose 12-25 mm of water
- Reduces irrigation frequency
- Capital cost is no more than tillage – but operating costs are much reduced.
- Builds soil organic matter – tillage depletes organic matter
- Reduces CO_2 emissions into the atmosphere by several fold
- Reduces soil compaction.
- Increases soil trafficability – machinery and stock.
- Enables earlier grazing of new pastures – from reduced treading and pulling damage.

Compared with other no-tillage options:-

- Features several world-first functions – simply not available elsewhere
- Is recognized as state-of-the-art by international authorities
- Creates horizontal slots – only known no-tillage opener to do so – all others are vertical
- Creates true low-disturbance no-tillage by replacing residues over the slot
- Harnesses both liquid and vapour soil water to ensure that emergence always take place
- Self-adjusts downforce to match soil hardness, thus maintaining seeding depth & cover
- Is virtually unblockable in most residues, even from the heaviest yielding crops
- Greatly reduces risks - biological, mechanical and financial
- Eliminates almost all hairpinning problems
- Bands fertilizer close to the seed – with virtually no risk of seed burn
- Outstanding yield responses are common – up to 50%
- Needs only a 1 - 4% yield response to justify its cost compared with cheaper options
- Is the result of 30 years of internationally-published scientific research
- NZ owners consistently report 95%+ success rates with crops and pastures
- Is designed in NZ, which has some of the most varied farming conditions in the world
- Was designed by identifying and eliminating the failings of other no-tillage machines
- Leaves stones buried – not all no-tillage drills do this
- Most functions are self-adjusting – low skill dependency
- Is deliberately robust – to handle rough and steep surfaces without breakage
- Operates well on slopes up to 45º
- Has a minimum 10,000 hour (10 year) design life (similar to tractors)

There are no short cuts to reducing risk - lower prices usually mean higher risks