WHY HI-TECH NO-TILLAGE IS INEVITABLE

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INTRODUCTION

The inevitability of hi-technology no-tillage arises from the uncertainty which still surrounds crop performance by the technique using existing equipment, together with the increasing (an unwelcome) trend towards complexity of drill and planter designs. While increasing numbers of farmers world-wide are reporting good and even outstanding results, these successes hide the failures which are still occurring. To be a sustainable technique the rate of failure for no-tillage farmers who can hold their hands on their hearts and say they have more predictable and successful emergence with no-tillage than they used to have with tillage, is still normal.

And yet that is exactly what no-tillage must do to be of short term benefit as well as to achieve its much-publicised benefits in the medium to longer terms. In the 15 year research program which underpinned the development of the Cross Slot™ no-tillage technologies in New Zealand, and to the consternation of early adopters, scientists insisted that they were more interested in seeing failed no-tillage fields than successes which the early-adopters were justifiably proud of. The scientists felt that only if they could identify why failures occurred and correct the underlying problem(s) could they truly claim to fully understand the requirements and limitations of no-tillage and therefore begin to design equipment which was anywhere near fail-safe.

Even at that time the concluded that hi-technology no-tillage would be necessary to minimise the risk factors from the technique.

PRESENT TRENDS

In North and South America, Australia, New Zealand and other temperate climates where residue-retention is synonymous with no-tillage (such is not the case in some countries of the world where crop residues are collected as a source of fuel) the most pressing drill and planter technological problems are condition-specific. The most common of these problems however, are unreliable germination and emergence, the need for separate fertiliser placement, avoiding residue hairpinning (or tucking), "instant" adaptability to a wide range of residues and soil conditions, inconsistent seeding depth, low speeds of operation and (at least in USA) the perceived difficulty of handling sod in anticipation of this being an option for expired CRP land.

None of these problems are new but most of the answers to them seem to have involved ever-increasing complexity of machine design. For example a recent survey of 12 sophisticated designs of no-tillage openers available in North and South America, showed that on average each opener assembly comprised 9 separate soil-engaging components for each row drilled or planted (range, 7-12) with up to 14 different adjustments on each of these to accommodate varying soil and residue conditions (C J Baker, unpublished data, 1994).

By contrast the Cross Slot™ hi-tech no-tillage opener has just 5 soil-engaging components per row and only 3 adjustments are necessary, one of which is controlled from the tractor cab anyway.

IN WHAT WAYS DOES HI-TECHNOLOGY CONTRIBUTE TO BETTER NO-TILLAGE?

No-tillage ins not a complex undertaking but it requires openers with incredible adaptability because, by definition, operators must forego the opportunity to manipulate the soil conditions through incremental tillage to optimise them for the critical operation of drilling or planting. The notion that there will always be an element of "horses for courses" amongst no-tillage openers and machines is simply not tenable. What use is it to a farmer if one machine suits his / her soil when it is dry and covered with cotton residue while another machine is best when it is wet and covered with wheat? Or worse, how does an operator cope with the necessity to stop and adjust the machine when passing from one soil type to another within the same field, or cope with the effects of an over-night shower or even in some cases dew? And what about the possibility of drilling into sod? In the "old days" almost all of these variables would have been nullified by tillage and burial or burning of residues, but not so under no-tillage.

In some cases the problem is self-perpetuating and cumulative. For example in many dry and / or low-organic matter soils no-tillage will increase yield levels, thus increasing the level of residue to be handled for the next crop which, if utilized correctly, will further optimise the conditions for even greater yield increases, and so on. Eventually it all levels off at a new sustainable yield level but in the process no-tillage will have made increasingly sophisticated demands on the machinery which was probably not anticipated at the outset.

In his keynote address to the 1994 World Congress of Soil Science, Nobel Prize winner Norman Borlaug reported the estimated current and projected world demand and yield requirements for cereals to be as follows (Table 1. Borlaug, 1994).

Table 1. Current and Projected World Cereal Production, Demand and Yield Requirements

	Current Production	Projected Demand		Yield		
				Actual	Required	
	1990	2000	2025	1990	2000	2025
	million tonnes	million tonnes		tonnes / hectare		
Wheat	600	740	1,200	2.2	2.6	4.0
Rice	520	640	1,030	2.2	2.9	4.8
Maize	480	620	1,070	3.3	3.7	5.3
Barley	180	220	350	2.2	2.4	3.7
Sorghum / millet	85	110	180	1.3	1.8	2.4
All Cereals	**1,970**	**2,450**	**3,970**	**2.2**	**2.6**	**4.2**

On this basis world cereal production alone (which accounts for 69% of world food supply) will need to be doubled by the year 2025 (and along the way, raised by 24% by the year 2000). More importantly however, to achieve this, taking account of the limits to creating new arable land, Borlaug estimated that grain yields will need to increase by 80% over the same time span.

Until now yield increases have come largely from increased fertilizer and pesticide use and genetic improvement to the species grown. *The challenge now is for no-tillage to contribute to the future increases*. But this is only going to happen if no-tillage is practised at the highest possible technology levels.

It has always seemed a nonsense that although the practice of no-tillage arms farmers with the greatest soil protection and rebuilding tool nature has ever devised in the form of surface residues, the majority of machinery designers have been content (or "forced") to treat this residue differently in the row zone than for the field as a whole.

In the row-zone no-tillage openers variously chop it up, bury it, push it into the slot, or sweep it aside for the mechanical expediency of solving a residue-handling problem (Baker and Choudhary, 1988). From this frustration the word "trash" developed indicating that surface residues were an unwanted commodity. But clear evidence has existed for many years that not only are surface residues the field's greatest ally but they are also the sown seed's greatest ally in controlling the germination and emergence micro-environment within the sown slot (Baker, 1976; Baker & Afzal, 1986; Baker & Mai, 1986; Baker *et al*, 1988; Choudhary & Baker, 1981; Lynch *et al*, 1992). No other resource, either man-made or provided by nature, comes anywhere near being as important and influential on germination and emergence as the micro-management of residue over, in or close to the sown rows.

This is where hi-technology equipment has its greatest potential - to eliminate the unwanted nature of trash and instead utilize its undoubted potential in all facets of crop agronomy - and in so doing, to raise the level of reliability of yields, and lower the risks commonly associated with no-tillage.

WHAT IS HI-TECHNOLOGY EQUIPMENT ANYWAY?

Since not all no-tillage drills or planters which are expensive or complicated can be considered hi-tech, it is important to establish the criteria which distinguish hi-tech from other drills and planters.

As a result of the 20 years of research in New Zealand and USA into the causes of no-tillage failures which was referred to above, a detailed list of requirements can be drawn up, most of which have the objective of providing optimal conditions for seeds, seedlings and growing plants regardless of the intervening weather or soil conditions or how difficult the consequential engineering designs might be. All of the criteria have arisen from specific scientific studies and / or extensive field experience, and can be shown to have had a measurable and positive biological effect. Most of these effects have been published in the international scientific literature and are described in detail in a forthcoming book by the author and colleagues (Baker *et al*, 1995).

1. The openers of a hi-tech drill should create seed slots which protect the seed (and just as importantly, the sub-surface seedlings) from desiccation (in dry soils) low oxygen status (in wet soils) and birds and other pests (in all soils). Realistically these demands can only be met by inverted-T shaped slots. This is the only slot shape developed especially for no-tillage (Baker, 1976) and has been shown to promote significantly more seedling emergence in soils which are otherwise hostile to seeds, seedlings or plants, than any other known no-tillage slot shape.

2. In creating seed slots the openers should avoid mixing and inverting the soil and residue in the slot zone. This is partly to avoid stimulating weed seed germination but most importantly a properly layered cover traps moisture vapour in the slot zone. The openers should be capable of re-layering loose or standing residue on top of loose soil to cover the slot, or fold back more structured (and even damp and "plastic") soils and sod or stubble layers, or re-layer a dry soil mulch on top of more damp soil beneath it where no residue exists.

3. The drill and openers must handle without blockage, any form of surface residue, even when the openers are configured in narrow (6 inch) rows. The range of residues should include dry and wet lying straw on hard or soft soils, fibrous and woody stalks as well as crisp brittle material, and at concentrations of up to 10 tons per acre.

4. The openers must either avoid hairpinning (tucking) the residue into the slot or they must separate the seed from contact with such hairpinned residue.

5. The openers must not compact or smear the slot in such a way as to restrict root growth. If smearing is unavoidable (as is often the case) the opener must create the slot in such a way that the internal surfaces of the slot do not dry to form an internal crust.

6. The slot shape should avoid the creation of near-vertical walls in the root zone which restrict root exploration outside of the slot especially when such walls are also smeared or locally compacted.

7. Each opener must close the slot as it travels rather than rely on slot closure being achieved by a separate machine and / or operation.

8. Each opener must effectively separate the seed from the fertilizer in the slot so that the two do not contact one another to avoid toxicity effects but are so placed as to maximise utilization of the nutrients by the growing plant. Horizontal, vertical and diagonal separation are all acceptable but greater distances are required for vertical separation than for horizontal separation.

9. Each opener must be capable of faithfully following ground surface variations as large as 500 mm (20 inches) and to sow seed at a consistent depth throughout this range of travel.

10. In order to assist the openers in maintaining a consistent depth the drill design must be capable of reducing the bounce of the whole machine to a minimum as it travels at speed over uneven terrain.

11. The machine must be capable of storing, metering and delivering seed, fertilizer and pesticides to the openers in the manner which is most appropriate for each crop.

12. The machine must be capable of performing all of these functions without compromise at speeds up to 16 kph (10 mph).

13. General maintenance and especially the replacement of soil-engaging components should be rapid and inexpensive.

14. As many as possible of the functions of the machine and its openers should be self-adjusting and unaffected by wear and changing soil and residue conditions. There should be a minimum of adjustments necessary when changing from one soil or residue conditions to another.

15. The machine should be robust and durable with a design life of at least 10,000 hours.

SUMMARY AND CONCLUSIONS

There has never been a stronger case hi-technology no-tillage machines. The fact that they were not available from the outset of this still-relatively-new farm practice 30 years ago, is understandable since it has taken at least 15 years to establish what those criteria should be let alone design and solve all of the engineering problems too. It is also commendable that the no-tillage industry has expanded without the benefit of hi-technology. In doing so however, it has yet to convince the majority of drill and planter purchasers in any country that no-tillage is truly cost-effective, sustainable and "fail-safe".

The inevitability of hi-tech machines was signalled early in the evolution of no-tillage when the no-tillage industry embraced the then more expensive but broader-spectrum (some would say higher-technology) herbicide glyphosate in preference to the more limited-spectrum but then cheaper herbicide paraquat. Machinery adoption will surely follow the same trend as herbicide adoption on a cost-benefit basis since in no-tillage herbicides play a role of similar importance to drills and planters.

Until recently no readily available commercial machine had fulfilled all of the criteria for hi-technology. One, at least (the Cross Slot™) is "in the pipeline". It is time now to move on the next phase in development of international, sustainable and "fail-safe" no-tillage practices and machines.

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