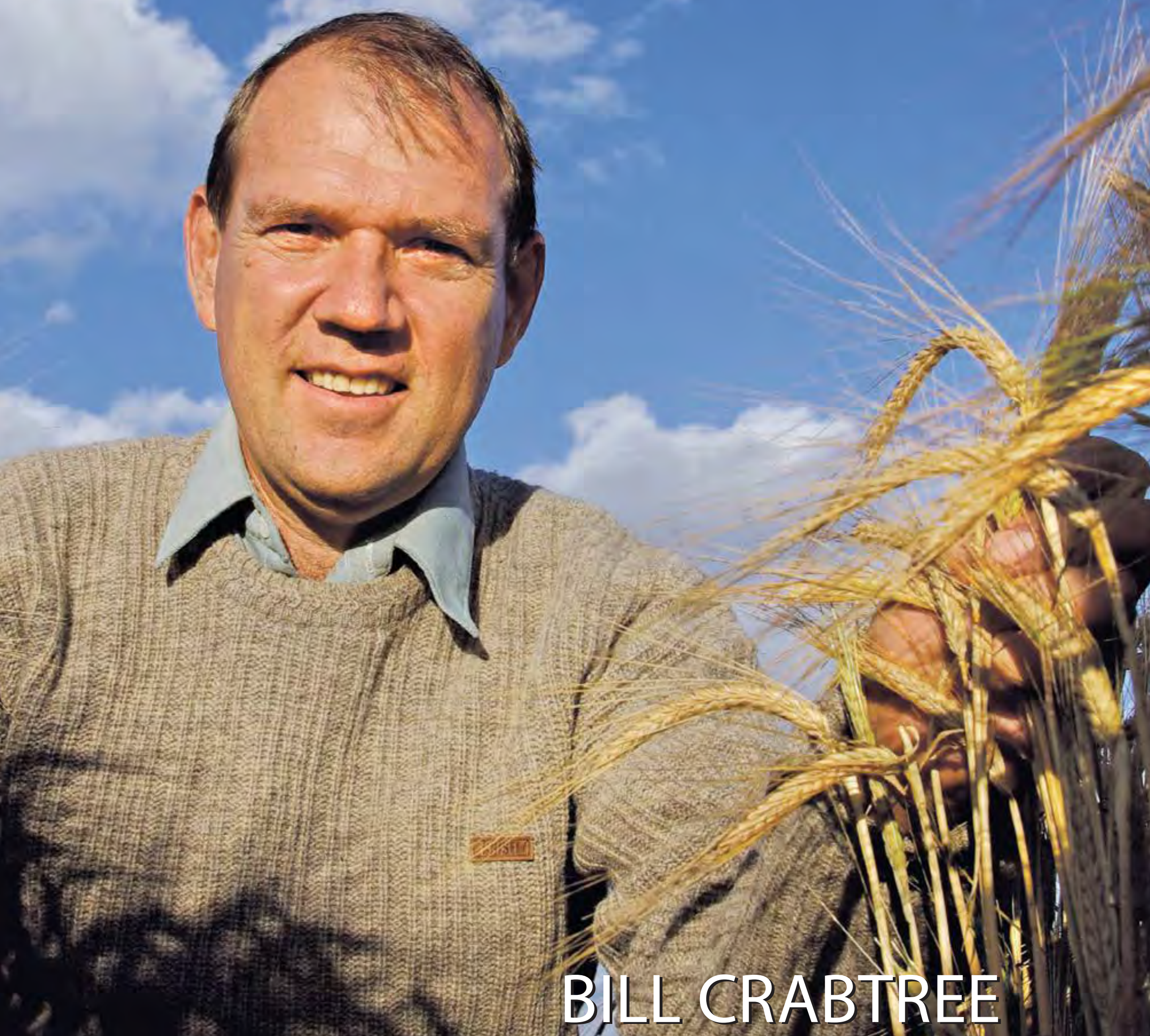
# SEARCH *for* SUSTAINABILITY

## *with* No-Till Bill

### IN DRYLAND AGRICULTURE



BILL CRABTREE

www.no-till.com.au

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**Search for sustainability with No-Till Bill in dryland agrIculture**

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- Individual WA Landcarer Achiever in 1996
- Honorary WANTFA Life Member, 2003
- Seed of Light Award, GRDC Western Panel, 2006
- McKell Medal, 2009

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I would like to recognise here the generous and loving support that I have received from my patient wife Monique and our four dear children; Jonathan, Brianna, James and Samuel. All have travelled with me often and have put up with my constant desire to understand and improve agriculture and to help make it more sustainable.

Thanks to those who have journeyed with me—in particular Geoffrey Marshall, Kevin Bligh, Ray Harrington and Ken deGrussa. Also thanks to WANTFA and the WA Department of Agriculture who allowed me to explore various aspects of no-till, as well as GRDC and the National Soil Conservation Program who have supported much of the sustainability exploration.

**Disclaimer**

Mention of any trade names does not imply endorsement or preference of any company's product by the author or publisher, and omission of trade names is unintentional. Please note that examples and results given may differ due to regional, environmental and ecological factors. Farmers are encouraged to seek professional advice before implementing ideas contained in the book.

Opinions expressed are sometimes speculative for the purpose of stimulating thought and should not be considered gospel.

# Contents

# Preface

**THIS BOOK,** *Search for Sustainability with No-Till Bill in Dryland Agriculture*, has several valuable and unique features. It is perhaps the only book looking at no-till in truly dry Mediterranean conditions, namely the rainfed cropping environment of the south-western corner of the state of Western Australia (WA) where annual rainfall in the wheat zone ranges from 275 to 500 mm. The closest match would be no-till rainfed cropping in the Great Plains or the Pacific North West of North America, but mostly cropping there relies heavily on soil moisture stored during a prior fallow period. In WA, summers are mostly hot and dry, and cropping is in the cooler, wetter winter-spring. Water is almost always scarce, although sometimes there are opportunities for storage of moisture from autumn rain ahead of seeding; crops almost always finish under hot dry conditions in the late spring, while sometimes flowering is hit by late frost.

Some may quibble that direct seeding with knife points is not true zero-till, but it amounts to a dramatic reduction in soil disturbance relative to conventional tillage and, when combined with residue retention, a huge improvement in soil sustainability for the farmers who practice it. WA topsoils are generally light textured and low in native fertility, hence very susceptible to wind erosion. All this partly explains the unique rate and extent of adoption of zero-till in WA over the last 20 years. However a big role was also played by short-term economic factors such as the earlier seeding and fuel and time savings associated with zero-till, for WA farmers are probably the largest and most efficient family farmers in the world. The average cropped area per farm is currently several thousand hectares. As elsewhere, farmer self-help groups and their advisers like No-Till Bill played a big role in no-till adoption.

Zero-till in WA has not been without problems, the most unique being the upsurge in herbicide tolerant weeds, like annual ryegrass *(Lolium rigidum)*. Other special challenges have been non-wetting soils, hard pans, changed pest and disease incidences, maintaining enough crop residue, and the integration of zero-till with grazing livestock, often a significant business on wheat farms in WA. All the above aspects of no-till and more are covered in this short and focussed book. This is aided by a host of truly excellent pictures and diagrams illustrating the text. WA experience dominates but examples are included from elsewhere in Australia and from South and North America.

The author is from a wheat farming district in WA, and has a unique background in farming, agricultural science, hands-on no-till research—mostly with farmers—and no-till extension. He has assisted the establishment of No-Till farmer groups in the states of South Australia and Victoria. He has been recognised for his effective extension work, with awards of the WA Individual Landcarer of the Year (2005) and the GRDC Seed of Light (2006). Yes, No-Till Bill is an advocate and champion for no-till, and the world needs more enthusiasts like him. The book should be of great interest to farmers and advisors alike, and an important challenge to sceptical scientists, especially those in other Mediterranean regions of the world.

**Tony Fischer**, Ph D, FAIAST, FSTE, AM

Canberra
April 2009

'For the fragile, infertile and shallow soils of southern Western Australia, something had to change in the way we have been farming…'

CHAPTER 1:

# The search for sustainable agriculture

**WELCOME** to an exciting journey in agriculture—a journey of searching for answers—a search for sustainable agriculture! And we certainly need to take this journey! For the fragile, infertile and shallow soils of southern Western Australia, something had to change in the way we have been farming. We used to lose large amounts of our soils every year to wind erosion. Necessity is the mother of invention they say and, fortunately for us, glyphosate became available in the early 1980's to help us embark on a journey of reduced tillage.

This is my story and also the story of thousands of my fellow farmers across Western Australia, and indeed Australia, as we seek ways to grow crops in a sustainable way. We have, and continue to, face challenges of all sorts: practical challenges, philosophical challenges, financial challenges, technical challenges and emotional challenges. They say change produces friction and action creates reaction. This is a story of all these issues. The journey is on-going and evolving, but, so far, it has been highly profitable and incredibly entertaining. If we had not embraced no-till farming our regional towns would have suffered severely during the recent string of dry years and low grain prices of the early 2000's.

Civilizations started growing crops about 6000 years ago—and created soil erosion as a result. In more recent times, my mother recalls the enormous dust storms of the 1930's that regularly blackened the afternoon sky on her way home from school to her parents farm in the Victorian mallee—similar to the North American dust bowl experience, also in the 1930's. Blowing sand invaded every space of their humble farming homestead. It was considered a normal part of farming life.

Then it was my turn. In 1972, on the south coast of Western Australia at the age of 12, I recall riding on the school bus from Gairdner to Jerramungup, and seeing paddocks blowing away. I remember thinking 'there must be a better way to farm than this'. Ploughing was an important part of agriculture and soil erosion was its annual companion. How else were farmers to kill weeds and grow crops?

My brother Geoff stacks bags of wheat in the early days of agriculture at our Gairdner family farm.

My older brothers Geoff (left) and Tim are ploughing and raking new land.

Bare ground and ploughed paddocks exposed the soil to severe soil erosion.

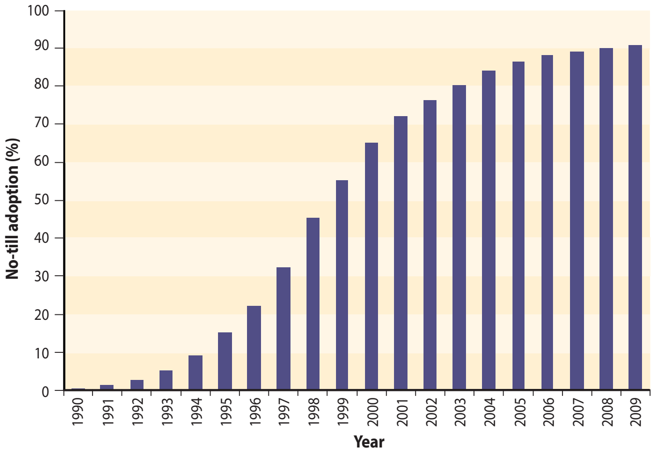
It was not until about 1970 that Spray.Seed® (a 50:50 mix of reglone and gramoxone), was developed as the first broad-spectrum herbicide. Many more herbicides became available soon after. The most powerful one, Roundup®, (glyphosate) was sold in Australia from 1982. This herbicide is unique in its molecular simplicity and broad-spectrum herbicidal nature. The ability to control weeds with chemicals rather than ploughs paved the way for initial research into no-tillage and its early adoption.

The no-tillage system requires weeds to be sprayed with herbicides and crops to be sown with little soil disturbance. Seed and fertiliser are placed into narrow slots made by openers. This technique means the soil is not inverted or greatly disrupted—except for within the narrow slots. By popular definition no-tillage is defined as the amount of topsoil (the top 10 cm) disturbed is less than 20%.

With no-tillage farming most organic matter can be left on the soil surface. Although there are some challenges to leaving organic material on the surface it also provides many benefits. Organic matter acts as an insulator to reduce evaporation, it improves biological soil fertility and acts as a shield to protect the soil from rain drop impact—an important asset in heavy soils. Therefore soil erosion can be almost completely eliminated with the use of no-tillage and organic matter retention cropping systems.

In 2009 the level of adoption of no-tillage in Western Australia (WA) was approximately 90% of the cropped land. This puts WA amongst the highest level of no-tillage adoption anywhere in the world. This proportion would be similar to some regions of South America (Rolf Derpsch, *pers. comm.*) and Canada, and much greater than in most other dryland cropping systems around the world. The acceptance of no-tillage has been greatly aided by self-help farmer groups.

**Crabtree's estimated adoption of no-tillage in Western Australia**



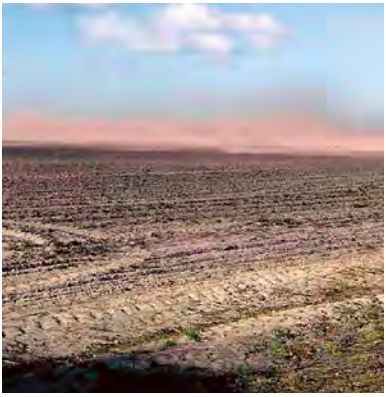

Government agencies have been of both assistance and a hindrance to no-tillage adoption. No-tillage adoption was a matter of necessity for WA soils. These WA soils are the oldest, most weathered and infertile soils anywhere in the world (Prof R.J. Gilkes, *pers. comm.*). Many of these soils have sandy surfaces, often containing little clay (only 1–3%), few nutrients and very low organic matter levels (<1% organic carbon).

WA desperately needed a sustainable way to farm. Food is needed worldwide and WA had become known as an efficient farming region. Now it has become known as an efficient and sustainable farming region due to its widespread adoption of no-tillage systems.

The purpose of this book is to share our exciting no-tillage journey in the hope that it might encourage others to adopt no-tillage or further refine it for local conditions. In rural areas that are new to no-tillage it is common to hear people say 'it won't work here'. However, once people give it a try they are usually pleasantly surprised. Hopefully, there is also some useful material here for the experienced no-tiller and students of sustainable agriculture.

RIGHT: Esperance farmers in 1991 share keenly with each other what they are learning as they adopt no-tillage amid continuous comments of caution.

FAR RIGHT: An Esperance dust storm caused by just one tillage.



Global warming forecasts, if indeed accurate, suggest that the drier parts of the world will become drier, and the wetter parts wetter…

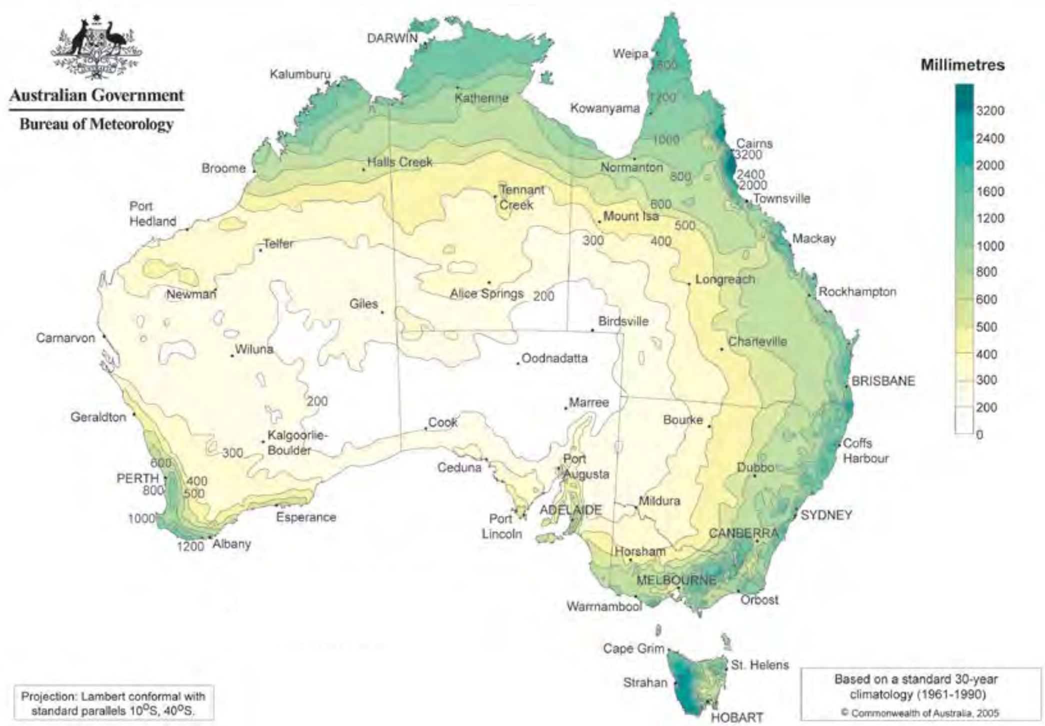
CHAPTER 2:

# Background to Australian agriculture

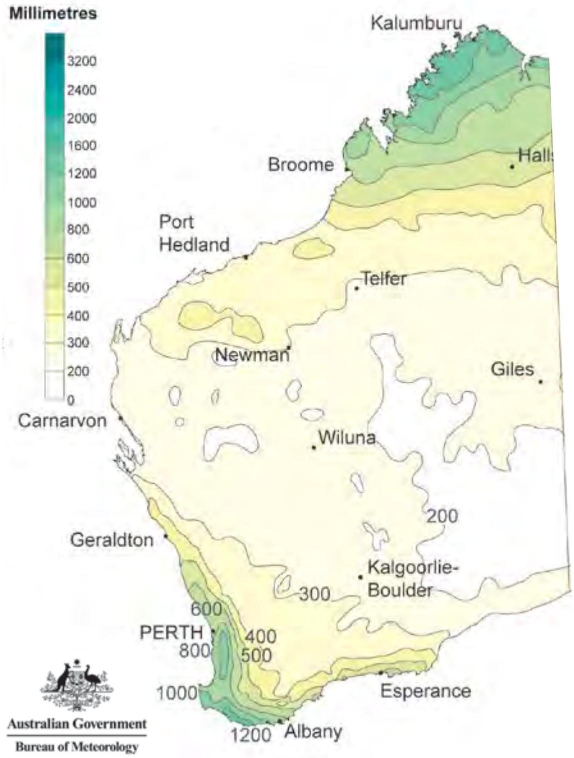
## 2.1 Australia is 80% desert

Australia is one of the driest continents on Earth. South Australia and Western Australia are its driest states and this is where a majority of broadacre agriculture takes place. Global warming forecasts, if indeed true, suggest that the drier parts of the world will become drier, and the wetter parts wetter.

**Average annual rainfall (mm) for Australia**



**Average rainfall (mm) for Western Australia**




Wise use of all available soil moisture is imperative for long term viability in these states, but also elsewhere. No-till is the key to utilising this water resource efficiently.

The northern half of Australia has a summer-dominated rainfall pattern suited to growing mostly summer crops. The southern half experiences cool, wet winters suited to winter crops. Southern winter daily temperatures typically range from 3–17°C (less in southern Tasmania or high altitude areas). Wheat, barley, oats, triticale, lupins, canola, faba beans, lentils, field peas and chickpeas are all part of agriculture in the southern states at present.

## 2.2 Western Australian agriculture is young

Agriculture began in WA in the 1830's in the slightly fertile river flats and valleys. However, it was not until the discovery of trace element deficiencies of copper and zinc that significant agricultural expansion occurred in the early 1950's. The sandy-surfaced soils could not support even modest crop or pasture growth without these trace elements.

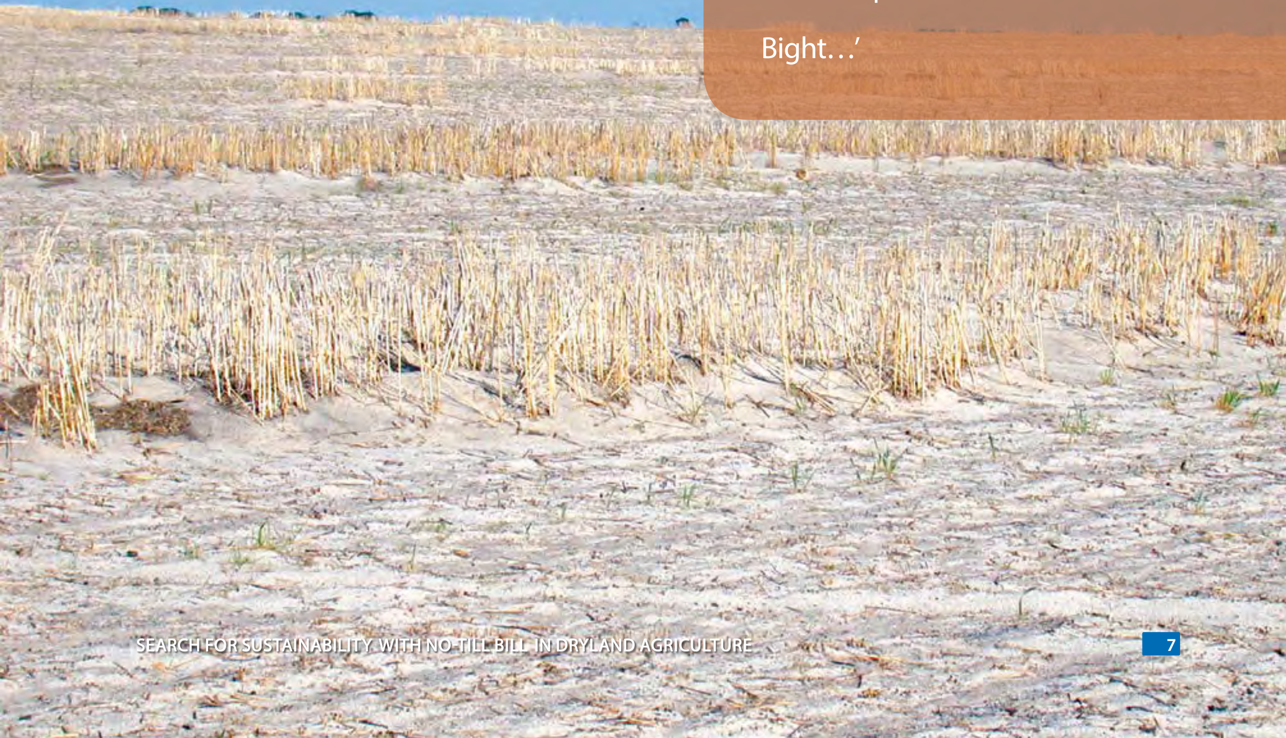
During the 1960s the state government 'opened up' new land at 1 million acres a year for 10 years (400,000 ha/yr). The soil was mostly acidic and very infertile: it typically contained 3 mgP/kg of soil (phosphorus), 0.3–0.8% organic carbon, a pH of 5–6 ($CaCl_2$) and 1–8% clay. The application of trace elements (copper, molybdenum and zinc), macro elements, P (phosphorus), K (potassium) and S (sulphur), and the introduction of legumes (producing N [nitrogen]) into the agricultural system have greatly increased the fertility of WA soils. However, this is not without some environmental cost.

Sadly, soil degradation has followed the development of our agricultural system. This book focuses on the development and knowledge required for the adoption of no-tillage, without which soil erosion threatened to irreversibly place our soil in the ocean depths of the Great Australian Bight!

ABOVE: A summer dust storm in the central WA wheatbelt. Such storms march across the land and are started by softened soil without residue cover and strong winds.
PHOTOGRAPH BY TERESA MORASY.

BELOW: Soil erosion near Esperance.

‘Soil erosion threatened to irreversibly place our soil in the ocean depths of the Great Australian Bight…’



'No-tillage—knife point or disc seeding with less than 20% topsoil disturbance…'

CHAPTER 3:

# Definitions—what is no-tillage?

**NO-TILL** is defined by the author as sowing without prior cultivation while disturbing less than 20% of the topsoil. There are many tillage terms—however I believe the main and/or useful ones are:

- **multiple tillage**—two or more tillages before seeding (replaces the term 'conventional tillage');
- **reduced tillage**—one pass of full soil disturbance prior to seeding;
- **direct drilling**—one pass seeding with a full-cut or greater than 20% topsoil disturbance;
- **no-tillage**—knife point or disc seeding with 5–20% topsoil disturbance; and
- **zero-tillage**—disc seeding without soil throw (but note that some discs do throw soil).

A combination of discs and knives can offer the strengths of both systems.

Väderstad Seed Hawk® shows strong emergence (left) compared to a disc seeder at Esperance (right) at Coomalbidgup in 2007.

From an agronomic point of view each system has different implications. Water harvesting, soil firmness, nutrient mineralisation, herbicide efficacy, crop safety, soil drying, stubble handling, fertiliser placement, diseases and insects all react differently to tillage or lack of it. From a farmer's point of view they also affect horsepower requirements, cost of the seeder, paddock trafficability, ability to chase moisture, soil stability and timeliness of sowing.

Obviously none of these tillage terms are perfect. Factors such as wider row spacings and the presence of harrows also change the amount of soil disturbance. No-till sowing of pulse crops, with knife points, on wide rows, may throw less soil than a disc zero-till operation. Heavy harrows can move significant amounts of topsoil and fill in the furrows.

There is also the confusing term of 'minimum tillage'. It has a different definition in all regions of Australia and indeed globally. This term in WA has traditionally meant one working before seeding, the same as reduced tillage. Nowadays the minimum tillage term has become less specific. The term is probably best used as an umbrella to all the other 'less tillage systems'. The term 'conservation tillage' is possibly in a similar category as minimum tillage, although it is usually linked to the idea of farmers attempting to retain significant levels of stubble with a range of minimum tillage techniques.

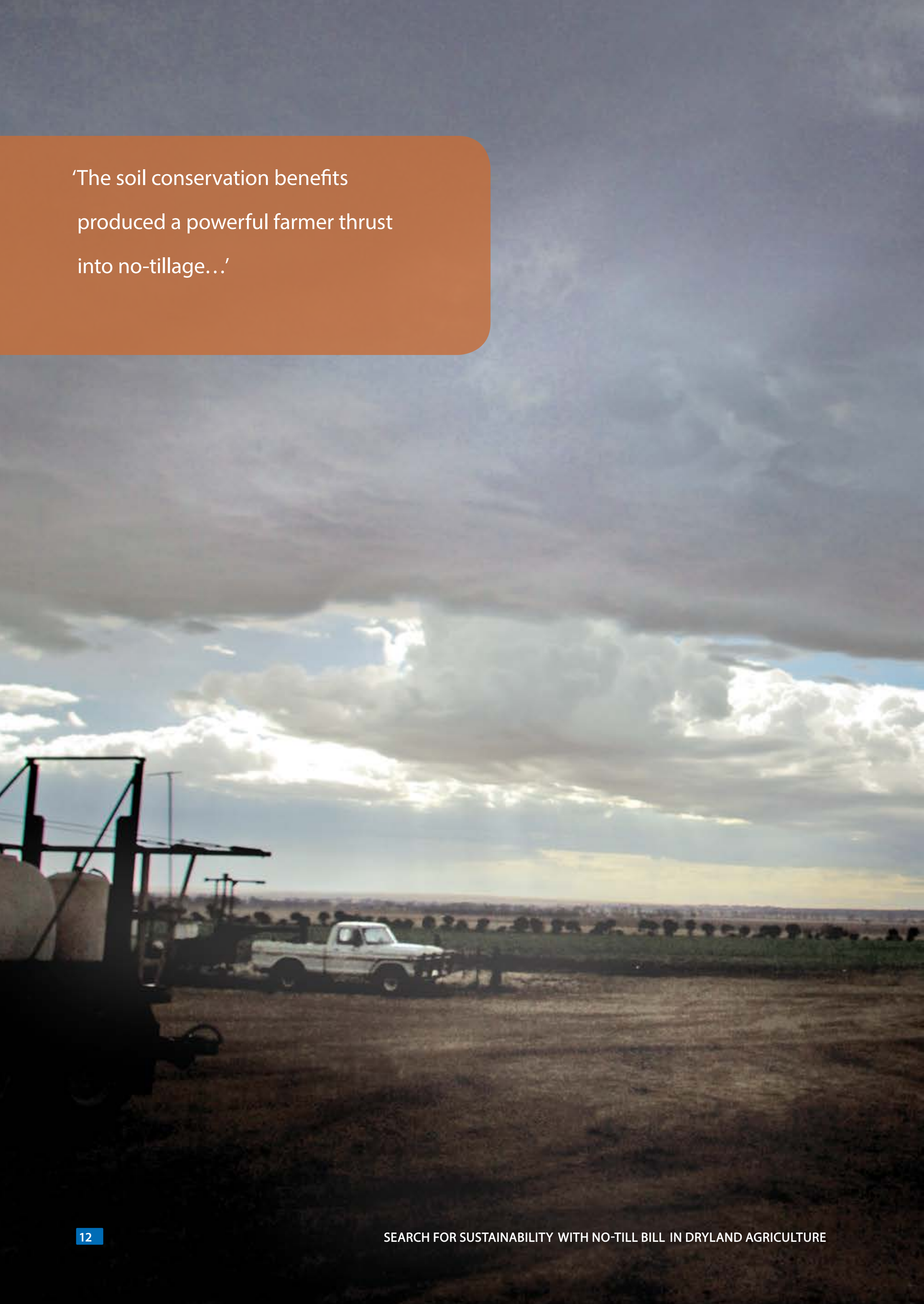
In soils that respond to deep cultivation, some farmers deep rip on wide rows without topsoil inversion. This technique may still be considered no-till.

Here is the Speed drill which can sow at near 20 km/hr. Its advantage is getting the crop in the ground in a timely manner, however, seed and fertiliser placement are not world's best practice.

ABOVE: Here 70 cm wide rows of wheat obtained 4 t/ha adjacent to 35 cm wide wheat rows that also yielded 4 t/ha at St Arnard, Victoria.

BELOW: The press wheel and two openers either side of centre are a cheap banding system called Knuckey's that has been popular.

'The soil conservation benefits produced a powerful farmer thrust into no-tillage…'



CHAPTER 4:

# Adoption of no-till in WA and Australia

**IN THE 1980'S** many WA farmers experimented with direct drilling, particularly seeding wheat into lupin stubbles. Subsequent increases in crop yield and profitability created a desire to grow more crops and run less livestock, but higher stubble loads caused problems for farmers at seeding. Growers were advised to burn or remove stubble, or to seed subsequent crops using offset discs or culti-trash openers capable of getting through the stubble, but this resulted in poor and inconsistent seed placement.

Many farmers, especially those on the sandy-surfaced, wind erosion-prone soils of the south coast, rejected the conventional advice that farmers should burn. At the same time, farmers in the high rainfall areas on the south coast were often getting bogged in their daily travels across paddocks—paddocks made much rougher by the water running off the paddock surface. This was attributed to the tillage-based crop establishment techniques. These farmers were keen for more sustainable farming systems.

So, in 1992, under careful guidance of WA engineer Kevin Bligh, WANTFA (the Western Australian No-Tillage Farmers' Association, Inc) was born.* The soil conservation benefits produced a powerful farmer thrust into no-tillage. There were many examples of zero-tillage producing a 2.5 t/ha crop in 1990 at Jerramungup when conventionally sown crops could not be established at all. These experiences were regularly recounted to others and captured many farmers' imaginations. It caused a clash with some scientists who were negative about no-tillage. Some agency trial data showed that farmers would incur a 10% yield penalty by adopting knife point no-till or disc zero-till. Indeed, my own research data showed this was common, but interestingly it was not always the case.

In 1994 farmer strips and plots showed that trifluralin and no-tillage worked together exceptionally well. Trifluralin performed better using knife points in no-tillage crop establishment than full tillage and did so with good crop safety. Some farmers were desperate for new herbicides to control ryegrass that had

*See more on the combination of trifluralin and no-till in sections 6.3 and 6.4.*

* For a more comprehensive history of early no-till adoption in WA and its pioneers please see *WANTFA Newsletter* articles by Kevin Bligh in 1995, 1996 and 2009.

1985—Bill Crabtree's first tillage versus no-till trials at South Stirlings, Western Australia.

become resistant to Group A and B herbicides. This positive marriage of no-till and trifluralin increased the momentum for farmer adoption of no-till.

## 4.1 No-till adoption patterns in WA

Farmers using no- and zero-tillage techniques (2009) account for over 90% of WA's cropland. As the graph opposite shows, adoption was rapid with most occurring in the mid to late 1990's. About 30% of farmers now have more than 10 years of no-till experience and believe their soils continue to improve with every year of no-till.

There are varied adoption patterns observed throughout the regions of WA. Areas of the state where the soils are very sandy and have persistent winds have seen the most rapid adoption—in particular on the south coast and the northern sandplain (Eradu).

In the early 1990's the zero-till disc seeders were readily embraced on the south coast. Today some regions of the south coast have up to 80% of farmers using disc seeders. Only a few farmers in the northern and central agricultural regions purchased disc seeders. Today there is still a low uptake of this technology in northern and central regions.

The availability and suitability of seeders has also influenced farmer adoption. In the early 1990's the Great Plains™ disc drill and John Deere's single disc drill (known as Biomax™, later called the Germinator™) machines were popular. However, the weaker Australian dollar against the US dollar, and the Great Plains' slow reaction to making the drills more robust and able to accommodate air seeder systems resulted in new zero-till farmers tending to purchase other seeders. These initially included the WA-built Walkers discs, the Canadian-built K-Hart disc seeders and, more recently, a whole range of other disc seeders. There are currently about 60 different makes of disc zero-till seeders manufactured in South America.

The benefits of no-till are clear in Mediterranean climates with acidic soils, and in the sub-tropical northern regions. In low rainfall areas with alkaline soils, such as south-eastern Australia, it seems that farmers require more diligence to make no-till work reliably. In these regions farmers have the challenge of root lesion nematodes and rhizoctonia.

Disc seeders do not seem to be effective in the alkaline sandy soils of WA. These soil types are confined mostly to a small area just north of Esperance. This is partly due to root lesion nematodes *(Pratylenchus* sp*)* and possibly rhizoctonia *(R. solani)*. More diverse crop rotations and resistant crop varieties would help to overcome the nematode problem.

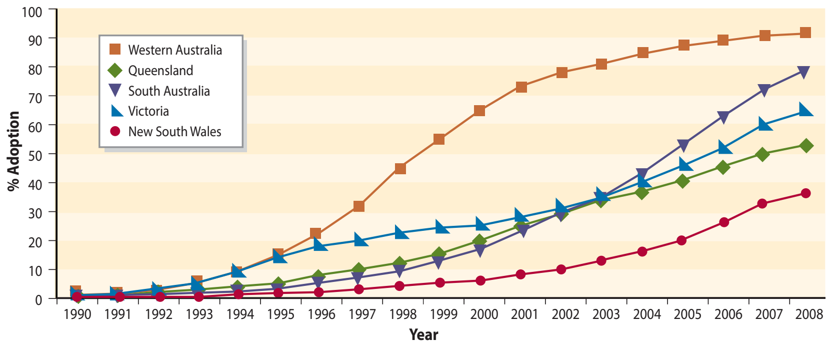
On the issue of nematodes and rhizoctonia, I had an interesting experience in the early 1990's. At a field day with about forty farmers from Salmon Gums with Circle Valley sands, they told me that rhizoctonia stopped them from adopting no-till on their slightly alkaline sands. I suggested that they could overcome rhizoctonia by deep ripping as I had done on acidic sands to the south of them and had published this result in a reputable scientific journal. They told me that ripping made no difference and curiously I publicly refuted this idea. They then said they had a ripping plot just down the road, so I said let's go and see. They were right! There was no visual reduction in what they called 'rhizoctonia' as a result of 30 cm deep ripping at 33 cm intervals.

This observation and conflict motivated me to talk to different people with different knowledge. I spoke to Dr Tony Rathjen at Adelaide, and decided to conduct a survey of the Esperance district. I travelled over 700 km in one day and collected soil and plant samples in September. The samples were analysed for nematode numbers and showed that where deep ripping worked to control rhizoctonia there were no nematodes and where ripping was unsuccessful there were record numbers of nematodes in the alkaline sands. Prior to this survey nematodes were not realised to be a problem in the region.

## 4.2 No-till uptake in other states

My understanding of the adoption rates of no-till in other states, through the Australian network of no-till groups, is that they are all lower than in WA. I would suggest that the percentage of cropped land sown with no-till in each state in 2008—from most to least—would be South Australia at 80%, Victoria at 65%, Queensland at 52%, NSW at 35%, and finally Tasmania at 5%. I estimate that currently (2009) 12 million hectares of land is sown with no-till across Australia.

**Estimated rate of adoption of no-tillage for Australia states (Crabtree)**




Frequent summer rains stimulate strong germination of summer weeds. These weeds are costly to control with herbicides due to the numerous summer rain events. However, this is a vital part of a successful no-tillage system. There is evidence that farmers are making no-tillage work well in the dry South Australian and Victorian mallee regions down to 250 mm of annual rainfall.

Harrington knife point.

## 4.3 Knife points take no-till forward in WA

In the early 1990's, farmers were rapidly embracing the new hard-wearing knife point openers. The welding technology required to strongly attach tungsten carbide to the front of steel or cast iron points was refined. As a result the life of a knife-opener increased seven- to ten-fold.

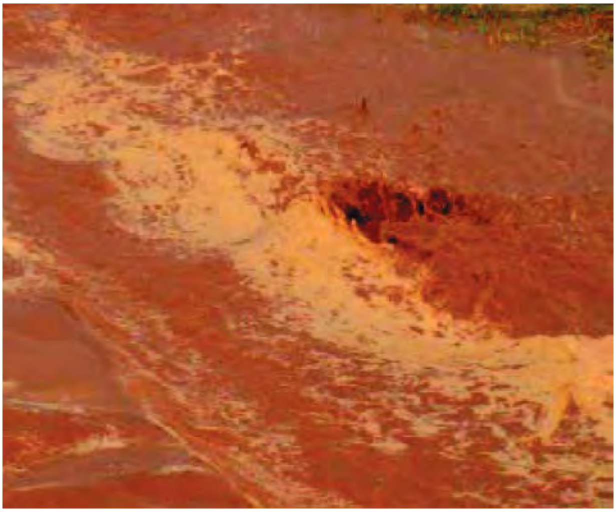
Local knife point manufacturing companies flourished during the 1990's, especially the Harrington™ knife point *(see left)* and the Primary Sales Super Seeder™ and knife points. Similarly, the WA-designed Ausplow DBS seeder is also very popular. The knife point system has been very effective at controlling weeds when used with trifluralin and this is one reason why so many WA farmers have rapidly adopted no-tillage.

## 4.4 World-wide adoption of no-till

More than 50% of farms in Australia, Canada, the USA and many countries in South America have now adopted no-till. No-tillage adoption is also on the increase in many other countries. There are some areas in the world where no-tillage has yet to be widely embraced, despite some genuine attempts. These areas include the whole of the Red River Valley of Manitoba in Canada, much of western Europe and some areas of alkaline sands in southern Australia.

Soil erosion was of catastrophic proportions in South America. Here Paraguayan farmers used to turn their rivers red with fertile loams being lost in large rainfall events after tillage.

PHOTOGRAPH RIGHT COURTESY OF ADEMIR CALEGARI.



The constraints to adoption of no-tillage are often driven by pests, excess water, a lack of heat units, thick stubble and poor rotations.

Crop subsidies in the European Union (EU) have also discouraged diversity of crop rotation and this has slowed the adoption of no-tillage. When farmers are given artificial financial incentives or subsidies to grow some crops and not others it creates a mix of rotations that can work against sustainability and this may not create a healthy outcome.

*For more information on global adoption of no-till see Rolf Derpsch's work.*

Another form of catastrophic soil erosion, closer to home …

For example, wheat grown after wheat requires a modest dependence on fungicides to control leaf or root diseases. If prices for wheat remain strong, farmers are likely to apply much more nitrogen than would normally be considered sensible in a legume–wheat rotation.

I am confident that, with time, the constraints to no-till will eventually be overcome in all areas. This view comes from an understanding of the wide-scale benefits the system can offer when aiming to grow food in a sustainable way.

‘The benefits of no-till have been diverse and profound for both crop production and sustainability in most regions of Australia…’

CHAPTER 5:

# Overview of the benefits of no-till

**THE BENEFITS** of no-till are wide-ranging. They include improved soils, better weed control, easier management and improved efficiency and precision of placement.

## IMPROVED SOILS:

- Improved soil aggregate stability.
- Vast reduction in soil erosion.
- Soils becoming softer through time.
- Increase in soil organic carbon levels or an increase in C turnover.
- Soils becoming more biologically active.
- Even crop growth resulting from better microbial fertility.
- Increase in soil fertility.
- Slower nutrient release through steady state organic matter turnover.
- Generation of free soil nitrogen.
- Increased ability of soils to become suppressive of pathogens.

My family farm in 1982 where soils were grazed, without stubble and in dry and windy conditions.

Typical dust storm from bare ground and strong winds.

## BETTER WEED CONTROL:

- Better herbicide activity, less dust, soil is more moist.
- Weed seeds are left on the soil surface.
- Weed seeds are more efficiently controlled with soil applied herbicides.
- More predictable weed emergence from the surface.

## EASIER MANAGEMENT:

- Better time management.
- Less machinery, labour, fuel, repairs and maintenance required.
- Farmers can manage larger areas efficiently.
- Increased ability to drive over young crops with less damage.
- Increase in paddock trafficability.
- Better agronomy results as agronomic errors are more obvious.
- Crops can be sown into dry soil without soil erosion.
- Crops can be established on minimal soil moisture.
- Crops are protected in the furrow when young.

### IMPROVED EFFICIENCY AND PRECISION:

- Earlier time of sowing.
- Greater whole farm yields.
- Crops can be sown with precise placement of seed and fertiliser.
- Soil water is conserved and its use optimised.
- No-till furrows harvest water efficiently.
- No-till furrows harvest topdressed fertiliser.
- Fertiliser banding optimises crop nutrient use.
- Deep working knife points break plough pans, reduce rhizoctonia and improve early growth.

The benefits of no-till have been diverse and profound for both crop production and sustainability in most regions of Australia. This largely explains why there has been a rapid adoption of no-till in many regions of the world, particularly where water is limiting or where soil erosion is a constant challenge.

Tillage itself covers a multitude of sins. When tillage is removed farmers can sharply focus on the real problems that soon become apparent in their farming systems. No-till is not just the removal of tillage, it is embarking on a whole new system with complex interactions.

Some of the significant benefits of no-tillage are covered in separate chapters to follow. These are improved soils, better weed control, easier management, optimising time of sowing, improved efficiency and precision with superior soil-plant water relations. Some of the other benefits are discussed here in this chapter—however this is not an exclusive list.

Structurally damaged soil requires years of no-till, some gypsum and organic matter to recover.

Crops can be established into strong clay soils, enabling soils to further soften through root growth.

## 5.1 Improved farm management efficiencies

The high cost of labour and the challenge of finding experienced labour in declining rural populations make no-tillage a very attractive technique. The tillage operations are replaced with wide booms of 20–35 m operated at 20–30 km/hr, covering large areas in a short space of time. The relatively low cost of glyphosate makes killing weeds with the boom efficient in both time and money. In contrast, slow cultivation with narrow width ploughs or scarifiers is expensive in time, fuel, maintenance and repairs.

## 5.2 Fewer banks and drains and more 'up-and-back'

Soil structure continues to improve with increasing history of no-tillage. Such soil improvements mean that water will soak into the soil more quickly and the stubble further slows the movement of water and effectively holds it until it can soak in. This reduces the need for banks. Many contour banks have been filled in and this trend will likely continue into the future.

Graded banks make farmers plant their crops on the contour. This was seen as desirable in the 1970's and 1980's and was seen as good farmer stewardship or a sensible soil conservation practice. While it is good for slowing water movement from heavy summer rainfall on bare pasture paddocks it also made wide seeders and boom spraying operations less efficient.

Where stubble is retained and no-tillage is used, the soil absorbs water more efficiently and, consequently, contours are often considered less useful to the whole system. Farmers in WA now prefer to spray and sow in an 'up-and-back' method. Obviously some farms may never be 'up-and-back'—it depends on the terrain. Full stubble retention and no sheep make contour seeding less necessary.

Banks can be filled in with little concern of erosion with full stubble retention and softer soils.

Some banks are essential to manage excess water flow off rocky outcrops—like this one at north-east Morawa.

Earthworm food harvested away from their reach. Carlos Crovetto calls these ‘monuments of stupidity’. Cereal straw is mostly carbon which is energy that builds soil health.

Agriculturalists from Queensland, where heavy rains can saturate soil, believe that sowing up and down hills with stubble and no-till is safer than seeding on the contour. The idea is that each furrow carries (takes) its own load so this does not run into adjacent furrows. It has been said that contours are designed to fail—this idea has a lot of merit to me.

## 5.3 Earthworms become very active

Often after one year of spraying weeds with knockdown herbicides and no-till sowing, farmers have observed levels of earthworm activity not seen with multiple tillage systems. This activity has been reported in all regions of the state, though it is more pronounced in wetter southern regions. Dr Margaret Roper (CSIRO, Perth) and many others report that earthworms are a good indicator of microbial activity.

These consistent earthworm observations have made farmers realise that soil life plays an important role in nutrient recycling and soil vitality. These greater numbers of earthworms, and also increased ant activity, combined with no-till, help us to understand why soil water infiltration is higher under no-till and why the soil is more trafficable and soil aeration is also improved. It has also helped farmers realise that stubble has soil conditioning properties that need to be harnessed, rather than burnt or removed.

## 5.4 The tillage treadmill

If tillage is done for weed control—when the soils surface has dried—then 10–20 mm of soil moisture is lost by bringing wet soil to the surface. If tillage is used when the soil’s surface is wet then more weeds will germinate from the tillage, which will require another tillage to kill these new weeds and this tillage will cause another flush of weeds, and so on! Such repetitive tillage has been nick-named ‘recreational tillage’ and it destroys soil structure.

If farmers then want to break this tillage cycle, after a cultivation, they will find that their weeds are dusty, making spraying less effective.

The tillage treadmill: here the soil is bare from a lack of organic matter, overcultivation and water erosion removing the topsoil. This will take a few years of no-till and stubble retention to heal.

On the other hand, if emerged weeds are sprayed then no soil will bury the surface weed seeds, and further weeds will rarely germinate from a rapidly drying soil surface.

The tillage cycle also creates other significant problems, such as uneven paddock moisture. Intense summer thunderstorms, common in southern Australia, will cause the water to run off these cultivated paddocks. This process usually causes soil erosion, an uneven distribution of soil moisture and can result in machinery being bogged in low lying areas where the water accumulates.

Cultivated land that is located high in the landscape will therefore miss out on an opportunity to absorb such rainfall—making it more drought-prone! In contrast, land that is not tilled and has stubble can adsorb much of this water. This water-holding ability will be further improved by increasing soil organic matter and improved aggregate stability from no-tillage systems.

There is an exception to tillage reducing infiltration and soil water relations. On soils that are bare and compacted (usually through sheep grazing) there can often be a benefit of tillage to crack this firm soil to allow water penetration. This can be done with knife points. This tillage will not only let more water in, it may also reduce capillary rise and reduce water loss to evaporation.

Crops grown in tilled or "fluffy" soil that releases more soil N, will create more early growth than no-tilled crops. However, this means crops grown on tilled soil usually try to set up greater grain yield potentials than are usually achievable with subsequent dry periods. No-tilled crops use little early soil moisture (or N) and they capture what rain does fall more effectively *(see next section)*. The releasing of soil N from tillage also depletes soil organic matter.

Sandy soils cannot tolerate tillage. Apart from the direct effect of erosion, a sandy soil is inherently low in fertility. Tillage loosens the soil and brings the fines (fine particles) to the surface from where they can be easily eroded until the soil 'armours up' with coarse fragments. Repeat tillage brings more fines to the surface from where these can erode as well. While small amounts of N can be released with these tillage events it is not a sustainable way to farm.

‘With no-till the weed seeds are more exposed to herbicides and are in closer contact with soil-applied herbicides …’

CHAPTER 6:

# Weed control is superior with no-till

**THERE ARE** many worldwide observations and published papers that show weed control is better with no-till compared to tillage-based systems. Perhaps the most comprehensive studies are by Dr Randy Anderson in the Great Plains of North America. It is clear that most weed seeds need to be incorporated for optimal germination. Weed seeds also deteriorate chemically, physically and biologically when left on the soil surface.

With no-till the weed seeds are more exposed to herbicides and are in closer contact with soil-applied herbicides than with tillage. In tillage systems weed seeds can be buried, protecting the seeds from close contact with the herbicides.

There is an important difference between disc (zero tillage) and knife point (no-tillage) in this regard. While discs are superior due to their lesser soil disturbance which results in lower numbers of weeds germinating in the inter-row, they are only 50–65% as effective as knife points at controlling our problem weed, ryegrass, when the herbicide trifluralin is used.

Disc seeders do not fit well where sheep are incorporated in the cropping systems. Sheep will press weed seeds into the soil and allow them to germinate on each rainfall event. Sheep give weeds a seedbed by planting them. When weeds seeds are not planted (as with no sheep) and are left on the surface they can be more effectively targeted with herbicides.

## 6.1 Discs best in some environments for weeds

On the south coast of Western Australia wind erosion risks are high and the soils are very sandy. In these environments double and triple disc seeders are popular as the disc seeders can get through thick stubbles. The discs also seem effective in suppressing ryegrass populations and trifluralin is less relied on than in the warmer and dryer regions of the state. It may be that in these southern regions more ryegrass germinates before seeding allowing knockdown herbicides to be more effective as compared with the more northern regions of WA.

This photograph illustrates weed emergence with absolute no soil disturbance (centre strip), with disc zero till (left side) and disc zero till used twice (right). The right strip needed to be re-sown as the box was empty the first time. More tillage gives more weed emergence.

In both disc and knife point sowings, the soil-active herbicides that are applied immediately before sowing (IBS) give more effective weed control than any other tillage or herbicide option. These IBS herbicides are also much safer on the crop than those applied post-sowing pre-emergent (PSPE) either with or without tillage. It is the obvious advantage of this difference that has thrust most WA farmers into the no-tillage system—not soil erosion control, although this was the initial catalyst for many to adopt no-till.

## 6.2 Increasing herbicide resistance weeds makes farmers embrace no-till

In the late 1980's many farmers experienced the failure of 'fop', 'dim' and 'SU' herbicides to control annual ryegrass *(Lolium rigidum)*. This selected ryegrass resistance became acute for many farmers. Many of them were forced to change their weed management practices, although reverting to tillage was not one of the options commonly adopted—despite a lot of promotion of this tillage for herbicide resistance management.

Most progressive farmers realised that leaving weeds on the surface and in close proximity to soil-applied herbicides was a good way to manage weeds. Consequently no-till became the base tool and other secondary tools were adopted within the no-till system. Other tools included:

- delayed sowing until a knockdown herbicide is applied;
- rotating with different crop types and therefore different herbicides or herbicide groups;
- collecting the seed chaff;
- optimal fertiliser placement that gives the crop the advantage over the weeds;
- crop topping or pasture topping; and
- grazing.

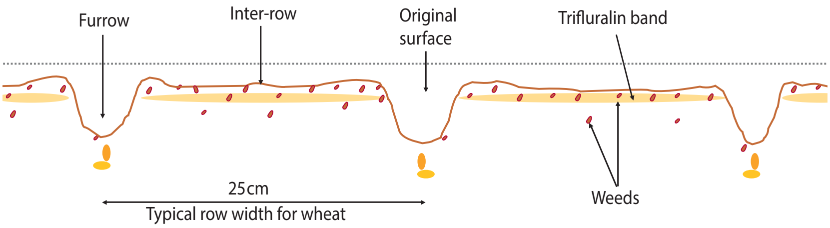
The re-invention of trifluralin occurred due to its effectiveness within the WA no-till system. Less popular advice was to burn stubble in situ, while another more sensible and less risky burning strategy was to burn narrow rows where weed seeds had accumulated. Burning is a loss of carbon from the soil system. Such carbon can be better used as an effective soil ameliorant.

## 6.3 Trifluralin and no-till—go hand in glove!

Trifluralin does not need 'proper soil incorporation' for it to work well as was previously understood. A thin layer of soil, perhaps 2–3 mm, is all that is needed to stop trifluralin loss and ensure it has strong weed activity. With knife point no-till systems the trifluralin is applied onto an undisturbed soil surface, which is where most weeds seeds are located (especially after a few years of no-till).

The seeding operation from the knife point throws a thin layer of soil over the weed seeds and the herbicide which are in close contact to each other. This allows the herbicide to work most effectively on the emerging roots, as trifluralin activity is most effective on growing root tips. I have supervised a dozen trials over 5 years with this approach and have compared it to full tillage trifluralin efficacy and it is obvious why it has become such a widespread system.

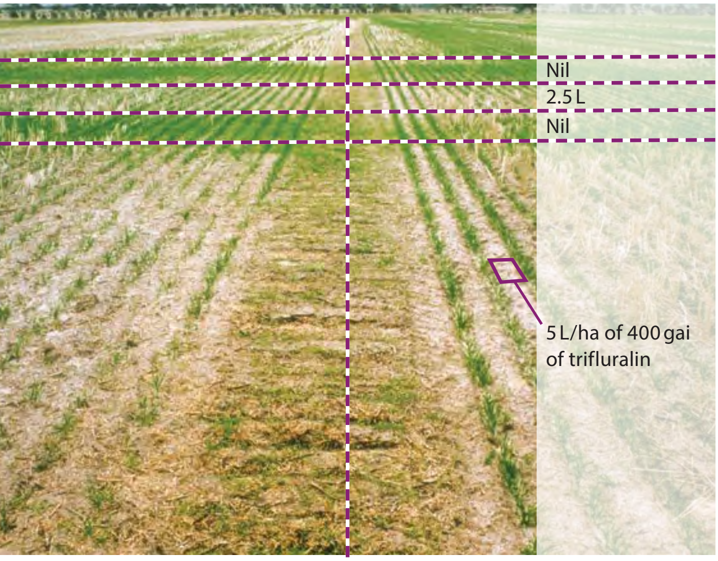
The trifluralin (displayed as the yellow strip in figure below) is sprayed onto the weed seeds that are concentrated on the surface. This is then covered with a layer of soil. The thickness of this soil layer depends on row spacing, opener width, length of opener, opener angle, speed of travel, soil type, soil moisture and the speed of weed root decay. Many farmers have seen this pattern where a dye is sprayed out before sowing and a fluorescent light is used to see the location of the product.




Fourteen years of farmer adoption in WA, and follow-up trial work by researchers and the company Nufarm, encouraged Nufarm to put no-till trifluralin on the label at 2 L/ha—but note that this is only recommended with no-till using knife points before sowing (IBS). In 2006 this rate was lifted to 2.8 L/ha with 480 gai (grams of active ingredient) trifluralin.

The photo on the next page illustrates many things that are common with the no-till and trifluralin package for ryegrass control.

Trifluralin gives excellent safety and strong ryegrass control with no-till sowing (right foreground).




Press wheels + harrows | Press wheels, no harrows

For a closer look at this photo please see page 26.

High rates of trifluralin are safe when applied immediately before sowing using no-till without harrows to pull the trifluralin back into the wheat seed row. The foreground of the photograph (left) shows an area where 5 L/ha of 400 gai trifluralin was applied. There are two control strips with no trifluralin applied going across the photo. The second strip with ryegrass control is with 2.5 L/ha of trifluralin: this is between the two nil trifluralin strips. The wheat on the right was sown with knife points and press wheels on 250 mm spacings (10”), the left was the same—except heavy harrows were trailing pulling trifluralin into the furrow and causing approximately 50% wheat emergence.

LEFT: In contrast to trifluralin safety on wide rows is this common old 180 mm row spacing with a high rate of trifluralin killing the wheat? The last row of tines are always the best—soil is thrown from this furrow along with the herbicide.

BELOW: Row spacings should not be too wide though as weeds will explore the gap and proliferate.

Here is evidence that trifluralin control is very effective up to about 200 mm from a furrow generated by seeding.

## 6.4 Trifluralin still works in stubble and on the seed

WANTFA no-till trials with applications of trifluralin across the state from 1998–2001 typically achieved 70–90% ryegrass control. Higher rates of trifluralin and higher water rates will improve control. However, if farmers have very high ryegrass numbers then burning gives better ryegrass control with trifluralin use. If no-till farmers do not adopt burning as a strategy because of its inherent weaknesses (wind erosion risk and loss of stubble for reducing evaporation) then they need to embrace other strategies such as tank mixing other herbicides or more diverse crop rotations.

Burning stubbles can improve ryegrass control. Burning header trails without grazing can be a useful tool, but it still comes at a cost of lost carbon and food for the soil.

Trifluralin applied to exposed seeds lying on the undisturbed soil surface has been effective. This is evident in the main photograph at the beginning of this chapter (see page 26) on the unsown strip between the seeder rows. There has not been any soil disturbance and there is a marked difference between with and without trifluralin—showing perhaps 60% ryegrass control with trifluralin use even without incorporation. This is consistent with studies by Dr Michael Walsh at the University of WA.

## 6.5 Harrows encourage ryegrass to germinate

Compare the two nil trifluralin strips going across the same photo. Note that where the harrows are used (on the left) there has been a higher rate of ryegrass germinating than where no harrows were used (on the right). This has also been observed in other trials.

Pre-seeding tillage will reduce the precision of this approach with trifluralin. Tillage will relocate ryegrass seeds through the soil profile, whereas, with years of no-till, ryegrass seeds can become depleted at depth. Tillage places the seed away from the herbicide. The herbicide is not mobile, unless the soil that the trifluralin is attached to is moved. Perhaps the biggest drawback with trifluralin and no-till is that there is no trifluralin remaining in the furrow. One way around this problem is to drag some soil back in the furrow—but this is risky; another is to add a water-soluble herbicide with the trifluralin.

## 6.6 Complement with soluble herbicides

Soluble herbicides like diuron, metribuzin, Logran® and metolachlor have also become useful herbicides with increased crop safety with no-tillage. These herbicides are also more efficient with no-till than with tillage systems. In dry conditions they may not work as well on weeds, while in wet conditions they may be very effective on weeds in sandy soils and can cause some level of crop damage.

In no-till the furrows catch water from the inter-row. The water that falls on this inter-row will dissolve soluble herbicides from the soil surface, which is now covered with a thin layer of soil, and can leach a proportion of the herbicide through the shoulder of the furrow and into the furrow. This water and herbicide leaching will then suppress the weeds that have emerged in the furrow and may, in very wet periods, result in more herbicide moving into the furrow than desired. The intention is that these herbicides may suppress the weeds in the furrow without crop damage and the crop may then out-compete the weeds.

## 6.7 Soluble herbicides put to the test!

With no-till, it is much safer to apply various soluble herbicides before sowing rather than after. In the two photos on the next page, atrazine has been applied at 2.2 L/ha across a range of broadleaf crops (background) and pastures (foreground). These two atrazine herbicide strips are 2 m wide and separated by one 2 m wide plot of metribuzin.

The no-till sowing operation was across the direction of these herbicide strips. Both herbicide treatments occurred on the same day. The bare strip was with atrazine applied immediately after sowing while the other strip of mostly healthy

No-till and furrow sowing here are shown to capture water-soluble herbicides (atrazine, simazine and metribuzin) into the furrows when applied immediately after sowing, killing a whole range of crop and pasture broadleaf species.

The same herbicides applied the same day—but just before no-till sowing—are shown to be relatively quite safe. What an amazing contrast!

crop and pasture growth had atrazine applied immediately before sowing. This illustrates that atrazine can be quite safe on a range of broadleaf crops and pastures when applied before sowing with no-tillage, yet is dangerous when applied after sowing—even on the same day. Our experience here is not saying that damage will not happen but that the risk of damage is greatly reduced with before sowing applications.

The reason for the stark difference, which also occurred with numerous other herbicides, is the effective minimal and precise incorporation from the knife points. The IBS-applied herbicides end up being placed on the flat soil surface that is then covered with soil. The action of the knife point also removes the herbicide from the furrow and places it in the inter-row. Some rain is required to move this water-soluble herbicide back into the furrow. In contrast the herbicide applied on the surface after sowing will easily move into the furrow where crop seeds are located. Such 'wash' can cause undesirable levels of crop damage. The disc zero-till systems also usually result in the potential for more damaging herbicide to wash into the furrows as they move less soil during the sowing operation compared to knife points.

## 6.8 No-till made ryegrass control more achievable

During the 1990's in WA it became apparent that most weeds were more simply and effectively controlled with no-tillage. This benefit rapidly induced even those farmers who otherwise might have been reluctant to adopt no-till. The discs were observed to disturb less weeds—with fewer weeds resulting in crop. This has been observed to the point where, after 4–5 years of zero-till, south coast farmers say that ryegrass has fallen out of their zero-tilled paddocks. This is also often, but not always, associated with less sheep on the paddocks.

In similar dramatic fashion, farmers and researchers have found that the herbicide trifluralin works best with no-tillage. It has been shown that knife points incorporate high rates of trifluralin without crop damage while being highly effective on ryegrass control.

The resulting improved ryegrass control with no-till and liquid trifluralin gave a solid thrust to no-till adoption. Such improved control was perfect timing as ryegrass populations were rapidly becoming resistant to Group A and B herbicides by the mid-1990's.

Trifluralin does not work on thick stubbles as well as on bare ground. Therefore I conducted two trials in 2000–2001 where trifluralin granules were employed, using the same granules as no-till farmers in Canada have done with success. This formulation allows the granules to fall through the thick straw and come in closer proximity to the weed seed, whereas a liquid spray would bind to the straw. While these trials were successful no company was supportive as they believed that higher herbicide and water rates were more cost effective than making and transporting granules for farmers.

David Minkey inspects David Bowran's weed by tillage systems trial at Beverley in the late 1990's. No-till area on the left and tillage-based cropping on the right.

It is an interesting observation that trifluralin resistance in ryegrass has not become a problem in WA. We still mostly observe excellent efficacy, despite predictions to the contrary. This is different to South Australia, where they did not switch to SU herbicides in the late 1980's as WA did, and then continued to rely on low rates of trifluralin to suppress ryegrass populations in inefficient direct drill systems.

In WA we used no-till with high rates of trifluralin when it was illegal to do so and with good effect. We controlled almost all ryegrass in the inter-row and left some unexposed ryegrass in the furrows to set seed—not having any selection pressure applied. This worked and still works to our advantage from a low resistance pressure, I believe. High rates work well in the inter-row and the few escapes in the inter-row cross with the susceptible plants which survive in the furrows.

The irony is that farmers had for many years been cultivating to control ryegrass germinations. We have noted up to 14 cultivations at Wongan Hills in the mid-1970's, which still resulted in a new germination of ryegrass. Interestingly, cultivation is still being promoted by the Western Australian Department of Agriculture and the Western Australian Herbicide Resistance Initiative, in the RIM model. They suggest that all tools should be used and do not seem to comprehend the system implications of tillage on farm profitability. Their suggestions have had little uptake.

## 6.9 Changing weed populations

While there have been strong weed control improvements with no-tillage there are also some weeds that have benefited from no-till. Marshmallow, couch-grass, windmill grass and perennial native vegetation such as various native trees and shrubs have become more common. In some cases no-till farmers have had to resort to cultivation to manage these and, in other cases, new herbicides and herbicide mixes have become available to provide control. One farmer has successfully used a rolling chain to pull weed roots from the ground without having to resort to tillage.

The adoption of WeedSeeker®or Patchem® technology is likely to assist greatly with these weed challenges. The WeedSeeker® is a sensor located every 50 cm along the boom spray and high rates can be accurately applied to areas with large weed burdens while it does not spray the ground where there are no weeds.

## 6.10 South American weed suppression

The use of cover crops is a common tool in South American no-tillage to control weeds. The value of this technique has also been proven in Australia. However, in my view, the cost of controlling weeds in this manner is yet to be proven economic when compared to other options. The idea of sacrificing a paddock for a year with no return and some costs is debatable. In my mind we would be better off adopting GM weed control measures and making money in the same year as controlling the weeds.

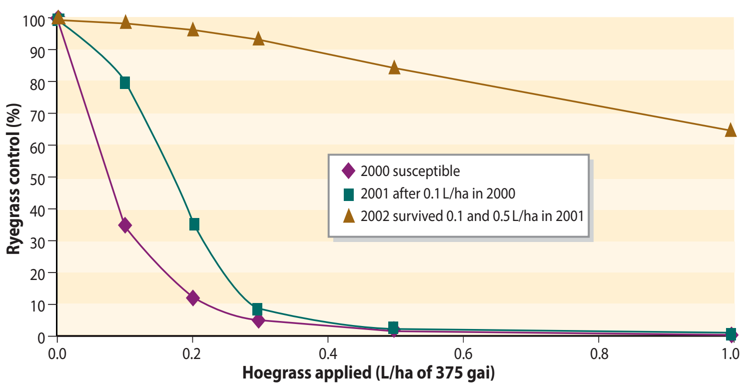
Evidence of ryegrass regrowing after a sub-lethal dose of glyphosate.

## 6.11 Low dose rates speed resistance

Carefully controlled glasshouse experiments by Dr Paul Neve at the University of Western Australia from 2000–2002 have shown that low rates of herbicides can rapidly select for resistance. This has been a hotly debated issue in Western Australia after Israeli academic Professor Jonny Gressel suggested the possibility to a large WA audience at a WANTFA Conference in August 1997.

Jonny suggested that creeping resistance through multiple genes was possible. This data set in the graph below shows that the long-standing practice in Australia of using low herbicide rates can cause a rapid development of herbicide resistance, which is consistent with Jonny's hypothesis. Jonny suggested that alternating from low to high rates may help slow the rate of resistance as effectively as all the other techniques that we know to kill weeds.

**Generation herbicide dose response curves**



'By spraying before the season's breaking rains, reliable crop establishment in marginal soil moisture conditions is possible…'

CHAPTER 7:

# Time of sowing

## 7.1 Earlier sowing means better yields

No-till means that crops can often be sown 2–3 weeks earlier than with a tillage-based system. Trial data shows there is typically a 1% yield decrease per day by delaying sowing after 5–15 May, solely due to time of sowing.

Remember, tillage involves more time than just the time on the tractor. There is also the time lost while you wait the next 6–10 days for further weeds to germinate before tilling again or spraying and sowing. Earlier sowing usually ensures that the crop is sown into moister soil.

## 7.2 Tillage dries the soil

Typically, in a tillage-based system, the soil is cultivated after the first winter weeds have emerged. This means that moist soil is brought to the surface and then dries out. In fact, tillage kills weeds most effectively in drying conditions of strong sunshine, low humidity and wind, when 10–20 mm of moisture is lost from the soil brought to the surface. Without these conditions weed transplants become an issue, and are harder to kill next time with either herbicide or tillage.

There is a case for tillage to break hard surface sealed soil which will allow rain to penetrate the soil. Heavy soils can become less penetrable if stock graze them while wet. In this compromised situation a tillage—even with a knife point seeder—can catch more rain and retain it where it falls, compared to significant run-off that would otherwise happen.

LEFT: Spraying summer weeds after a rain and retaining organic matter helps hold moisture at depth—this benefit has been observed annually with autumn rains.

## 7.3 Time is not wasted

In Australian agriculture the time spent conducting tillage is significant. A no-till farmer would rather get his 'plough' out of a drum, in the form of glyphosate or other knockdown herbicides. Wide boom sprayers (25–30 m) travelling at 25–30 km/hr can cover much more ground than a tractor pulling a cultivating implement. These extra hours can then be used for more timely sowing of the crop.

Labour units are often in short supply on farm, and non-essential activities such as tillage will reduce the crop's yield potential. Including a non-essential tillage activity is commonly referred to as 'recreational tillage' for a very good reason.

## 7.4 Moisture is conserved

Dying or dead weeds can conserve soil moisture! Weeds will stop growing soon after a knockdown herbicide is applied, and the decaying organic matter from these weeds, along with the previous crop's residue, acts as an insulator or impediment to soil water evaporation. This moisture can then be used more efficiently to establish the crop over many weeks of subsequent dry weather. This ensures an earlier time of sowing for a large portion of a farm in dry periods.

In our Mediterranean agriculture the term 'break to the season' defines the substantial rain event after which the annual crops and pastures will survive through winter and can go on to maturity in late spring. Spraying weeds after the first significant rains but before the 'breaking' rains has been termed a way to 'make your own break' to the season! A breaking rain usually occurs in late autumn or early winter, when soil water evaporation is low. By spraying before the season's breaking rains, reliable crop establishment in marginal soil moisture conditions is possible. While it is possible to reduce soil water loss by tillage on some more clay-based soils, thereby breaking the capillary action, this does come at a cost.

Moisture is conserved at depth through spraying ahead and no-tilled crops can make efficient use of this conserved moisture. No-till sowing of wheat and barley is usually done in the bottom of the furrow on 25–30 cm (10–12 inch) row spacings. These wider row spacings (convention was 18 cm [7 inches] before no-till) enable moisture to be 'chased' with sowing and ensure precise seeding depth. If the moisture is at 7 cm depth then the top 4 cm of dry topsoil can be thrown from the furrow into the inter-row while the seed is placed 4cm below the new soil surface. This ensures that the seed is now sown 1 cm into the moisture in the furrow, yet 8 cm down from the original soil surface.

Small spray 'misses' over summer are readily observed to give poorer crop yields in the shape of the miss at harvest time. Tillage can also do this but destroys the organic insulation blanket.

The evaporation of water from the furrow is minimal compared to a traditional harrow levelled surface soil from tillage-based agriculture. With a traditional tillage soil surface that is flat the moisture would have been evenly wet to depth and so remained near the surface, more prone to evaporation and capillary loss. With these no-till furrows much of the water preferentially gravitates into the furrows and little moisture remains in the proud inter-row.

The moisture in the furrows can form a hydraulic head as it is harvested into the furrow and this allows more water to get to depth, away from evaporation forces. This zone also happens to be where the crop seed is establishing—consequently good crop establishment is increasingly assured *(see section 8.2)*. Experienced no-till farmers believe that now they can establish a crop on 3–4 mm of rainfall, provided it falls after sowing and in the absence of soil erosion, which can still occur if no-till farmers burn their stubble.

There can be penalties where no-till farmers get the timing of small rainfall events wrong and seed too soon after a small rain. This can happen as the moisture is slowly being absorbed into the topsoil and the seeding process removes 4 cm of topsoil from the furrow. If the moisture has not yet penetrated deeper than this 4 cm then this moist soil can be thrown from the furrow and the seed is then placed into a furrow that is dry and may remain dry until the next rainfall.

No-till can allow farmers to use non-wetting sands to their advantage. The furrow created with the press wheel can channel a greater percentage of the rainfall over the seed, resulting in more even crop emergence. The inter-row remains particularly dry and therefore hostile to weed growth. The stubble retention generally stops the water running straight down the hill into the furrow, although sowing across the hill slope is safer in these 'special' non-wetting soils.

This furrow effect is generally most useful, with 30% emergence improvements being common with press wheel use, in the first few years of no-till. In time, however, with continuous cropping, weeds can build up and weed control becomes more challenging in non-wetting sands with this approach with no-till. The technique 'claying' is the best solution for these problem soils.

*For more on claying see section 18.2.*

## 7.5 No-till seeders penetrate dry soils

The ability of no-till seeders to penetrate dry and often tough soil, to 8–12 cm depth, is widely appreciated. With tyne breakout strengths (or shanks) commonly being 25–35 kg/cm$^2$ (350–500 lb/inch (or 24–34 bar) the knife points (openers) can penetrate all soil types and all moisture contents. The common knife opener width is 12 mm and the length is 12 cm. The knife is usually inclined at an angle of about 70 degrees. With highest spring tyne breakout pressures, knife points are usually 16 mm wide for improved strength.

With traditional seeding on wide shears it was not possible to open the soil and evenly place the seed in marginal moisture conditions. With knife point no-till openers such penetration is now commonly achievable. Given that wheat is renowned for being able to germinate and emerge in slightly moist soil, no-tillage opens a seeding window that was otherwise nonexistent—and with quite accurate seed placement. This is especially true the longer the soil is no-tilled as heavy soils soften with a no-till history.

## 7.6 Soils soften through time

Long-term no-till farmers, especially those who have also retained organic matter, see higher levels of soil moisture than tillage-based farmers or 'novice' no-tillers. Water infiltration is greatly increased with improved soil structure, and more macro-pores from long-term no-tilled soils also means increased biological activity. An increase in organic matter associated with no-till enables the soil to hold more moisture. The infiltration of a heavy rainfall event is also greater on paddocks with retained stubble. The stubble physically holds the water until it can soak in. Such no-tilled soils allow large volumes of water to rapidly enter the soil and greatly reduce run-off at the same time. This means less water is lost from the crop.

Esperance farmer Neil Wandell observes how with years of no-till his tight soils have become soft—now even friable by the hand—when dry after over 20 years of no-till.

## 7.7 More even paddock soil moisture

In tillage-based systems intense rainfall causes several problems. Tillage destroys both soil structure and surface cover causing reduced water infiltration. The loosened soil then promotes water erosion and the run-off water is lost from the farmland or gravitates to the low-lying areas. These low-lying areas can become too wet and waterlogged, so losing production, as well as limiting machinery movement or trafficability.

Uneven moisture over the paddock can then compromise the whole paddock's time of sowing. Delayed sowing can occur, as by the time low lying areas become dry enough to be sown, the soil on higher ground may have become too dry for optimal crop establishment.

Bare soils without organic matter cover and with varying soil type and structure typically emerge at staggered times as this photo shows.

## 7.8 Surface sealing rarely occurs

Damaging the soil structure from tilling heavy soils increases the probability of surface sealing. This rarely occurs with no-till. I have observed that after 25 years of no-till, surface sealing and restricted crop emergence are almost eliminated. I believe that this is because the seed is sown in the bottom of the furrow and, in Australia, the furrows remain mostly moist with regular dews and frequent small rain events during crop emergence. Also the seedlings in furrows are shaded from the direct sunlight and its evaporative powers for a large part of the day.

Tony White, Miling, shows soil that used to build-up underfoot is now structurally much better.

With long-term no-till and stubble retention, the structure of the soil is improved and the infiltration of the rain is more even. Consequently, with intense rainfall there will be soil moisture penetration at depth, even on poorer quality soil. This deep moisture is a valuable resource for crops—especially in drought years where sub-soil moisture will enable the crop to mature with reduced stress.

‘Not only does no-tillage mean earlier time of sowing it also means less chance of crop failure from drought…’

CHAPTER 8:

# Better plant–water relations

**NOT ONLY** does no-tillage mean earlier time of sowing it also means less chance of crop failure from drought. I have observed that no-tilled crops are more persistent and finish better than crops grown with tillage-based agriculture. There are several reasons for this persistence:

- the furrow effect of harvesting the water for the seedling and crop;
- increased ground cover to limit evaporation to the atmosphere between rows;
- a more efficient use of fertiliser in a band away from the weeds;
- the slower initial early growth of the no-tilled seedling;
- less early tillering of the crop; and
- softer subsoil allowing better root growth, an increased soil microbial activity, less soil compaction and more subsoil moisture accumulation.

These factors are explained below in more detail.

## 8.1 The furrow harvesting effect

Since the seeds are sown in the furrow and water gravitates to low lying areas, any rainfall will gravitate to the furrow. I have observed this to occur regularly (see photos opposite and next page). The 'U' shaped no-till furrow is generally well defined as the opener removes soil from the seed placed slot and the press wheel helps to firmly define the 'U'.

The harvesting of water into the furrow makes small rainfall events very useful. It even makes dry sowing more likely to succeed. The effect continues through the season. But its effects are usually most profound at the beginning of the season (the break to the season), and at the end when evaporational pressures are much greater that during mid-year.

LEFT: A small 4 mm rainfall event moves into the furrow to assist with early crop growth at Hyden.

The location of fertiliser and weeds is an added bonus to the no-till system. Weeds are left on the surface and between the rows, where little rain will penetrate initially. The fertiliser is placed in the zone to where water will frequently gravitate. This makes the fertiliser available to the crop and positionally

ABOVE: Sandy soil wets in the furrow where the seed and fertiliser are placed on only 4 mm of rain—see small canola just established.

ABOVE: A late 18 mm rainfall event at Cadoux preferentially flows into the furrow—away from strong October evaporative conditions.

BELOW: About 80% of urea top dressed ends up in the furrow—especially if the soil surface has consolidated after a rainfall before topdressing.

unavailable to the weeds. Significant rains are required before the roots of the weeds can grow far enough to extract the banded fertiliser.

The furrow not only harvests water—it can also harvest post-sowing fertilisers. Fertilisers like N, K and S are all required by the crop in sandy soils and they can be harvested into the furrow when spreading (top-dressing) them post-sowing. I have found that 70–80% of these granules bounce into the furrow and when rain falls these granules wash into the immediate crop root zone.

Care needs to be taken in deep sands and in high rainfall areas to avoid excessive leaching. Using a split application approach—doing applications several weeks apart will optimise the efficiency of these fertilisers in such conditions.

Solid ground cover usually associated with no-till limits evaporation.

## 8.2 Ground cover limits moisture loss

Retaining stubble and organic matter reduces the amount of evaporation possible from the soil's surface. In no-tillage systems stubble retention is usually seen as highly desirable, and indeed essential, with most long-term no-tillers. However, not every no-tiller subscribes to this idea. While no one will debate the idea that soil health is better with increased organic matter, stubble can interfere with our ability to control some weeds and therefore in the short term can reduce crop yield.

Ryegrass *(Lolium rigidum)* control with trifluralin is reduced from 85% (in burnt stubble) to 70% (in retained stubble). This is not a problem where there are low ryegrass numbers and diverse rotations but for much of the Western Australian wheatbelt, where up to 80% of crop grown is wheat, it is a serious challenge. I believe that genetic engineering offers significant potential in this regard—more on this later.

Stubble reduces evaporation and, consequently, there is more soil water available for plant growth and microbial activity. Where stubble is flattened and small rainfall events occur, the stubble can actually prevent water from getting into the topsoil. Conversely, large rainfall events are well captured by stubble. Indeed, a thick stubble layer will allow soil microbes to go through more generations and convert more organic carbon to nitrogen through free N-fixing bacteria *(see section 9.3)*. Stubble also slows wind speed at the soil surface and

The foreground shows taller lupins where stubble is tall.

can make transpiration more efficient and the canopy more humid. This may have the negative consequence of promoting leaf disease in the crop due to increased humidity and non-diverse rotations.

Research at Swift Current, Canada, has shown that a consistent 10-15% grain yield increase was found in legume crops grown in tall stubble compared to short stubble (Cuthbert *pers. comm.*). The researchers sowed spring wheat, desi chickpea, field pea, and lentil crops into cultivated short (17 cm) and tall (25–40 cm) spring wheat stubble. The various stubble treatments were manipulated just before seeding, without snow catch complicating the trial design. (Note: In their climate it becomes warm quickly after seeding and it may be dry for long periods afterwards. Our situation is obviously different.)

Compared with cultivated stubble, the average yield benefits for seeding into short stubble were 6%, 10%, 4%, and 4% for spring wheat, chickpea, field pea, and lentil, respectively. Seeding into tall stubble increased the average yield by 12%, 13%, 6%, and 20%. The standing stubble changed the microclimate near the soil's surface by reducing soil temperatures, solar radiation, wind speed and evapotranspiration—even after the crops grew above the stubble. Crop height was also influenced.

Spring wheat, chickpea, field pea, and lentil all grew an extra 2–7 cm taller with tall stubble than with cultivated stubble. The lowest pod height was about 2 cm higher with short stubble, compared to cultivated stubble, and a further 2 cm taller than short stubble when grown in tall stubble.

Only chickpeas (in 1998) yielded less when grown in tall as compared with short stubble. This may be due to shading effects on the relatively small chickpea canopy that grew entirely within the tall stubble.

## 8.3 More efficient fertiliser in bands

No-tillage ensures precise placement of crop seeds and fertiliser. The fertilisers placed near the seed at sowing are usually granular, although there is a trend for more farmers to adopt liquid fertilisers. Liquid N and P fertilisers cost 15–40% more than granules. In some soils they are well worth using, at least for a portion of the fertiliser. I suspect that 20–35% of the N and P fertiliser requirements may come from liquids in future evolving no-till systems.

Liquid fertiliser is being placed behind the knife opener.

Since our soils are typically some of the most nutrient deficient of any in the world, liquids give a positional availability advantage that granules cannot. This is particularly important for micro-nutrients of Cu, Zn, Mn and Mo which are not mobile. A continuous stream of liquid fertiliser carrying these nutrients ensures that all seedlings have a strong probability of intercepting a supply. In contrast granules flow unevenly and it is highly likely that many of the crop seeds will not be located close to a fertiliser granule.

No-tillage encourages precision. With legume crops we have shown a grain yield advantage to placing non-leaching fertilisers at depth, below the seed. With some seeders banding below and to the side is possible and likely beneficial. Banding causes the weeds to be disadvantaged which means greater potential yields. Some long-term studies in the Canadian Prairies and the Pacific North West (USA) have shown better weed control with fertiliser banding compared to fertiliser being evenly spread.

Nitrogen banding is important as it gets nitrogen in close proximity to the crop's seeds and a distance away from the stubble in the inter-row. This effectively forces the likely carbon-rich stubble to break down in the absence of fertiliser nitrogen and puts healthy biological pressure on the bacteria in the soil to be free-living nitrogen-fixing bacteria.

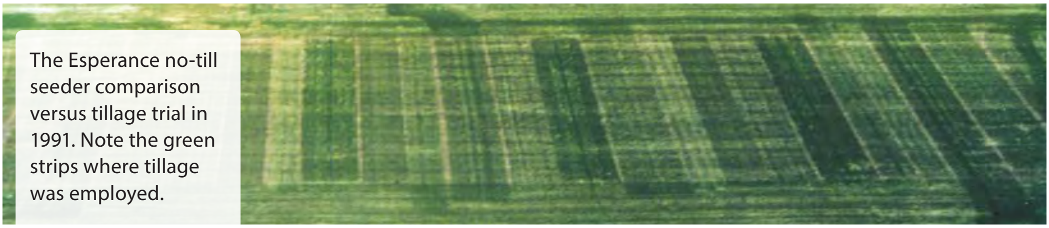
*For more information on nitrogen and soil bacteria see section 9.3.*

## 8.4 Slower early growth

Cultivated soil will make plants grow more quickly as the soil is softer. Also, since no-tillage does not stimulate an early release of N through the breakdown of organic matter (unlike tillage), the N supply is less with no-till. This lower N supply also slows the growth of a no-tilled crop. This can work to the plants' advantage as the growth rate is slowed.

Arguably, the number of plant tillers is also reduced. However, my experience has been that the no-till crop tillers less but also loses fewer tillers as it grows to maturity.

The slower early crop growth means less water is used early in the plant's life. If a drought type year occurs then the water can be available later on to take the crop through to maturity. Slower early growth may be seen as a negative in higher rainfall years and research by Jeff Ladd (South Australian) has shown that an extra 20 kgN/ha might be needed in young no-tilled soils to compensate. In high rainfall areas this less N release has not generally been a concern as it has effectively enforced canopy management in these environments. Nitrogen is then applied later in quantities appropriate to match subsequent rainfall.

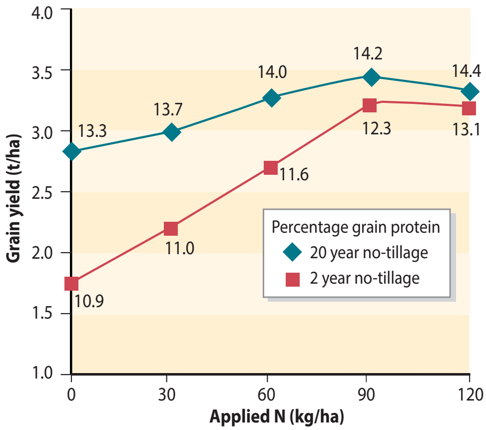


The Esperance no-till seeder comparison versus tillage trial in 1991. Note the green strips where tillage was employed.


Conventional tillage on left and no-till trial on far right (showing as darker green).

Long-term research by Lafond in Canada has shown that after many years of no-tillage, the soil has an increased ability to release N that a tillage-degraded soil does not (see the graph below).

**Canadian 2002 wheat yield response and protein (%) to N with history of no-till (Lafond, 2003)**



Jim Halford's soils (centre) after two decades of no-till have soil organic matter levels close to native soil levels as shown by organic matter staining (right) compared to long-term wheat fallow farming (left).


## 8.5 Less early tillering

In Australian agricultural environments it is not always beneficial to have tillage-induced crop tillering. A prolific amount of tillers are generated by tillage that cannot always be sustained through to the crop's maturity. A 'no-till induced' tiller reduction does not appear to have reduced cereal grain yields in most situations.

## 8.6 Softer subsoil with no-till

There is currently widespread promotion of tramline farming in Australia. While I agree that it will reduce compaction and is of value at further softening the soil, I believe there are many soils where the benefit will not be as large as some espouse. Reducing compaction is a desirable activity and it does give strong economic benefits in loamy sandplain soils of WA.

However, my own unpublished data suggest it may have limited value on south coast duplex soils and this may extend to the other 75% of Western Australian soils that are duplex in nature. In several trials in 1986 I tested compaction and deep ripping. Whereas other areas of the state sometimes obtained a 50% response to deep ripping I found some deep sandy soils that did not respond to ripping, despite deliberately compacting wet sand with 20 passes of a heavy tractor.

This work was followed up by researchers at the University of WA (Daniel and Cochrane) and they showed that sandy soils with a uniform particle size, like those I tested, were unresponsive to deep tillage, in contrast to sandy loams with a range of particle sizes.

*GPS guidance is discussed further in Chapter 22.*

Using tramlines and GPS guidance has many other economic benefits through by reducing over-lap and precision pesticide and fertiliser placement.

No-tillage itself does soften soil through time and this occurs in at least four ways:

1. Less traffic on the soil.
2. More root growth from earlier time of sowing and less traffic causing root damage.
3. More organic matter on the surface and in the root zone—this ensures increased and sustained slow microbial activity, and also creates soil heaving through organic decay.
4. Limited soil structural damage from tillage activity.

'The more that farmers retain stubble, the more they see the value of the stubble…'

CHAPTER 9:

# Greater biological activity

**THE ADOPTION** of no-till means that the soil organic matter is largely retained on the surface. No-till use generally inclines the farmer towards retaining stubble. The more that farmers retain stubble, the more they see the value of the stubble—especially where diverse rotations are practiced. Pioneer Chilean no-tillage farmer Carlos Crovetto believes passionately in this philosophy, so much so that he has written a book called *Stubble Over The Soil*.

Carlos says that 'stubble is for the soil as the grain is for man'. In other words stubble is food for the improved life of the soil and this will be reflected in improved crops. Many soil microbiologists worldwide promote the retention of stubble for improved soil fertility (e.g. Margaret Roper [CSIRO, Perth], Jill Clapperton [USA], Marcia Monreal [Brandon, Manitoba] and V.V.S.R. Gupta [CSIRO Adelaide]).

Carlos Crovetto, Bill Crabtree and Carlos' daughter Hermana.


LEFT: Long-term no-tilled soil near Horsham, Victoria, looks alive and is softer.

Specific benefits from this activity include increasing the levels of organic matter in the soil, leading to increased biological activity. This in turn leads to increasing the chemical and physical fertility of the soil. This is a total win–win situation for farmers, especially when the price of inorganic fertilisers is considered.

Other benefits that arise from stubble retention are softer soil, indications of more biological activity, the availability of free nitrogen, increases in beneficial mycorrhizal activity and the likelihood of increased resistance to soil disease. These are discussed in more depth below.

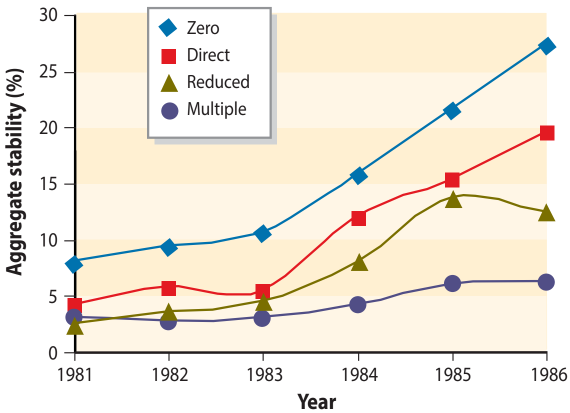
## 9.1 Softer soil

Softer soil is commonly observed by farmers after a few years of no-tillage and in the absence of stock grazing the land. The farmers typically say, 'the long-term no-tilled soil is much softer or I needed to use lower tractor gears in the soil with a tillage history'. It is common for no-till farmers to observe this when they purchase a neighbouring tillage history farm. This is also reported in scientific papers where soil structure improves.

Many farmers believe that their soil just keeps getting softer with every year of no-tillage. Some really tight soils can become very friable with 4–6 years of no-tillage. New no-tillers often think that no-tilled soil is harder, however it is not too firm for good root growth.

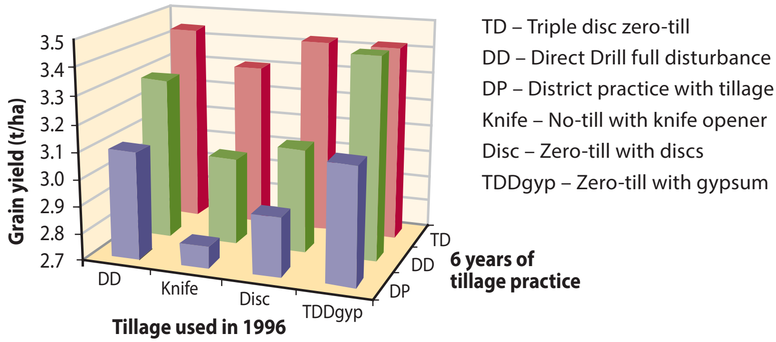
While tillage appears to soften the surface soil it is more a 'feel good' softening than a reality for crop yield response. Tillage, in the long-term, damages soil structure, which actually makes the surface soil firmer. Tillage also makes the sub-surface soil more compact due to the extra vehicle traction. Research and hands-on experience shows that no-till softens the soil through time—worldwide!

**Decrease tillage, increase soil structure**
**(Department of Agriculture, Western Australia—Merredin)**




Softer soils that have been observed by no-tillers have encouraged some farmers to be less concerned with following tramlines. They have observed that their soils are spongier and rebound after vehicle traffic. Although there are some no-till farmers who observe that, once some soil types really soften, tramline farming is needed to reduce compaction.

**Tillage history affects current tillage results**




## 9.2 Increased earthworms indicate more biological activity

Microbiologists often say that earthworm numbers are an indicator of a soil's biological fertility. This is because they are at the top of the soil fauna food chain. Their abundance reflects an abundance of soil life below them in the soil-life hierarchy. With no-till, earthworm numbers proliferate. Before no-till there are often no earthworms apparent and afterwards they are easily observed.

Earthworms enjoy the presence of surface degrading organic matter and they also eat the fungi that live on these dying plants. It seems that decaying plant material, like dying weeds, or decaying stubble, are a good source of slow-release energy. Regular 'three square meals a day' seem to be a good thing for earthworms as well as for humans! In the warmer regions of WA and NSW, ants and termites replace the earthworms in nutrient recycling and building of soil structure.

LEFT: Earthworm casts are common with no-tillage.
RIGHT: Ant activity also increases under no-till.

The underground activity of earthworms and ants is important for creating pathways where gas exchange to depth can occur and improved water infiltration. The channels built underground can be complex and extensive. They allow oxygen and water to get deeper into the subsoil. These physical effects have a profoundly positive effect on plant growth.

## 9.3 Free nitrogen from soil bacteria

There is clear evidence from CSIRO scientists (Gupta, Roper and Roget) that retaining stubble enables bacteria to fix N from the atmosphere. The bacteria responsible are termed 'free-living nitrogen-fixing bacteria' and the amount they may fix is often 15–25 kgN/ha. These bacteria are non-symbiotic and do not require a living host. The bacterially driven process is dependent on the amount and timing of summer rain, the abundance of non-legume crop residual, crop rotation and the length of time in no-till. Long-term no-tillers, without a legume in their rotation, with strong summer rains (50–100 mm) are most likely to experience strong free N-fixing activity. Levels up to 75 kgN/ha have been recorded.

*For more on rotations and cover crops see Chapter 15.*

This is one of nature's exciting activities—and the N is free of charge! Evidence for this is seen in the graph in section 8.4. This build-up of free N-fixing requires an accumulation and retention of organic matter. For optimum build-up of organic matter, livestock should not graze stubble. More evidence of free N is farmer practice and is regularly observed.

The bacteria responsible are those that thrive in the absence of available soil N and the absence of legumes. Rotations without legumes, and where stubble is retained for several years, often produce crops that exceed the N budget expected and are proof of this phenomenon of nitrogen-fixing bacteria. Further proof that this occurs is that soil organic matter levels rise, and crops perform better than expected, given the amount of N applied. Some agronomists have suggested the N must be coming from lightning but this could only account for about 7 kgN/ha, not the 30–40 kgN/ha that is often calculated to be happening.

Perplexed by nature! A group of South African farmers are bewildered by no N response. Compare the plots of 8 versus 56 kgN/ha in foreground and background respectively (given this is the fifth non-legume crop in a row).

There is debate between some scientists and leading no-till farmers regarding the rate of increase in soil organic matter possible under no-tillage and stubble retention systems. Many long-term no-till farmers believe that after 5–10 years their soils experience a rise in organic matter that is much higher than conventional science would expect, especially for sandy soils. Through time, more evidence will be measured and more accurate numbers published. However, there is no doubt that tillage-based agriculture runs down the soil's organic matter.

What drives this and other beneficial effects is organic matter turnover. It is a bit like a business: a healthy business has modest assets but, more importantly, a strong cash flow. More cash in and modest cash out is a sign of a healthy and robust business. It is the same for the soil. While large assets are a comfort they are not the most important sign of a healthy and vibrant business or soil.

## 9.4 Arbuscular mycorrhizea (AM)

Numerous microbiologists (including Gupta, Roper, Monreal, Wright, Abbott) have documented the increased mycorrhizal activity that occurs in no-till systems. These arbuscular mycorrhizea (AM) fungi grow in symbiosis with many crop types. Their glass-type filaments are deposited in the soil each year within the rhizosphere and largely stay intact from year to year, provided tillage is not employed. The filaments can remain because no-tillage does not destroy them—and subsequent crops can use these and can even add to the network.

The AM fungi are like a factory that trades products with the plant. AMs require sugars from the crop, while they have been documented to provide the plant with P, Zn and water. In drought conditions the power of this relationship is clearly evident, with no-tillage crops being able to withstand much drier conditions. Since fungi are able to extract water at very tortuous levels (high pressure suction of 30 bar) in the soil, the plant is able to access water that without this relationship would not be possible. These fungi also provide aggregate stability for the soils and help create a complex web of biological activity *(see Chapter 10)*.

## 9.5 Negative biological activity

An increase in stubble—most evident in high-yielding situations—can mean an increase in pest pressure on crops. In non-diverse crop rotations stubble presents a challenge. Farmers in WA using wheat–wheat rotations sometimes resort to burning the wheat stubble particularly for ryegrass control. While no-till purists like myself usually discourage this, it is unfair to insist on them adopting a practice that will likely cause them to forfeit yield and profit in the short-term—unless there is robust evidence showing the long-term benefits outweigh the short-term economic benefits in such an unbalanced rotation.

The common way to mitigate the negative effects of biological pests (weeds, insects and diseases) is with rotations, varieties, pesticides and stubble. South Americans have developed cover crops to help uncover diseases.

South American cover crops being knife rolled.

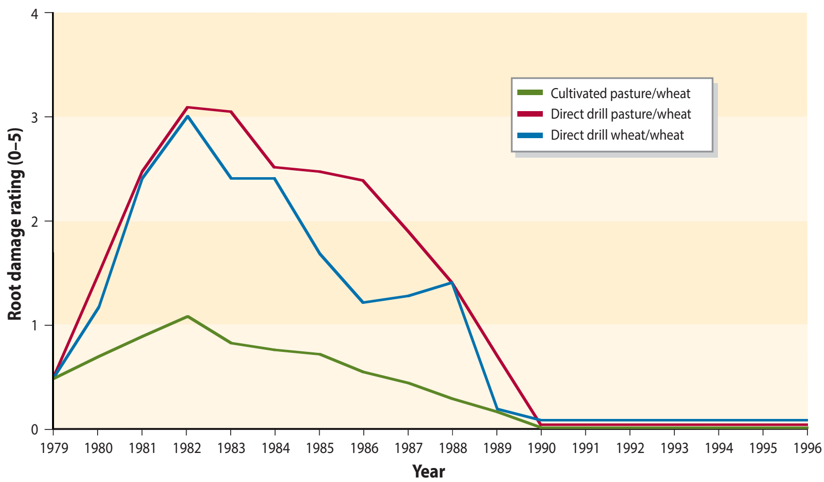
## 9.6 Suppressive soils

South Australian CSIRO scientists have discovered another natural tool to fight negative biological activity. This phenomenon has been termed 'suppressive soils'. While it does not work for leaf diseases it has been proven effective for root diseases.

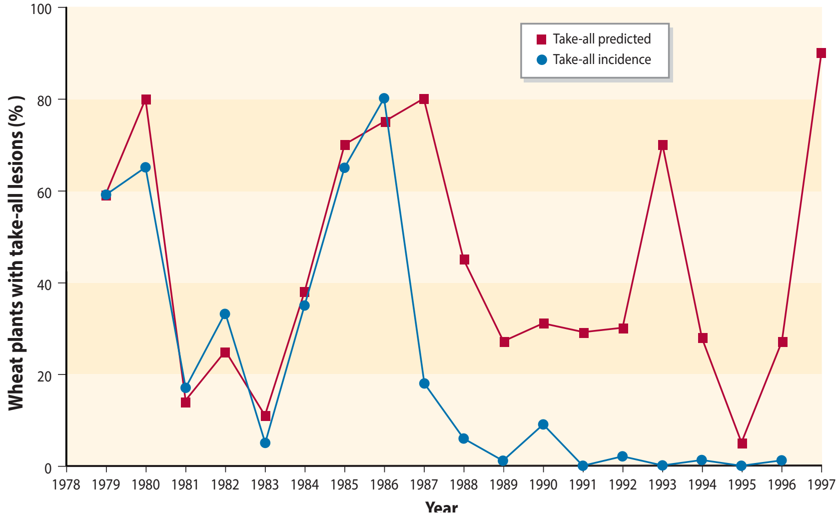
Nature's biological competitors to diseases build up in the suppressive soils. These biological competitors, which do not attack the crop, build up in soils that have had stubbles retained and the soil not cultivated. Both rhizoctonia bare patch and take-all have been suppressed in long-term no-tilled soils due to the increased presence of biological competitors.

*For more on rhizoctonia see Chapter 16.*

**Decline in rhizoctonia root damage in direct drilled wheat at Avon, South Australia, over the period 1982–1996 (Roget)**



**Expected and measured incidence of take-all in wheat at Avon, South Australia (Roget)**




## 9.7 Making soils fertile through biology

With no-till a large portion of the increase in biological activity observed have probably come from the increase in cropping intensity. In these systems paddocks are fertilised every year, growing more biomass, more often than a cereal pasture rotation. The leaking of carbohydrates from the greater amount of living roots through the growing seasons is probably a significant contributor to microbial increases, rather than just the stubble contribution.

The particular contribution of increased carbon and microbial activity has been vital in sandy soils, which are naturally low in clays, cation exchange capacity and fertility. South Australian mallee observations (Chris McDonough *pers. comm.*) suggest that it is in these soils that they have seen the biggest gains, so much so that many farmers would now say these soils are now their most productive, yet they used to be full of weeds and disease and low in fertility.

The fact that these sands are chemically infertile, compared to clays and loams, mean that what happens in them in terms of nutrient mineralisation and retention through microbial activity is readily plant-available. This increased 'microbial fertility' is also valuable because it means that when it rains through the season, there is a flush of microbial activity that very soon leads to an increase in available nutrition. This coincides with the increased crop growth, so the crop actually gets the nutrition when it needs it most. People often worry about putting too much N up front in low rainfall areas and not getting a chance to put more out later. This natural system means that more N is supplied as needed later.

The system also means that, over summer, much of the nutrition is held in the microbial biomass and is protected from leaching rains, particularly in sandy soils with big summer rains. A difference of about 50 kg/ha was measured in 2000 (V. Gupta) over the fallow system which lost much of its N from leaching after a wet summer.

Crops in adjacent paddocks in the Wimmera region during drought conditions.
ABOVE: Barley crop showing normal fertility.
BELOW: Excess organic matter (mainly N) has caused the crop to 'hay off'.

## 9.8 Caution with biological fertility

This aspect of soil fertility is the least understood in a scientific sense and consequently is probably the most exploited by new agricultural product inventories. The term 'snake oil salesman' comes to mind. There are new companies coming and going regularly who want to sell farmers a special biological brew that will supposedly replace most of the proven nutrient requirements with a single dose of snake oil.

Perhaps the reason this happens is because farmers have seen free-living N-fixation occur *(see section 9.3)* and their respected agronomists and some respected scientists do not support this science. From here they may conclude that there are other biological fertility factors ignored by scientists, so they go looking and there has always been salespeople who will sell 'pseudo fertility' without supporting independent data.

I say to such farmers that they should not trial these products at their own expense. Rather, they should encourage the salesperson to pay for an independent researcher to do proper trials and bring the results back next year. Then the farmer can consider whether to use the product.

Remember, big plant roots mean little and can be achieved simply and cheaply with off-the-shelf growth hormones. What matters is yield. Farmers don't want or need big plant roots at the expense of grain yield or increased organic matter above the ground.


'The biological activity of no-tilled soils, with its stubble retention and use of cover crops, will be much greater than soils with multiple tillage…'

CHAPTER 10:

# Increased macro soil biology

**ANOTHER** heading for this chapter could be 'nature's way of tilling with insects and earthworms'. Many of the ideas presented in this chapter come from Brasilian entomologist Dirceu Gassen and they are used with his kind permission. Strategies that have been learnt in Brasil (Brazil), an older and more experienced agricultural landscape, are transferable in principle to our Australian landscape.

In Brasil they have been no-tilling since 1972 and now commonly grow two-and-a-half crops a year. They have experienced over 75 crop sequences during this time. This contrasts with our environment where we can still only grow one crop per year and few people have been no-tilling for more than 15 years, consequently with 15 crop sequences. This encourages us to learn from their experiences. Diverse rotations are very useful in managing soil pests but unfortunately in Australia we are limited in robust and diverse crop types.

## 10.1 No-tilled soil is biologically different!

The biological activity of no-tilled soils, with its stubble retention and use of cover crops (in Brasil), will be much greater than soils with multiple tillage. This is because the no-tilled biological web will establish food chains that are almost unknown in multiple tillage systems. A new equilibrium needs to be established.

In tropical and subtropical regions the soil insects (like termites or white grubs) will develop on stubble and plant residues. They do the initial fragmentation of the organic matter. Some insects dig holes and incorporate organic matter in this process. This allows both rainwater to be absorbed and the exchange of gases into the soil. Plant roots will then grow through these insect holes. In southern Australia's more temperate climates, earthworms and ants replace the soil-dwelling insects of the tropics.

When first adopting no-till, farmers were sometimes worried about unknown soil fauna. Traditional entomological recommendations for pest control are historically directed towards multiple tillage ecosystems. Consequently, such recommendations usually focus on a few species that frequently reach damaging levels. Studies can sometimes be made in laboratories under environmentally controlled conditions, the results of which are too simplistic to draw conclusions from for no-till systems.

No-till fauna needs to be analysed as a complex system with long-term interactions and intensive biological activity. Local research and field data are needed from scientists working in many different research areas (pests, diseases, weeds, organic matter, microbiology, allopathic effects and plant nutrition) and analysed together. Stubble and organic matter will bring the soil to a new biological, chemical and physical equilibrium.

## 10.2 Migratory pests—the 'r' strategists

The pests and fauna that are known to migrate from other areas and have a high reproduction rate are classified in biology as 'r' strategists. These creatures increase their population and reach damaging levels very rapidly. A couple of weeks after spraying with insecticides the population numbers of these 'r' pests may recover to levels that can again cause damage. Aphids, caterpillars, locusts and stink bugs are typical 'r' strategists and are common pests in multiple tillage systems. They travel from elsewhere and are capable of flying long distances.

Soil-dwelling pests are secondary pests under a multiple tillage system. Physical control with tillage, combined with high soil surface temperatures on sunny days and the absence of stubble, does not allow this fauna to establish under multiple tillage systems. There is therefore not much macro biological activity to study.

## 10.3 Steady state—the 'K' effect

With no-tillage, where stubble is left on the soil surface, resident fauna will establish throughout the year. Species with a low rate of reproduction and a longer life cycle are classified as 'K' strategists. These populations will build up slowly after some years under no-till. In this group are pests, predators, parasites and saprophytic organisms that live off dead matter.

The underground fauna of a no-till soil is similar to the fauna of native pastures. Insects such as crickets and white grubs will occasionally cause damage in no-tilled crops.

Soil cover with stubble and no-till stimulates soil fauna activity. Plants and stubble will maintain the soil surface temperature and humidity at levels that are favourable to living organisms. Plants and stubble are also the basic food for a group of organisms that will start the food chain. Predators and other natural enemies will establish on these species in the farmland, and will help provide biological control of pest species.

With the increase of the species' diversity, natural biological control occurs and populations will reach equilibrium. Keeping the soil covered with stubble and plant matter will improve the natural control or suppression of pests, diseases and weeds.

## 10.4 Monitoring is useful and educational

Under no-till, monitoring the potential pest population is helpful in order to adopt strategies that aid bio-control and suppress pest populations. The use of a hoe or a mattock to scrape the soil's surface is a practical and quick way to search for soil dwelling insects (see photo). If there are open holes in the harder soil layer it will be necessary to excavate deeper to find the insects.

Earthworms, grubs and ants proliferate in long-term no-tilled soils.

Pest fauna under no-till can be grouped into 'resident fauna' and 'fauna associated with previous plants'. The resident fauna will be present all the year, such as crickets, white grubs, wireworms, termites and slugs. These can be monitored, the damage potential predicted and control strategies planned in advance.

The fauna associated with weeds, soil cover, plants and crops present before sowing can potentially become pests themselves. Insects choose host plants to feed on and live in. When these plants are killed with herbicides the insects will then move onto the crop, causing damage.

## 10.5 Use precision insecticide placement

Applying insecticides broad-spectrum over the whole crop is common in Australian agriculture. However, adopting a precise pesticide management system will provide a biological balance. Insecticides that kill all insects create a vacuum for invading 'r' strategists. It also selects for other insects that can tolerate these insecticides and, in the absence of insect competition, these may proliferate. As Sam Neill said in the movie *Jurassic Park*: 'nature will find a way'.

Applying insecticides directly to the seeds and only the crop row will enable some of the desirable soil fauna to survive and compete with potential invading insect species. Most crops only need protecting at the seedling and podding stages. Leaving the inter-row untreated when the crop is young provides a safe space for 'K' strategists to persist.

## 10.6 Slugs and snails

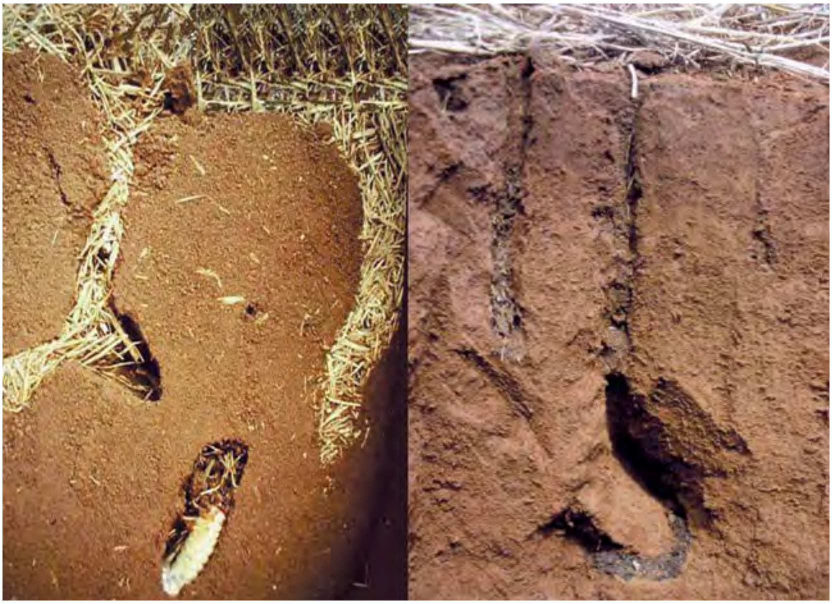
Slugs and snails are two major pest problems for southern Australian no-tillage farmers who retain all their stubble. They occur in specific regions and have been most difficult and expensive to keep at manageable levels. South Australian researchers have found that cabling the stubble on a hot, dry day lowers their

Snails are a huge challenge in areas of South Australia where there is free lime in the topsoil. The calcium in lime assists in shell growth.

numbers significantly and then baiting snails on the first April or May rain is effective. High rainfall areas are very suited to slugs, and soils with free lime are a haven for snails.

Brasilian experience would suggest that the broad-spectrum insecticides commonly used have the potential to make these pests worse. Many 'K' strategists already exist in our stubbles, eating the larvae of slugs and snails. Their numbers are being depleted by broad-spectrum insecticide use. More specific insecticides or their precise use in a paddock situation would be a way of working with the biological agents. Research into the biological cycles of these pests would also be very useful. Know your enemy!

Deep burrowing grubs create large air pores that can capture heavy rainfall events.
PHOTOGRAPH COURTESY OF DIRCEU GASSEN.



Cross-section of South America loam in long-term no-tilled soil—water infiltration is greatly improved. Earthworms and ants in Australia can have a similar effect.

PHOTOGRAPH COURTESY OF DIRCEU GASSEN.

## 10.7 Understanding biological systems

The main factor limiting robust integrated pest management is our imagination and understanding of the biological complexities. The Brasilian experience shows us that all pests, diseases and weeds can be controlled within the no-tillage system, thereby removing the need to return to multiple tillage of the soil.

There is a need for more study and extra work when initially adopting no-till. The level of human resources available for research and a real desire to learn how to practice true sustainable agriculture will determine how successful and painless the adoption process will be, particularly in relation to soil fauna.

'The two most important things to achieve with sowing are correct seeding depth and sowing into adequate soil moisture…'

CHAPTER 11:

# Type of openers

**THERE ARE** two main types of no-till openers used worldwide for plant establishment: disc openers and knife points. Over 90% of no-till in Australia is performed with knife openers. Canada exhibits a similar statistic. However, South American no-till farmers exclusively use disc openers, while no-till farmers in the United States are more evenly divided between disc and knife openers. There are valid reasons for choosing each type of opener and it may not be wise to insist on a 'one-only' approach globally.

In some environments it is useful to add a leading disc coulter to both. This improves the ability to cut through plant material and avoid blockages at sowing. There is also a unique opener that combines the disc and knife openers. This is the Cross Slot—there are only a few of these in commercial use in Australia, yet they offer a potential advantage in some conditions.

*For more on leading coulters see section 11.7.*

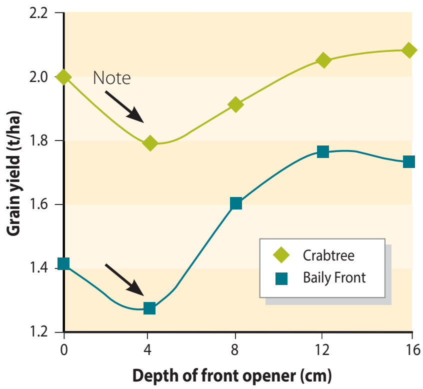
## 11.1 Buffalo #1 and #2

Dwayne Beck recounts the interesting analogy of how nature plants seeds in his prairie environment of South Dakota. The hooves of Buffalo #1 push seed into firm, moist soil. Then Buffalo #2 comes along and scuffs loose soil over it. Nature requires both Buffalo #1 and #2 for the best plant establishment, particularly in dry and warm soil conditions. This idea is applicable to Australian farmers in warmer regions, in heavy soils and when significant evaporation can occur at seeding.

Northern NSW and Queensland with warm season crops should especially take note of Buffalo #2 to get a good strong emergence. The importance of Buffalo #2 is not as great as Buffalo #1 for germination and emergence in cold and the more frequently moist conditions that are more typical in southern Australia. However, it is still important when dry conditions occur at seeding.

Two tillage trial results of my own from 1986 show the value of placing the seed into firm, moist soil. I experimented with two rows of openers whereby a narrow (5 cm width) cultivation opener was followed by another narrow (5 cm) opener, which placed the seed. Interestingly, where the tillage opener was used at 4 and 8 cm depth it significantly decreased wheat emergence, growth and also, on one occasion, yield (Crabtree site). The lower growth was overcome by 12 and 16 cm deep cultivation, but at some extra fuel cost.

**Wheat yield at two WA south coast trial sites (Crabtree and Baily Front) showing the impact of changing the depth of a leading opener in 1986**




Subsequent farmer experience with double disc seeding and no subsoil cultivation further confirmed that minimal subsoil cultivation is a valid economic option. Both long-term no-till farmers and long-term trials show that soils soften with a history of no-tillage and where the soil is not driven over. This further reduces the need for subsoil cultivation. Extrapolating this data indicates that controlled traffic farming likely has a real benefit in these situations. However, sandy loamy soils in WA have been shown to benefit from subsoil tillage even with controlled traffic in place. They recompact naturally.

*For more on subsoil tillage see section 11.5.*

## 11.2 Disc openers

There are two main types of disc seeders—single disc and double disc. There is also a combination of both referred to as a triple disc. The single disc openers travel at a slight angle, sometimes with an undercut angle as well. Seed and fertiliser is placed behind the disc. Most double disc seeders have one disc leading the other. Some, however, have both discs opening the soil equally.

There are many brands of disc openers made globally. The commonly used double discs in Australia are the Canadian-made K-Hart, the Australian-made Gessner-Walker, Deslisle and Agrodrill double discs. The Great Plains and John Deere double disc openers were popular in WA in the early 1990's. The Australian Daybreak single disc has become popular recently. There are many South American disc seeders—yet few of these have been imported into Australia as of 2009.

The greatest advantage of a disc seeder is its ability to seed through thick residue while not stimulating weed germination at the time of sowing. The farmer no longer needs to remove or reduce thick stubble, a common practice when using knife points on narrow rows. The discs do not disturb the soil and this suppresses weed emergence, leaving weeds largely undisturbed and near the surface for biological degradation. The discs fit the adage for weeds: 'What do you do with sleeping dogs—stir them up and shoot them, or let them lie?' Burying seeds with shallow tillage protects them from temperature volatility and predation by insects, particularly ants. Another benefit farmers report is that the speed of sowing can increase up to 18 km/h.

Disc openers, however, can cause hair-pinning of straw. Hair-pinning occurs when the straw gets bent around the disc and is forced into the seed zone. The seed is then not placed into firm soil. Subsequently dry air, bacteria and fungi that can proliferate in the root zone disrupt crop emergence.

Farmers can manage the amount of hair-pinning with disc seeders by using several different approaches. They can lift their seeding rate; avoid sowing into thick residue when the surface is wet; avoid grazing stubbles to leave them standing; and harvest the previous crop tall.

Rotating away from cereals towards pulse crops and canola will also minimise hair-pinning as these stubbles have less biomass and will break down more quickly than cereal stubbles do. This does not always optimise profitability, although it does improve crop diversity.

Disc openers are not as effective as knife openers for incorporating the herbicide trifluralin, which is important for ryegrass control in southern Australia (as discussed in section 6.3). Trials I have supervised with 1.5 L/ha of trifluralin (480 gai) typically gave a 50–60% ryegrass control with disc openers compared with 75–85% ryegrass control when using knife openers. These results occurred even with the aid of the wavy or turbo coulter and when travelling at high speeds to try to increase the amount of soil that might cover the trifluralin, which leads the double disc openers. Some farmers boast that the Daybreak discs can be set up for better ryegrass control than knife openers, although I am sceptical of such an improvement.

The initial adoption of no-tillage seeders in WA in the early 1990's was predominantly with disc seeders. Except for the south coast, discs have generally decreased in popularity since then, although there is a renewed enthusiasm to encourage farmers to use them currently. Some experienced no-tillers who have seen their soil soften with no-tillage are now experimenting with disc seeders again. New no-tilled soils in heavy and sticky soils often require softening with knife openers for a few years before the soil might be suited to sowing with disc seeders.

Disc openers are not popular in the driest regions of Western Australia. There are several significant reasons for this. Less ryegrass control is possible due to their reduced ability to incorporate trifluralin; they have less ability to penetrate heavy soils; and less ability to chase deep moisture. The cost of their maintenance is also an issue as is the increased risk of fertiliser toxicity. It is also commonly observed that knife point openers are more effective at harvesting water than disc openers and this is valuable in dry regions and dry years.

### WHERE TO USE DISC OPENERS

Disc openers are preferred in—but are not exclusive to—regions where:

- farmers can regularly grow more than 3 t/ha of wheat;
- rainfall is greater than 400 mm annually;
- soils are acidic and sandy;
- soil compaction is not a problem;
- rocks are prevalent; and
- where wind erosion is a high risk.

*For more information on disc seeders and technology see WANTFA's publication 'Disc seeding in zero-till farming systems: A review of technology and paddock issues' at www.wantfa.com.au.*

The success of disc seeders in South America has encouraged Australian farmers to reconsider the use of disc openers. The adoption of no-till in South America has occurred as part of an agronomic package that includes cover crops and glyphosate-tolerant crops. Without cover crops and both glyphosate-tolerant and glufosinate-tolerant crops being restricted for southern Australian farmers, I feel that discs may remain relatively unpopular technology.

## 11.3 Knife openers

The knife opener is commonly either 12 or 16 mm wide and 100–200 mm long. These two widths are due to the width of tungsten that is manufactured. The 12 mm width is commonly used on seeders that have break-out less than 450 lb per square inch or where hydraulic tynes are used. Sowing speeds with such openers are typically 8–10 km/h. The 16 mm wide openers are used for spring tynes with break-outs of 600 lb, where the narrower openers are not strong enough to reliably withstand high spring break-out pressures. Hydraulic tynes place much less stress on openers and therefore the 12 mm wide opener is adequate.

The knife openers are commonly set at 70–80 degrees from horizontal. This angle appears to provide a good compromise between soil throw and soil shatter in most soils. The more vertical the angle of the tines the greater the soil resistance, the greater the soil fracture and higher the probability of soil smearing in heavy soils.

In clay soils, subsoil cultivation is rarely desirable. Large clods can be ripped up, causing the seeding slot to stay open. This results in poor seed-to-soil contact. Farmers commonly use shallow points on such soils, where the opener goes only to the depth of desired seed placement.

Shallow knife openers experience less soil resistance and are sometimes used on seeders that do not have strong break-out pressures. Setting the opener at a more horizontal angle also reduces the risk of smearing. When no-tillage and

ABOVE: Harrington knife opener.

LEFT: Deep slots on heavy soil do not give good seed placement or seed–soil contact. Ray Harrington uses a great phrase—'do not no-till to the sound of the motor'.

press wheel use first began in Western Australia there was a general fear that smearing would be a common problem on heavy soils. To our delight this is not the case.

I was present in Katanning in 1997 with a group of over 100 farmers. A discussion was held on the risk of soil smearing and sealing. I was asked the question: 'Is it a problem?' I threw it back to the group and we discovered that about 30% of those attending had sown into such an environment where they would have expected smearing and sealing over the previous two seedings. Interestingly, none of them had experienced the problem. Why? Pingrup farmer John Hicks felt that perhaps it was because heavy soil would always be moist at sowing time. Evaporation is low, dews are common, the sun's rays are weak (late May–early June), the seed zone is sheltered in the furrow and small rainfall events are likely. These conditions do not favour soil drying in the furrow, next to the seed, therefore perhaps this is why smearing doesn't occur. John's logic sits well with me.

The two most important things to achieve with sowing are correct seeding depth and sowing into adequate soil moisture. Obviously dry sowing is also an option and is often used in Australia to ensure that large farms are able to sow their crops in the correct window. Stubble retention allows dry sowing with minimal risk of erosion. However, weed control then becomes the critical factor in a successful cropping programme as a knockdown herbicide will not be used, placing more pressure on soil-active or pre-emergent herbicides.

Common knife openers currently used in Western Australia are the Harrington, Primary Sales, DBS, Maxi Point, Farm Innovation and Fowlers. Other less common openers include the Keech, the Baker Boot, Janke and a range of others.

A DBS opener—very popular in Western Australia.

## 11.4 Closer tools with knife openers

Knife openers need to be accompanied by either a closing tool, another opener or a press wheel to ensure adequate soil cover over the seed. The purpose of the closing tool is to ensure that soil falls into the narrow slot created by the knife opener. Once the slot is closed the seed can then be safely placed in this zone without it falling the full 8-9 cm depth of the opener. Such soil disturbance, however, can cause some soil drying in the seed zone. The seed is placed immediately behind the closer and a wave of soil from the closer follows and subsequently buries the seed. Often the seed coverage from the closer is adequate—but is not the best technique of soil cover to use. The most reliable and precise closing tool is a second opener and then the press wheel.

*For more about closers see Chapter 13.*

The closer tool is most often a hard-surfaced plate of steel made of tungsten or some form of hard facing welding that is unlikely to be dislodged. The closer plate is usually located in the wave of soil created by the knife opener as it moves through the soil. This is usually about 15 cm behind the knife and, in the case of the Harrington knife point, is attached to the opener.

There are two other dominant closer tools. They are the short, flexible hose attached to the lower part of the tyne as with Primary Sales or Maxi Point, and the strip of firm plastic (unique to Agmore fabrication) that is attached higher up the tyne. Both are adjustable so that seed can be dropped either close behind the closer or farther away to give a choice of seeding depths.

## 11.5 Depth of opener

In Western Australia farmers most commonly disturb soil 8–9 cm down. This creates what most farmers require: some sub-soil cultivation below the seed, and a well-defined soil profile for water harvesting.

Primary Nichols seeder capable of deep sub-soil tillage while 'no-tilling'.

The original Agmore closer tool. It is now made with plastic and is quite popular.

There are some soils that do require some form of deep cultivation to optimise yields. The soils that are most responsive to deep tillage are typically the sandy loam regions such as WA's Wongan Hills and Eradu sandplains, east of Geraldton. Other soils rarely give an economic benefit from deep tillage, especially when the increased amount of fuel and horsepower required for such deep cultivation are taken into account.

As mentioned earlier, it is not desirable to cultivate below the seed zone in heavy soils. When they are wet, heavy soils are soft enough for plant roots to not

The Gessner Walker residue manager.

require subsoil tillage. It is more likely that soils will be unnecessarily disrupted by such tillage. The term 'create a seedbed' through tillage, is now believed to be a misnomer. Nature is a great healer—give the soil time, food and rest from tillage and traffic and it will heal itself.

## 11.6 Dedicated banding seeders

There are at least three dedicated no-till seeders that reliably and precisely band fertiliser safely away from the seed and give precise seed depth. They are the ConservaPak™ (now sold through John Deere), the Väderstad Seed Hawk® and the Seed Master™. They have become increasingly popular in Canada, their country of origin, and are now being exported globally. Many other large seeder manufacturers are also attempting to copy these seeders.

The Ausplow DBS seeder and the Primary Nichols seeders are Western Australian-made and have the advantage of being able to separate the seed and fertiliser. Their mechanism for this is not, however, precise, although both seeders do well at placing the seed and fertiliser near the right zones.

The extra value to be gained from such precision seeders has yet to be weighed up by any possible subsoil tillage advantage that may exist. Farmer experience and observations suggest it could be significant—particularly in marginal soil moisture conditions and with crops (like canola) that are not easily established.

## 11.7 Leading coulters

Leading coulters are discs, either paired or single, that cut residue. Some farmers like to have such leading discs as an option, particularly in front of knife openers when melons, vines or other stringy weeds that need cutting are present. This allows the knife openers to follow unchecked. Leading coulters are sometimes also used to place fertiliser at depth in front of the seed opener.

The angle of the opener is often 0 degrees, although some paired coulters are at 3–5 degrees, in balance with each other. The longer the horizontal arm attached to the coulter, the more stable the coulters. Wider angles give more soil throw.

The Bougault seeder has the capability to place nitrogen between the sown crop row, called mid-row banding. This idea is not as relevant with our sandy soils, although the discs can provide some cutting action on viney weeds.


LEFT: Jim Halford, pictured here in 1998, released the first precise no-till knife opener that banded fertiliser away from the seed in 1988—which he named the ConservaPak™, now sold by John Deere.

BELOW: This Turbo leading coulter is capable of improving trifluralin efficacy by 10–20% over plain disc openers.


'A useful option is a residue manager that shifts or holds the residue, enabling an opener to pass without blocking or upsetting the seedbed…'

CHAPTER 12:

# Seeder set-up for stubble management

**SEEDERS** need to be balanced and the modules spaced out to aid stubble flow and to help avoid sideways movement of the bar when under load. For adequate stubble flow a rule of thumb is that the straw needs to be at least half the length of the distance between all hindrances or barriers within the bar. Most modern seeders are well set up to manage both of these problems.

## 12.1 Modifying existing seeders

When first getting into no-till, farmers often modify their existing seeder. Old drills or combines (as we call them) can be readily modified as a cheap way of starting the no-till journey. Many Western Australian farmers in the early 1990's did it by modifying a standard combine, an air seeder or a chisel plough.

### MODIFYING A COMBINE (SEEDER)

Here are five easy steps to modify a combine:

1. Block off every third seed and fertiliser run and this will widen the row spacing from 18 cm to 25.5 cm. Remove the spare tynes.
2. Add another horizontal beam to the front and the rear of the seeder (combine).
3. Place tynes on these extra ranks.
4. Strengthen the tynes by adding an internal spring, to give up to 300lb break-out pressure, if possible.
5. Lift the box, or place a hydraulic fan with a manifold, to move seed to the openers and finally fit 12 mm knife openers with closers to the tynes and add press wheels.

LEFT: A Gessner Walker residue manager was invented by double disc seeder producer John Walker from Merredin.


One of the first modified economical no-till seeders—thanks to 'Blue'.

To convert a chisel plough is quite simple. Farmers simply attached knife points, air hoses and press wheels with an air cart to follow. Chisel ploughs are typically at 30 cm row spacings, which works well with the incorporation of the herbicide trifluralin.

## 12.2 Residue managers

Where stubble is thick, farmers have to consider all options for seeding through it. A useful option for some is a residue manager that shifts or holds the residue, enabling an opener to pass without blocking or upsetting the seedbed.

The only practical residue manager of which I am aware that has worked so far in our Australian conditions is a Gessner Walker residue manager. The Yetter residue manager has not been popular in Australia—although apparently it works well for wide row corn crops in the US.

The other increasingly popular way to manage residue is through using GPS-guided auto-steer. This enables sowing to be done between the rows of the previous heavy crop residue. It works best on row spacings of 25 cm or more. Early sown pulse crops can use wider row spacings without lowered yield.

## 12.3 Shape of tynes and trash tubes

Dedicated no-till seeders commonly have vertical tynes. This is to aid stubble flow. Similarly, edge-on tynes are also popular. If modifying a chisel plough for no-till purposes a farmer needs to be aware that the stubble will ride up the wide 'C'-shaped tyne resulting in blockages, especially if continuously cropping cereals.

Example of a steel trash tube from Primary Sales. Farmers have made their own plastic tubes to do the same task with some success.

Many farmers use trash tubes as part of their set-up. These are tubes made of polypipe or steel that are placed above the opener in a vertical position. Trash tubes can help to seed through 20–30% thicker stubble.

As my agronomist friends Wayne Smith and Dwayne Beck say: ‘We should not use the word ‘trash’ as it infers something negative’. Stubble, when managed correctly, is a powerful force for good and for improving soil health, as discussed in Chapters 9 and 10.

‘Press wheels are an essential part of the crop establishment package, especially in marginal soil moisture conditions …’

CHAPTER 13:

# Press wheels and harrows

**PRESS WHEELS** are an essential part of the crop establishment package, especially in marginal soil moisture conditions. They are not always beneficial in wet soil conditions, particularly on heavy structureless soils with little stubble cover and little or no history of no-till. However, mature no-tilled soils rarely have problems with press wheel use. This is due to improvements in the soil's structure.

Structured soil requires firming around the seed zone. Every long-term no-till farmer I know uses press wheels. In dry soils press wheels are essential for even plant establishment. When I first began experimenting with different press wheels in 1986 they were rarely used. Farmers were experimenting with Flexi-Coil packers, finger harrow and heavy harrows to level the soil and give more even seeding depth. The pressing and soil disturbance caused by these tools caused a doubling of weeds while only a partial increase in crop establishment. This led me to conclude that precise pressure over the crop row only would be more beneficial. While this concept was already adopted in Queensland, at the time it was new to WA, which has now wholeheartedly embraced press wheels and no-till farming.

It is interesting to note that all effective disc seeders employ press wheels. When no-till was first adopted farmers noticed the clear benefits associated with the precise and firm seed placement obtained by using press wheels.

Press wheels also assist in making the seeding depth more precise with knife openers. Sometimes soil clods fall into the furrow behind the closer, but press wheels can squash these clods and allow the crop to emerge from below. Some openers give a large variation in seeding depth with some seeds being placed too deep. These seeds are unlikely to emerge, especially in dry conditions. Press wheels can reduce this depth by about a third, as well as giving better seed–soil contact, hence ensuring more reliable establishment  across a range of soil types.

So, what about harrows? Many farmers use harrows and they do offer some benefits. However, their value is limited and they create problems and challenges of their own. The main problem is that they stir up weeds, relocate trifluralin and reduce the water harvesting advantage created by press wheels. There was some interesting commentary on the use of harrows from the Victorian Department of Agriculture in the 1930's during some severe erosion events. Here it was said 'how long will it be before farmers learn that harrows cause severe erosion and discontinue with their use?'. We can now answer that question—65 years!

Loam soil without press wheel (on left) and with press wheel (on right), Site was south of Northam in 1999.

## 13.1 Firming the seed zone

As mentioned earlier, seeds like to be placed in firm moist soil (remember Buffalo #1). In dry seasons the benefits are obvious. Press wheels that push onto the seed are superior to those that do not. Seed press wheels are more than just press wheels. Their role is to push directly onto and only onto the seed. They push the seed into firm soil and their design ensures that they don't push soil in the inter-row. Effective press wheels are essential for ensuring good crop establishment in marginal soil moisture conditions.

## 13.2 Loose soil over the firmed seed

Pulling loose soil over the seed, a la Buffalo #2, is a very useful technique in marginal soil moisture conditions. It is important to disturb a minimum amount of soil while doing this as it can stimulate weed germination, increase seeding depth and also reduce the many benefits to the crop of having a well-defined furrow.

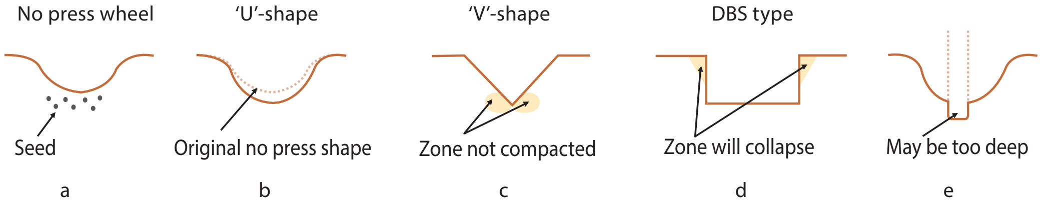
Excessive amounts of soil-applied herbicide can also be pulled into the furrow and affect crop emergence, especially when trifluralin is used. The 'snake chain'—as shown in the below photo—can effectively pull loose soil over the seed without disturbing too much extra soil.

The snake chain is typically about 40 cm long, with about a 12 cm large loop as the last link to drag behind the press wheel in the furrow.

## 13.3 Shape of press wheel

What shape of press wheel to choose? It is sensible to only press the soil around the seed as any other pressing may only encourage weeds to emerge. A 'V'-shaped wheel *(see 'c' in diagram over page)*, in all but non-wetting soils, may not push into the seed but rather may just push against the top sides and the very bottom of the furrows. Soil conditions will determine this. We can manage what we monitor, so observation is the key here.

**Press wheel shapes**




The 'U'-shaped press wheel *(see 'b' in diagram above)* has become most popular and, even with the near vertical side walls that they create, they still work well in Australian conditions. Where the sides are more vertical *(see 'd' in diagram above)* there is some soil that falls into the furrow from these edges by default. This allows loose soil to topple into the bottom of the furrow and effectively recreates the role of Buffalo #2 (as discussed in Chapter 11.2) by default.

## 13.4 Downward pressure of press wheels

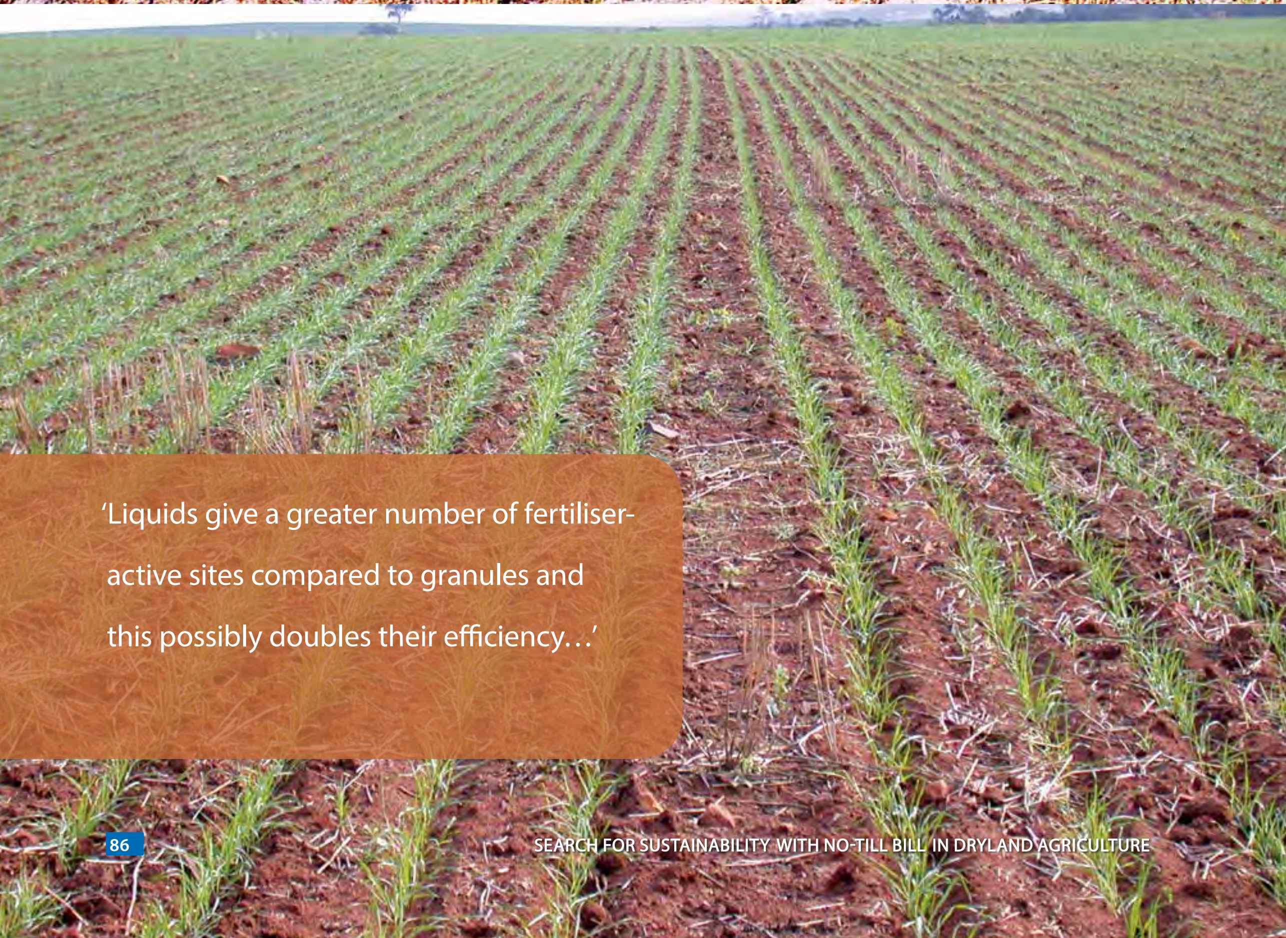
The longer that the land has been no-tilled the less likely that there will be problems with sticky, heavy soils. There are perhaps only a few situations where press wheels may give a negative result. The first is when sowing into very wet, sticky, heavy soil with too high a pressure. No pressure at all is required here! This can be a challenge if the press wheel is part of the opener design. If this is the case perhaps the best option is to go seeding on more forgiving soil, or just wait for a few hours or days for the soil to dry a little.

The second situation where press wheels may have a negative impact on crop emergence is in wet conditions on any soil type. The seed ends up being pressed too deep into a furrow and can rapidly become anaerobic and may not emerge effectively. Again, farmers may need to let the soil dry a little and find better suited land to continue seeding.

The third situation where press wheels may give a negative result is on loamy sands or sandy loam when the pressure is too high for broadleaf crop emergence. We have observed that press wheel pressure of less than 2 kg/cm width of the press wheel is required to avoid such problems with emergence in these soil types. Above this pressure the soil strength can become more than the seedling is capable of pushing through to be able to emerge.

## 13.5 Internal pressure of press wheels

Both firm press wheels and air-filled press wheels can be effective. Increasingly, however, the trend is toward air-filled or semi-pneumatic wheels. These wheels are adjustable for internal pressure. In very sticky situations their pressure can be lowered allowing them to bulge at the point when they touch the ground and then flex when they leave the ground. This ensures they are mostly self-cleaning. Their pressure may range from 3–15 lb/inch$^2$. When the flexible wheels are at low pressure their side walls can be penetrated by hard prickly seeds (like Rumex species or double gees) and, in this case, farmers have found it beneficial to partly fill the wheels with glue that seals small holes if they are made.



'Liquids give a greater number of fertiliser-active sites compared to granules and this possibly doubles their efficiency…'

CHAPTER 14:

# Fertiliser systems and issues

**ONE OF** the downsides of adopting no-till is that farmers have generally increased the risk of fertiliser toxicity if they place seed and fertiliser together (called a 'single shoot' system). Before no-tilling, a grower might have spread the seed and fertiliser over 5 cm on an 18 cm row spacing. Now the same amount of seed and fertiliser is placed in a 2 cm ribbon every 30 cm. With discs the row spacing might now be 20 cm with a spread of 1 cm.

The concentration of fertiliser can be expressed as a ratio called a seed bed utilisation (SBU). A lower percentage denotes higher risk as the seed and fertiliser are placed in a smaller percentage of the soil zone. In the above examples the SBU has gone from 5 cm out of 18 cm (28.8%) down to 2 cm out of 30 cm (6.7%) with knife openers or, if using discs, 1 cm out of 20 cm (5%). SBUs demonstrate the increased risk of fertiliser toxicity that occurs with single shoot no-tillage systems and, in these cases, they are 4–5 times the concentration of the old conventional tillage 18 cm (7 inch) row spacing system.

To lower the risk of toxicity, fertiliser companies initially lowered the nitrogen (N) component in their N and P (phosphorus) fertilisers. However, small-seeded crops like canola are still at significant risk of fertiliser burn or soil dehydration around the seed zone if there are modest concentrations of salty fertilisers placed near the seed.

### REDUCING FERTILISER TOXICITY

There are four options to reduce the risk of fertiliser toxicity:

- top-dress some of the fertiliser;
- switch to softer fertiliser forms;
- adopt some liquid fertilisers; and/or
- band some or all of the fertiliser applied at sowing.

TOP LEFT: Liquid P on left versus granular P on right at 20 kgP/ha.

BELOW LEFT: Liquid N and P on left and granular on right at seeding.

## 14.1 Topdressing fertiliser

Topdressing has been quite effective in soils that have a low cation exchange capacity, such as the sands of WA. Topdressing is most appropriate with readily leachable nutrients like nitrogen (N), potassium (K) and sulphur (S). However, topdressing of P has often been used as a short-term measure by farmers until more precise options become available and on soils low in phosphorus retention capacity.

Where WA soils are deficient in K we observe plants are twice as efficient at extracting it from the soil than if it is topdressed on the soil's surface. However, there is a risk of fertiliser toxicity if K is placed too close to the seed, especially in marginal soil moisture conditions at sowing. The same applies with P—but to a lesser degree.

The topdressing of urea is commonplace in southern Australia for sound economic reasons. Since our soils are mostly acidic, mostly sandy, and temperatures in the early part of the growing season are mostly cool with small, frequent rain events, we usually achieve very good plant uptake efficiencies with this.

With the adoption of no-till, I have found that urea and other granular fertilisers bounce predominantly into the furrows. The furrow is where the crop is and a long way from the most competitive weeds. Hence topdressing N, K or S post-sowing can be a reasonably efficient technique for applying highly soluble fertilisers if a deficiency is observed post-sowing.

Urea applied post-sowing bounces into the furrows created by no-till.

## 14.2 Apply softer forms of fertiliser

The switch to less aggressive forms of fertiliser is another option to avoid fertiliser toxicity. Applying calcium ammonium nitrate (CAN) instead of urea, or potassium sulphate ($K_2SO_4$) instead of potassium chloride (KCl), are valid options. Both of these replacement fertilisers are considered softer.

Indeed CAN has a less acidifying effect on the soil than urea and $K_2SO_4$ has a lower salt index than KCl. However, these softer fertilisers are also more expensive per unit of nutrient and many farmers do not consider them to be the most sensible economic choice.

Another softer fertiliser form that has been widely adopted is liquid urea ammonium nitrate (UAN). However, UAN is typically sold at about 15% more per unit of N than in urea. Despite the extra cost its use is increasing.

## 14.3 More liquid fertilisers

Liquid N and P fertilisers have a lower salt effect on emerging crop, and in dry starts this is useful. Liquid systems can create more precise placement and blending options with the continuous stream of fluid.

Liquid P has been shown to increase plant growth over granular P for the same concentration, for a range of soil types. Liquid P is more available to the plant than granular P. However, the extra cost of the liquid over the granules prohibits its widespread use. The agricultural industry is still learning which soils and what percentage of liquid P is sensible to use. At 20–40% more expensive than granular P, we can perhaps economically use 30% less liquid P on soils that are high fixing of P and perhaps not use it at all on soils that do not strongly fix P.

UAN has become a very popular liquid nitrogen in WA. It is often successfully used with herbicides, both pre-cropping and in-crop. When used in-crop with emulsifiable concentrate herbicides, and in lush, wet or windy conditions, there can be significant crop leaf burn. However, grain yields encourage farmers to continue this practice, even where burn occurs. Typically 30 L/ha of UAN (13 kgN/ha) is applied onto the crop's leaves.

Liquid UAN is also becoming a popular fertiliser to band at seeding. This practice gives the grower improved fertiliser efficiencies as well as the option to carry other nutrients or fungicides in the liquid's stream to the root zone.

The flexibility of liquids can be used to manage a diverse range of complex issues. Banding liquids at seeding enables farmers to simply use variable rate technology. UAN post crop emergence can also be readily incorporated into the GreenSeeker® technology—changing the rate on the go. Liquid systems also enable the switching from one in-furrow fungicide to another when varieties or crops change. Such flexibility allows farmers to purchase bulk granular fertiliser that is not treated with fungicide.

Dosatrons have been used with some success in liquid systems. The Dosatron enables a grower to add a dose (from 0.5% to 5%) into the main stream of liquid while on the go. With a growing understanding of soil type responses, nutrients and fungicides can be dialled up and pre-planned with variable rates while GPS receiving software can place the desired product and rate where needed.

Aside from this futuristic approach, a simple liquid delivery system has many advantages over granular systems alone. Liquids give a greater number of fertiliser-active sites compared to granules and this possibly doubles their efficiency when applying Cu, Zn and Mo for plant uptake. Liquids can also be directed precisely as a stream to a specific location relative to the seed.

## 14.4 Banding fertilisers

Good crop safety has been achieved by placing fertilisers in a band 2–4 cm from the seed. Importantly, with most nutrients, this has not led to any inefficiency in nutrient uptake. With high fixing P soils, however, some P should be placed with the seed as this is critical to early plant growth.

Banding can be achieved with varying degrees of success. A dual opener system is best either with knife or disc openers. Modest results are achieved with closer plates, as they are less precise due to their high level of soil movement and mixing.

## 14.5 Ca:Mg ratios

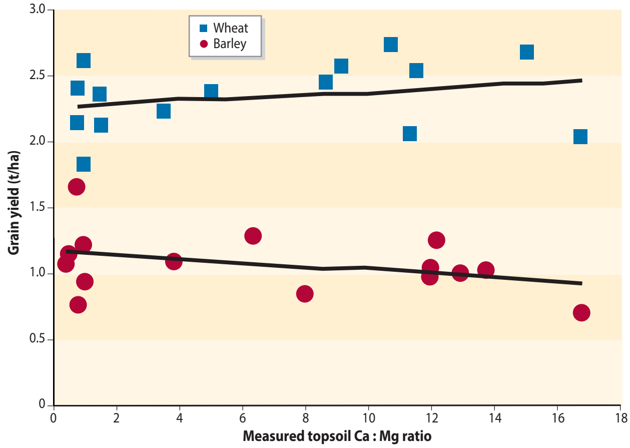
Within the global 'healthy soils' fraternity, there is a desire to do the best thing for soil. In a search for simple solutions the balancing of the soil is a common aspiration. However, in my agronomic experiences of talking with leading farmers and scientists, and travelling globally as a scientist, I am still to be convinced that spending money to change the Ca:Mg ratio is justified.

There is a view that the right balance of Ca (calcium):Mg (magnesium) is about 5:1 and this ratio was promoted in the William Albrecht papers. However, years of research by others and myself have not been able to support this theory. We do know, however, that heavy soils often have high Mg levels and applying gypsum to soften them and displace some Mg from the soil is effective.

*For more information see www.wantfa.com.au.*

There is a long-term trial conducted at the WANTFA Technology Demonstration Site at Meckering that compares five Ca:Mg ratios which I set up and supervised. After 3 years, the salt effects have settled and the trial shows no yield benefit to a shift in ratio from 0.5:1 through to 16:1. This trial is ongoing.

**Barley and wheat grain yields on soils with actual Ca:Mg ratios**




## 14.6 Lime movement and no-tillage

Farming is an acidifying process. When grain is removed from farmland then an alkaline material is being exported, making the soil more acidic. Most soils in WA are naturally quite acidic (pH of 4.8–6.0 in $CaCl_2$). Some are naturally highly acidic (pH<3.8) to depth, like the 'Wodjil soils', and perhaps even beyond our ability to economically ameliorate them.

Historically soils were ploughed to incorporate lime to the full topsoil layer of 10cm depth. Now, with the age of no-till, this physical moving process is not common. Without tillage it is difficult to achieve physical soil mixing of lime through the topsoil.

Soil pH increases when soil acids dissolve lime particles. Lime has a strong capacity to neutralise the soil that is in close proximity. Each lime particle affects the soil within approximately 2 mm of the particle. Therefore, more particles (using a finer lime) and better distribution through the soil increases the rate of reaction of the lime.

If no-till does not involve physical mixing of the lime particles through the soil can lime still move through the soil? Three Meckering trials were established by myself to test lime movement to subsoils under continuous no-till in a 380 mm rainfall environment. We have observed some lime movement to 150 mm depth with these trials. The benefits of no-till have been so compelling in southern Australia that few farmers are willing to give up the benefits of the no-tillage system to incorporate lime to depth.

Despite the challenges of lime movement, most WA farmers apply lime to the surface and allow it to slowly work itself into the soil. Is this approach sustainable in the long-term? Time will tell and perhaps we may be observing some lime complexing with soil organic matter which may facilitate some soil movement to depth as is observed in South America. In their no-till system Saia oats (*Avena strigosa*, also known as black oats) is used as a cover crop and it has been shown to pull lime to depth.

Published data supports farmer observations of this effect. Many soils in central Brasil were unable to be farmed due to their high acidic nature. Applying this cover crop and liming technique, followed by soybeans, has made these soils more fertile, productive and, hopefully, sustainable.

## 14.7 Nutrient requirements with no-till

Essentially most nutrient requirements are the same with no-till as with tillage. There are, however, a few subtle differences of which to be aware. These are N, P and Zn.

With tillage farming the organic carbon and organic matter in the soil is mineralised and this process releases N to the soil. This extra N is released as nitrate which is readily plant-available. It is estimated by Jeff Ladd (CSIRO, Adelaide) that there might be a further 20 kg/ha of N made available from tillage that is not available in the first year of no-till. However, this extra N comes at some organic carbon cost.

The use of tillage to release N from the soil is at the expense of the stored soil carbon. In contrast, long-term no-till builds organic carbon. This extra store of carbon can then more readily release soil nitrate as soil moisture dictates. When it is dry little nitrate is released. When it is wet more soil nitrate is released. This is a robust way of nature working for the crop.

Therefore, in the first few years of no-till, farmers are encouraged to plant high nitrogen requiring crops after a strong nitrogen fixing crop. Alternatively, they may need to apply an extra 20 kg/ha of N to the no-tilled crop. The extra N would be best placed in a band near to but away from the crop row. This ensures that the weeds cannot readily access the N and it is also away from the stubble. Placing the N near the stubble would encourage bacteria to use the N to break down C. Leaving the stubble depleted of N but high in C encourages the bacterial population to be more free-living N-fixing dominant *(see section 9.3)*.

In the long-term the addition to extra soil carbon built up with no-till in the system will help release more N and overcome this deficiency. A new equilibrium may take 3–5 years to occur for the no-tilled soil to not need extra N. But then there is more on the N story, as mentioned in the soil biology section *(9.3)*.

The story with P and Zn is also discussed in the soil biology section. But it should be acknowledged here that increased plant associations with the rhizophore due to the no-till system extends the plants ability to extract more P and Zn from the soil.

'The challenge facing growers in southern Australia is to find crops that compete economically with wheat and barley in a rotation …'

CHAPTER 15:

# Rotations and cover crops

**THERE IS** a common view that no-till needs diverse crop rotations to be truly sustainable. No-one would sensibly disagree with this. However, the challenge facing growers in southern Australia is to find crops that compete economically with wheat and barley in a rotation. In environments where wheat is 80% of a cropping programme it is hard to have diversity. Farmers who have devoted significant areas to lupins, lentils, canola and other broadleaf crops find that under adverse conditions, such as drought or disease, these crops do not perform as well as wheat.

At present we find that continuous wheat or continuous barley will often out-yield and have a better gross margin after several years than many diverse crop rotations. Many farmers lost a lot of money by growing rotational crops in the recent state-wide droughts of 2000, 2001, 2002, 2004, 2006 and 2007.

With constantly improving pesticide technology, the continuous wheat system can work for many in the medium term with crop yields appearing to increase in many soils or areas. Similarly, the economic benefits are hard to deny during years of drought. Such a non-rotation can often involve stubble burning. Wheat on wheat can perform poorly on sandy soils, particularly on the south coast, but not for the majority of the WA wheatbelt. The limited rotation of wheat then barley has been surprisingly useful.

The advent of herbicide tolerance and hybrid vigour from GM canola without that TT fitness penalty will likely improve a farmer's ability to grow an economic broadleaf crop throughout all dryland agricultural regions of WA. However, the southern Australian state governments' ban since 2003 on GM canola has made this a long time coming. The ban was for at least five years due to some community concerns and the promoted view that farmers would gain a non-GM market advantage. This, predictably, did not eventuate to any significant level.

*See more on GM crops in Chapters 23 and 26.*

LEFT: Lupins have been an important rotational crop for 20 years. Soya is displacing them in the protein market. PHOTO COURTESY JON CLEMENTS.

## 15.1 Crop diversity and sustainability

There are four main types of crops grown throughout the world. They are grasses for both warm and cool seasons, and broadleaf crops for both warm


*If interested you can peruse Dwayne Beck's findings in 'Advancing the Art of Zero-Tillage' by ManDak, which is free to download. Visit the South Dakota State University's website.*

Dwayne Beck and Geoffrey Marshall.

and cool seasons. Professor Dwayne Beck from South Dakota has done a lot of work on diversity of crop rotation. Dwayne's talks make for compelling listening, which is why he is regularly invited to speak again and again at no-till conferences all over the world. His views are based on extensive work he has conducted at South Dakota State University's zero-till research farm.

Dwayne compares crop rotation in sustainable agriculture to a stool. Three crop types, or three legs of a stool, are much more stable than two, and one leg is not stable or sustainable.

In the winter-wet and summer-dry Mediterranean climate of southern Australia, only cool season crops are grown. Warm season crops have been tried with only limited success. Perhaps no-one has tried more methodically than Dr Nigel Wilhelm from South Australia. Nigel has shown that, after dry winters and on soils without the ability to store soil moisture to depth, summer crop performance is normally modest.

In northern Argentina many farmers have made large amounts of money growing conitnuous soy for the last 10 years. Similarly, in northern Alberta, Canada, some farmers have grown continuous barley or continuous canola. The USA has had success with continuous corn. In Australia, the Pacific North-West of the USA and South Africa, farmers have had success with continuous wheat. Economics have made it attractive for farmers to adopt these unstable rotations in the short-term, but they are destined not to last, even with extensive pesticide use. Nature will eventually find a way to strangle such monocultures.

The challenge with agriculture is how to be economically prosperous in the short-term yet sustainable in the medium- and long-term. Two questions need to be asked: how important is sustainability, and what price do we need to pay for it? The most sustainable system is not always the most economic in the medium-term. I believe it is unwise to force others into a farming system that they are not comfortable with. For who knows, in the end, those who think differently to us and manage their soils differently may well surprise us and create a better way than we thought or understood to be possible.

Dwayne Beck has encouraging data for his environment that shows diverse rotations can be the most profitable and least risky. It is likely that they are also the most sustainable. Research such as Dwayne's would be of benefit to all agricultural regions, including southern Australia. One farmer who works closely with Dwayne in South Dakota told me quietly that Dwayne's views on rotations have made them a lot of money. So perhaps Dwayne's philosophy is universally applicable and we just need to find ways of making it work in our part of the world. But we all need to 'sift the chaff from the wheat'. This is best done with hard data, a scientific base with systems-based research that takes into account the complex biological systems found locally.

## 15.2 Water use intensity

As mentioned earlier, with no-till systems including full stubble retention, more water is stored in the soil. Similarly, at long-term no-till sites, more water penetrates to depth. Such improvements have enabled farmers to be more creative.

We have found farmers can grow lupins on soils heavier than was previously thought possible. Crops can now be grown in regions considered too dry for them in the past. Does this open the door for more warm season crops in southern Australia? Perhaps it will. However, the recent long period of very dry conditions experienced throughout Australia has not enticed many farmers to try. Is this the same for cover crops?

*For more detail see Ademir Calegari's discussion in Chapter 24.*

## 15.3 Cover crops and sustainability in South America

Sub-tropical agriculture in South America has always been a challenge. Where rainfall is continuous throughout the year (ranging from 1200–1600 mm), soil is silty and conditions are always warm, there is a lot of biological breakdown of organic matter. Combine this dynamic environment with the plough and there were perfect conditions for massive soil erosion to occur. Here is a brief comment on their situation.

PHOTOGRAPH COURTESY ERNI SWINDLER, PARAGUAY.

In the early 1970's many Brasilian farmers were desperate to stop the soils eroding, as they were being left with no soil to work with. This changed when Spray.Seed® and Roundup® became available. Although expensive initially, a group of dedicated no-till farmers learnt how to farm with these herbicides—the new tool of no-till. From this pioneering group, an over-arching South American no-till group (CAAPAS) has formed.

They have learnt that, for their environment, they must use disc seeders and cover crops. They now often grow five crops in two years and believe that one of these crops should be a cover crop. A cover crop is only grown to cover the soil. Such cover is never cultivated or incorporated into the soil. It is mechanically rolled down when the crop is in late flowering stage. The type of crop used depends on the rotations. *Avena strigosa* or black oats (known as Saia oats in Australia) is one of the more successful cover crops for their environment.

*Visit CAAPAS—at www.caapas.org*

*Avena strigosa* (known as Saia oats in Australia)—one of the more successful South American cover crops—shown here in flower.

PHOTOGRAPH COURTESY ADEMIR CALEGARI.

Broadcasting cover crop seed, Brasil.
Inset: Winter cover crops, Brasil.
PHOTOGRAPHS COURTESY ADEMIR CALEGARI.

A 2001 WANTFA Study Tour to
Maneol Pereira's farm, Brasil.

Brasilian farmers now lead the world with their adoption of no-till systems. The no-till revolution there, combined with both cover crops and herbicide-tolerant crops, may well help pave the way to making agriculture sustainable in their environments.

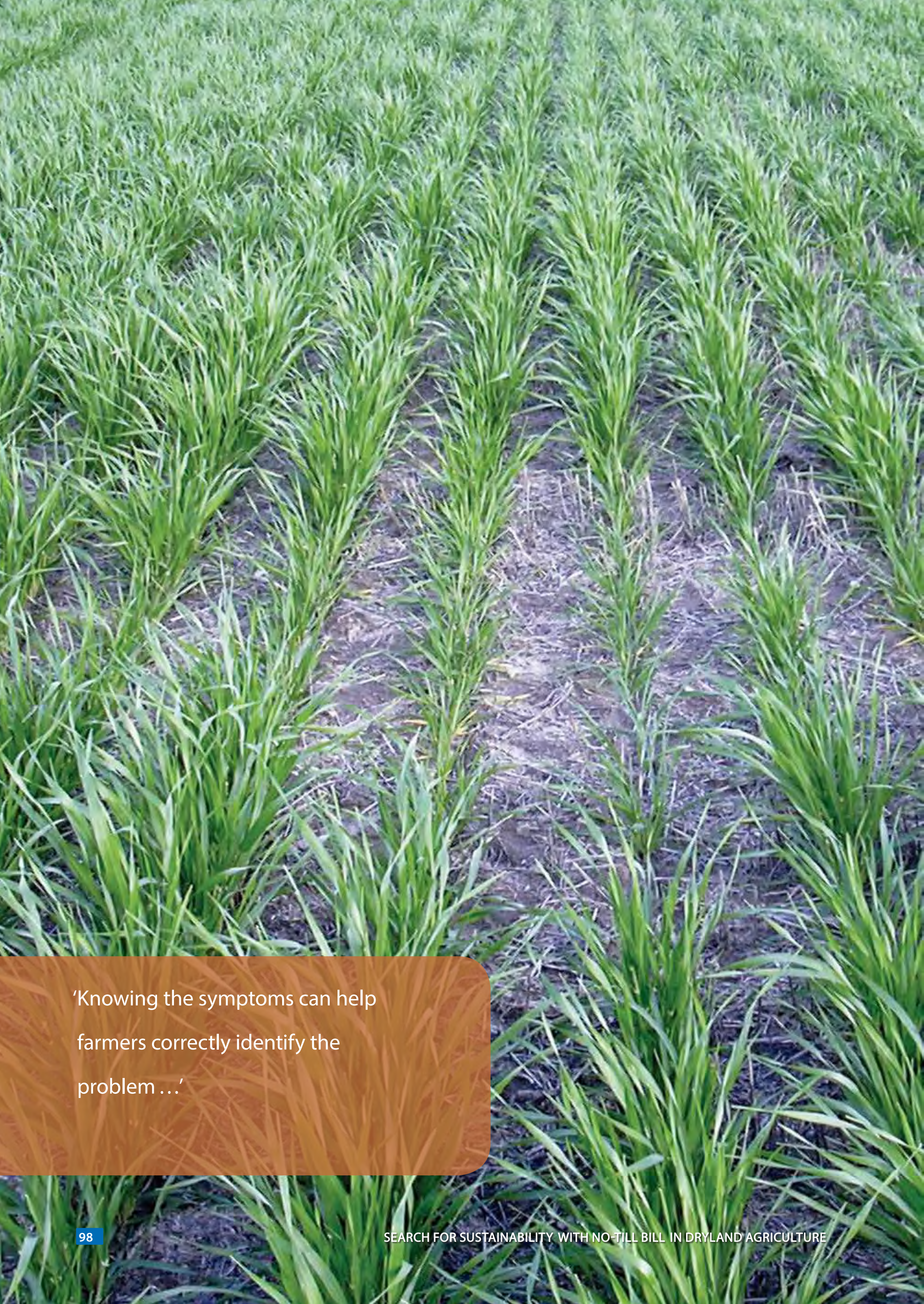
## 15.4 Cover crops for Australian agriculture

The success of cover crops in South America has encouraged Australian no-till farmer groups to extensively test them in Australia. Some preliminary research suggests that cover crops do use lots of water and their residues have made it difficult to seed through in the subsequent year. While the principle is sound, continuing research will show how applicable cover crops will be for improving soil and economic sustainability in southern Australia.

Some limited trial data from Fran Hoyle (WA), Kate McCormack (Vic) and myself showed that the residual benefits of cover crops are small and usually persist for not much more than one cropping season. Some of these trials experimented with both brown manuring (spraying with glyphosate) and green manuring (ploughing). These trials used black oats, fenugreek, clovers, brassicas and other grasses, studied over about 4 years.

My bias is that cover crops will have a minor role, if any, in taking Australian agriculture to sustainability. I feel they cost too much, as a whole 12 months of time and stored water is sacrificed to grow a cover crop. I am comfortable with the idea that they may have a role in some environments but, in my view, this is likely to be limited.

PHOTO COURTESY JON CLEMENTS.



'Knowing the symptoms can help farmers correctly identify the problem …'

CHAPTER 16:

# Some challenges with no-till

LEFT: Rhizoctonia bare patch has clear patches of poor crop.

BELOW: Mice enjoy the stubble and extra protection associated with no-till.

**NO NEW** idea is without its challenges—and no-till is no exception. Most of the difficult challenges with no-till are with plant and soil biological pests, and times of too much water. Perhaps the most powerful tool against the weeds, pests, diseases and excess water is diversity of crop type.

Soil biology is a slow science in Australian environments where it commonly takes a year to grow one crop. In contrast, South American scientists are perhaps the most knowledgeable on the biology of crop rotations, as they can study many different rotations in a short space of time.

The main pests in southern Australia are slugs, snails, mice, root lesion nematode, leaf sucking mites and root-eating grubs. All these pests have proved difficult to target.

## 16.1 Slugs, snails, mites, grubs, mice, weevils, beetles and grubs

We have observed with no-till that soil biology continues to change over time. When we successfully target some species others will take their place—this being nature's way of adjusting to pesticide or rotational selection pressure. Pests that used to be a problem, including cutworm (genus *Agrotis*), webworm (genus *Hednota*), Desiantha (*D. diversipes*) and cockchaffer (*Heteronyx obesus*), are now less significant.

In contrast, other pests have become more common under no-till.



Balaustium mite (*B. medicagoense*) and clover mite (*Bryobia praetiosa*) are the cereal crop pests currently causing the most frustration each year.

South Australian no-till farmers (as earlier mentioned in Chapter 10.6) have been challenged with snails in no-tillage. Snail baits have been partially effective, with the new types that do not dissolve in moisture giving better results. Farmers have also found that knocking down stubble with a chain on hot days can kill many snails through putting the snail onto the hot soil where excess heat can dehydrate and kill them quite effectively. In desperation, some farmers have resorted to stubble burning. But by doing so they leave their soil exposed to both wind and water erosion and increased soil moisture losses.

As with weeds, we need to use tools that keep insects 'off balance' and challenged. Again, a diverse range of crop types will help reduce soil pests. Seed dressings are also becoming an increasingly popular tool to manage pests. For more up-to-date techniques to manage these pests a good website to visit is www.agronomy.com.au. Insecticides coming off patent like imidaclopid (Gaucho®) and fiprinol (Cosmos®) will be useful tools as will many different seed dressings.

## 16.2 Root lesion nematodes

The next most prolific soil living creatures, after insects, are nematodes. These 'worms' are too small to be seen with the naked eye and the vast majority of them are benign to crops. However, there are about half a dozen types of these root lesion nematodes (RLN) that eat crop roots and so are more damaging and noticeable in no-till systems. The most powerful tool to manage these is diversity in rotation and varietal resistance.

Small nematodes, as seen in this root, eat into crop yields and are more common in no-till than tillage agriculture.

Root lesion nematode damage looks similar to rhizoctonia and they often occur together as in these photos.

Peas, beans and lupins are the most effective crop types for reducing nematode populations. Interestingly, chickpeas and canola generally make RLN worse, although there are varietal differences. Often RLN damage is attributed to rhizoctonia. Yet, while they often occur together, we know that deep tillage destroys about 95% of the rhizoctonia by rupturing the fungal hyphae in the soil. We also know that chemical fallow has no impact on rhizoctonia but is useful for lowering RLN activity.

Knowing these relationships can help farmers correctly identify the problem. Another tell-tale sign of RLN is the presence of healthy plants inside an affected patch. While rhizoctonia may still be there it is likely to be a secondary issue.

The damage observed with RLN can be quite severe in alkaline sandy soils and in zero-till situations when discs are used.

Farmers in these environments should perhaps start their no-till farming with knife points and work towards discs as their soils mature biologically. Ensuring other diseases are well managed with diverse crop rotations and good crop nutrition will help minimise the impact of these root diseases.

## 16.3 The trace elements

Western Australia has the most naturally nutrient deficient soils found anywhere in the world. The application of copper, zinc and molybdenum immediately after clearing of native eucalyptus forests in the 1950's and 60's has enabled profitable agriculture. These nutrients were initially topdressed and worked through the soil with significant and frequent tillage thus alleviating such deficiencies (one good thing about tillage!).

With the 1980's trend towards reduced tillage and increased crop production we have observed increased occurrence of trace element deficiencies. With the narrow bands of applied fertilisers under no-till, the plant roots are exploring the soil less in their search for trace elements. This has lead to more episodes of early and consistent crop nutrient deficiencies.

To help overcome this problem fertilisers have been blended with trace elements. However, this has had limited success as too few fertiliser granules contain the trace elements. Full compound granular fertilisers have been much more effective as they give a greater number of root interceptions.

*Two useful websites about liquid systems are www.liquidsystems.com.au or www.burandohill.com.au.*

Liquid fertiliser is injected behind the knife opener.

The most successful way to improve micronutrient uptake using no-till has been through banding of liquid fertilisers at sowing. Dribbling such nutrients into a stream of water or liquid nitrogen fertiliser has been shown to be twice as effective as using any form of granule at sowing. But liquid nitrogen or copper must not be placed on the seed in marginal moisture situations as they are toxic to the seedling. Best results are achieved by placing these nutrients below and to the side of the seed.

Liquid systems can be as simple or as complicated as you like. Some farmers have made their own systems using garden reticulation apparatus, their own manifolds, carts, tanks and a pump.

## 16.4 Getting through stubble

This issue has been discussed earlier in Chapters 11 and 12 in some detail so will only briefly be mentioned here. In the early days of no-till farmers readily found that disc seeders could seed through any amount of stubble. Grazing sheep would complicate stubble management as they would tread the stubble onto the ground and increase hair-pinning with discs and plugging with knife openers.

There were many solutions to these problems: installing residue managers and leading discs on the seeders; removing sheep from the paddock; raking the stubble or chopping it with slashers post harvest; or using wider row spacings. Now the answer can be simple: use 2 cm accuracy GPS autosteer and seed between last year's cropping rows. However, for this to work reliably it will require seeder row spacings of at least 25 cm.

An example of a seeder not managing stubble effectively.

## 16.5 Water-logging

No-tilled soils retain more soil moisture than tilled soils, and in high rainfall areas in cool conditions this can be a problem. Although, if the trend continues with the recent lower than average rainfall years it is only likely to be a problem when wet years return. In these environments farmers have four options:

- avoid cropping wet areas and leave them to pasture;
- adopt higher water using crop types in the rotation (e.g. sorghum, sunflower or millet);
- use raised beds; and/or
- put up with occasional crop failures.

Perhaps a combination of these techniques is also an option.

Small 2 m beds are shown here at Kendenup to help run water off wet paddocks.

Success with warm season crops has been limited in Western Australia, as success has partially depended on warm and moist conditions in spring for good crop emergence. To improve the chance of successful establishment of these crops a dedicated precision planter may be needed.


Farmer Owen Brownley shares his warm season crop experiences with NSW no-till farmer Scott McCalman, Victorian no-till farmer Neil Postlethwaite and NSW no-till researcher Warwick Felton.

Raised beds have been successful for some farmers. The width of bed can vary from 2–10 m and the depth can also vary. The use of autosteer technology with GPS has made raised beds and controlled traffic much more practical and will help when wet conditions arise.

## 16.6 Frost management

It seems that no-tilled crops are more prone to frost damage. The retention of stubble from the previous crop can still the movement of air in the crop canopy and this stubble also prevents the soil from losing heat during the night. Both of these canopy environmental effects increase the risk of lower soil temperature in the new crop canopy, making frost more likely.

Our main crop, wheat, is particularly vulnerable to frost during the month of September, when the crop is flowering. As no-till enables earlier crop establishment for more of the crop (due to greater time efficiencies) there is an increased risk that more crop will be flowering during the frost risk window. It also seems that no-till farmers are able to create a more uniform crop canopy—this may also increase the risk of frost.

It appears that the amount of crops lost to frost has increased in Western Australia over the last 20 years. More land is now cropped, and less pasture grown. Farmers have in the past trusted the saying that more grain is lost to the fear of frost than from frost itself.

Wheat stems are damaged by a cold 'stem frost' as seen here.

Perhaps there is also less cloud cover at night in September. Remember there is 30% less winter-spring rainfall in the south-west of WA now than in the late 1960's.

Farmers in frost-prone areas wish to reduce their exposure to frost damage. With wheat it is possible to delay the sowing of paddocks at risk of frost and use long season varieties and less inputs. More oaten and lucerne hay would also be an option, enabling feedlots to become common. Sunflowers are also an option for the lower lying soils where subsoil moisture often exists.

There is the possibility that desirable genes could be obtained from frost-tolerant plants or fish. Both of these options are currently being explored. However, the long ban in southern Australia on the commercialisation of GM technology required to achieve this could limit or delay investment into this technology.

Frost is a serious constraint in prairie environments—delaying sowing and inhibiting grain fill.

'Herbicide resistance is common in Australia and is increasing each year . . .'

CHAPTER 17:

# The herbicide resistance issue

**NO-TILL** is not possible without the use of herbicides. Even tillage-based agriculture is not as efficient or profitable without herbicides. All agriculture has benefited from herbicides that have only been available for about 50 years. Herbicide resistance occurs in no-tilled fields, but it also occurs in orchards, along train tracks, on firebreaks and in multiple tillage systems. It occurs wherever herbicides are used. It can occur with any type of farming system that employs herbicides.

Knockdown herbicides have been the most powerful tool for weed control and have removed the need to cultivate. Unfortunately, herbicide resistance is common in Australia and is increasing each year. Populations of glyphosate resistant ryegrass now number over 100 and are increasing in southern Australia each year.

## 17.1 Herbicide resistance becomes common

Australian farmers are generally quite knowledgeable about herbicide resistance issues. They have learnt to rotate herbicide groups to manage the problem. However, the sustainable use of herbicides is of concern, as most WA farmers still only use one knockdown herbicide—glyphosate—at full label rates.

For knockdown herbicide resistance management one good strategy is to use two knockdowns, perhaps every second year; the first knockdown being with glyphosate and the second application being of Spray.Seed® (50:50 mix of paraquat and diquat) or Gramoxone® (also diquat). The Australian agricultural industry has wisely set up a special 'sustainability' taskforce to help find and communicate ways to prolong the effectiveness of glyphosate.

WA farmers have two challenging herbicide resistant weeds: ryegrass and wild radish. Both have a great ability to rapidly mutate for herbicide resistance. Both have already become resistant to most herbicides commonly used to control them. Fortunately there are not yet any plant populations of either of these weeds that are resistant to all herbicide groups. Perhaps the most important key to the management of herbicide resistance is using a range of tools to control them.

LEFT: Ryegrass in stubble is difficult to control with gramoxone due to poor herbicide coverage—not herbicide resistance.

Ryegrass springs back to life after a sub-lethal dose of glyphosate.

This includes other herbicide groups as well as non-herbicide weed control techniques.

Cutting hay, collecting chaff, burning windrows, crop topping and mixing up the sowing dates by growing different crop species have all been useful tools. Other tools encouraged for integrated resistance management that I believe are not the best tools in the 'search for long-term sustainability' are full tillage and stubble burning (and perhaps sheep).

Keeping weed numbers at low levels, using a range of different herbicide groups and having healthy crops is perhaps the most powerful strategy of managing weeds. The use of herbicide tolerant crops has also been of assistance—for example, TT and IT canola and metribuzin-tolerant wheat

LEFT: Green manuring with tillage does not seem a smart nor sustainable way to manage weed challenges.

BELOW LEFT: Long-term no-till with good even crop emergence.

BELOW: Adjacent to previous photo: green manuring was advised to improve soil health at Ridley in Esperance. Farmer Alan Jones was disappointed in the technique.

and lupins. The introduction of GM canola with the option to use the herbicide glufosinate ammonia would greatly assist in ryegrass resistance management.

## 17.2 Herbicide resistance in US and Argentina

The advent of Roundup® Ready (RR) soya in 1996 and its rapid adoption in both the US and Argentina systems has probably delayed resistance to other herbicides for 10 years. Neither of these countries were much concerned about this problem until recently. They have had nearly 10 years of near perfect weed control and the prosperity that it has afforded.

Argentinean farmers have also had an economic advantage over US farmers, as Monsanto has not enforced royalties from Argentinean farmers through their Technology Use Agreement (TUA). The TUAs are commonplace and well enforced in North America. The TUAs vary for different crops.

The high value of soya to the Argentinean farmer, the cheap cost of Chinese glyphosate and lack of TUA has encouraged the over-use of glyphosate in northern Argentina. Here farmers have grown continuous soya for 10 years with no other crop in the rotation and almost no other herbicide use. It is common for 10 L/ha of glyphosate to be used in a 12 month period. Now, they are starting to see resistant populations of *chenopodium* species (fleabane in WA or mare's tail in US) or emerging. Glyphosate resistant Johnson grass (*Sorghum halepense*) has also become a problem in Argentina.

Similarly, US farmers who have rotated RR soya with RR corn have similar glyphosate resistance concerns. While it is no surprise to most WA farmers who would expect resistance as a result of repeated use of glyphosate-only use, it has surprised some in the US and Argentine agricultural industries. Yet it is in contrast to both the Canadian and Brasilian experience where glyphosate resistance has not yet occurred. I believe this is because they continue to use more diverse crop rotations and herbicide groups.

A TPos shielded sprayer for inter-row spraying of herbicide resistant weeds.

## 17.3 Herbicide resistance in Canada and Brasil

Canadian farmers had a similar level of herbicide resistance populations as Australian farmers back in the mid 1990's. Now, in 2009, with 13 years of experience with knockdown herbicide tolerant canola they have reduced their levels of herbicide resistance, while ours have increased. There are no glyphosate resistant weed populations in Canada, yet here in Australia there is an increasing number each year. The use of glufosinate ammonia in Canadian canola crops and hybrid competitiveness are two keys to the successful management of their herbicide resistance.

One commonly adopted strategy to manage herbicide resistance, encouraged by Graham Shields, is the collection of weed seeds at the back of the header as chaff (shown below) or more recently as large bales.

## 17.4 Managing resistance with shielded spraying

In Australia we have been trying to incorporate the herbicide Spray.Seed® into our cropping programs. This has to be done pre-sowing as it is a knockdown herbicide. However, it is expensive—being perhaps four times more costly than glyphosate. Spray.Seed® is also both highly toxic and has a horrible stench.

Farmers have been using Spray.Seed® at sub-lethal dose rates believing that they were managing potential glyphosate resistant weeds effectively. Recent research data from South Australia suggests that we have to use full and expensive rates to effectively manage resistance—rates which we do not generally use.

The use of full rates of Spray.Seed® or glyphosate in the inter-row of wide row crops has potential to assist in managing all types of herbicide resistant weeds. However, spraying herbicides with shields in the inter-row is more difficult than spraying a broadacre herbicide. This is because shields need to be narrower than booms to avoid sideways whip and the consequent damage to the crop row and because shielded spraying needs to done at slower speeds to minimise crop damage.

RIGHT: Applying glyphosate below canola or barley at swathing time has been a powerful way of reducing weed numbers.

BELOW: Glyphosate applied through shields 10 days earlier has worked on controlling the weeds but is also starting to kill some of the lupin plants.


'It is possible that, with creative management, issues may be solved with tools other than tillage …'

CHAPTER 18:

# Is full tillage unavoidable?

**FARMERS** sometimes feel that they have no alternative but to cultivate. This is generally due to:

- Rough paddocks;
- The need to ameliorate water repellent sands;
- A desire to incorporate lime to depth;
- The need to kill woody perennial vegetation—difficult to kill with common herbicides;
- The management of naturally glyphosate-resistant weeds such as marshmallow, fleabane and kerosene grass; or
- The green manuring of a crop.

Eucalyptus trees naturally regenerate in no-till paddocks. This is one reason for contemplating tillage.

LEFT: While not advisable, some new hydraulic no-till seeders are capable of excellent crop emergence right to the edge of rocks. This is the Väderstad Seed Hawk® in granite rocks.

It is possible that with creative management these last three issues may be solved with tools other than tillage. I know many farmers who have ploughed in cover crops for weed management and improved nutrient release. They have generally been disappointed with the results in the long-term. Rarely do they see a real economic benefit from doing so compared to maintaining their no-till system *(see photo in 17.1)*.

## 18.1 Rough paddocks

When paddocks become uneven due to water erosion, uneven ploughing from the past or bogged machinery in wet years then tillage may be necessary. Ruts will remain in a no-tillage system and to fill them in using a grader may be both too expensive and inaccurate. Some farmers have therefore found it necessary to cultivate and remove these ruts, and return to a no-till system in subsequent years.

In controlled traffic systems farmers have also found the traffic lines can deepen in very wet years. In this case grading some soil into these run lines or depositing imported loam soil, gravel or gypsum may help fill these lines.

## 18.2 Water repellent sands need tillage and clay

Southern Australian soils with less than 3% clay in the topsoil often refuse to wet up. It may take 20–30 years of agriculture for non-wetting to develop or it may occur naturally. Either way it is the cause of significant frustration and economic loss. Such soils will not wet and therefore will not give even weed emergence after a rain. This results in delayed sowing, significant yield loss and weedy crops. Pastures also suffer and become dominated by weeds. Such soils are also prone to wind erosion and are favoured sheep camps, which further exacerbate the problem.

The fats and waxes that naturally exist in all plant matter cause the problem. Soil microbes, which break down these chemical groups, seem to prefer to eat sugars, starch and cellulose—a bit like people really! They tend to leave the repellent waxes and fats in the soil as a food of last resort. Over summer days these waxes are exposed to hot, dry conditions causing them to melt and then re-solidify at night, often into the top 10 cm of very sandy soils.

Wax coated sand has water ponding in low areas. The first few years of no-till helps establish crops in the low furrows.

Wetting agent applied at 4 L/ha in 1988 improved crop emergence—but claying is the long-term solution.

Particles in sandy soils lack surface area, making them susceptible to being fully coated with wax. Thus these soils become water repellent. A lot of work has been done with wetting agents, tillage, rotations and furrow shape and all have proved to be only partly effective. The author did a lot of work for his Masters degree looking at seeding in the bottom of the furrow with press wheels (using no-till) and with a band of wetting agent (this work is published in several scientific papers). These techniques have been somewhat effective in improving crop emergence and crop growth.

RIGHT: A young Bill Crabtree (right) in 1987 with John Richardson inspecting the strong improvement in barley establishment with banded wetting agents in the furrows. The foreground is without wetting agent.

John Snooke, Meckering farmer, recently used furrow sowing, press wheels and wetting agents to give some improvement in crop establishment.

Even with good crop emergence, many other agronomic problems still exist in repellent soils that hinder crop and pasture production. More weeds will germinate in the furrow in the following year. Due to large areas of dry soil, plant roots are restricted to the wet areas as they slowly wet which limits plant nutrient uptake. It also ensures weeds continue to germinate throughout the crop's life and results in poor weed control and lower crop yields. The only sensible and proven long-term solution to water repellent soils is claying.

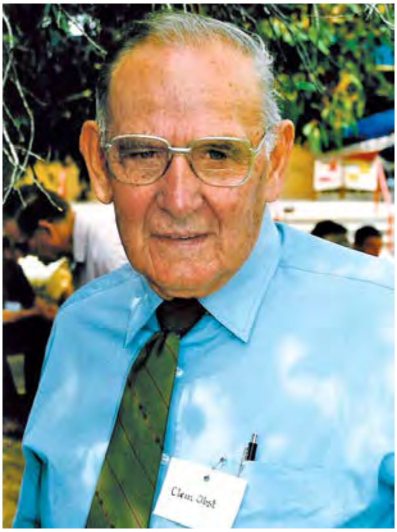
The application of wetting agents in the furrow of wide row lupin crops may be practical. The wider rows make the cost of the wetting agent more affordable. However, band spraying is more likely to be successful when used in conjunction with glyphosate-tolerant lupins. The staggered emergence of weeds could then be handled cost effectively with in-crop glyphosate use on more than one occasion. Unfortunately, these lupin types are likely many years away yet for commercial use.

Here clay is being uniformly mixed into the sandy organic matter stained topsoil.

Several long-term trials have shown crop yields to double from claying. Some farmers have lifted their yields from 1 to 5 t/ha after claying; yet in the Esperance area some farmers have had only 20% yield increases. The reasons for the poor responses in the Esperance region are most likely due to poor incorporation or tillage to depth, or excessive rates that limit even incorporation to depth.

Some South Australian farmers have also had poor responses in low rainfall environments where free lime subsoil has been used for claying. The free lime makes the soil tie up some nutrients and has induced zinc and manganese deficiencies. This would normally only be found in alkaline soils.

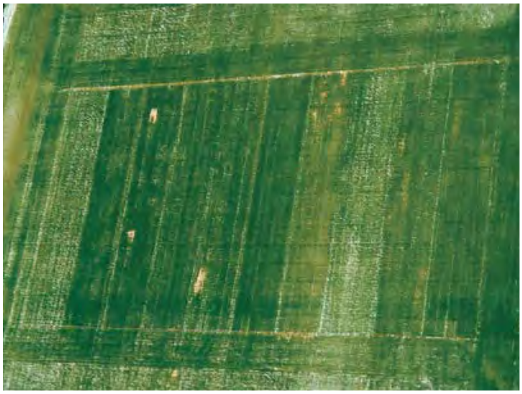
The technique of claying involves spreading subsoil clay on the soil's surface at about 200 t/ha (containing 30–40% clay) and then thoroughly incorporating it. There are many practical issues to consider—indeed a book can be written on this subject alone. The initiator of this technique is the delightful Mr Clem Obst who farmed at Mundulla, South Australia. He discovered the technique by chance in 1968 when he deposited some clayey subsoil on a sandy hill and noticed improved crop growth the following year. Clem received an Order of Australia for his discovery and promotion of the soil care treatment (I was privileged to have nominated him).




LEFT: Claying pioneer Clem Obst, now retired to Bordertown, South Australia has kindly travelled across Australia to share his experience.

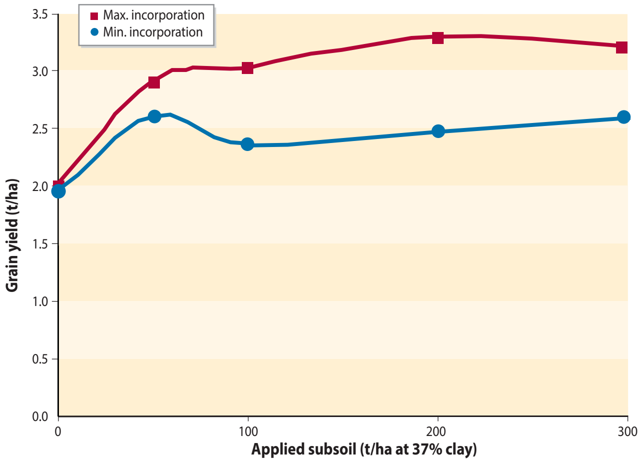
BELOW: South Australian researchers stand on the clayed line at Clem's farm.

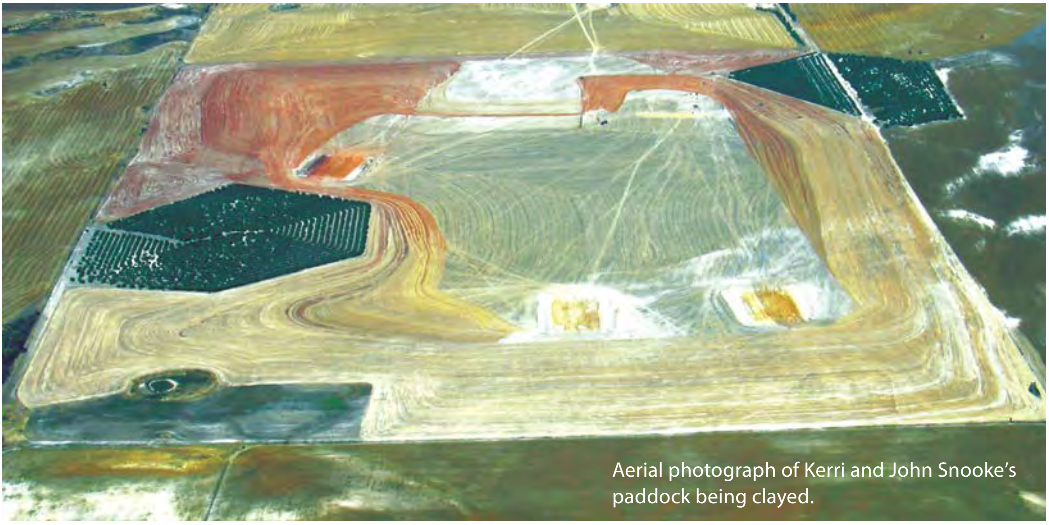
Claying reduces frost on the right irrigation bay compared to no clay on the left.



Large replicated trials of plots 15 by 85 m were conducted across Western Australia and showed significant yield improvements.

## Meckering wheat—second year clay (2001)



Aerial photograph of Kerri and John Snooke's paddock being clayed.

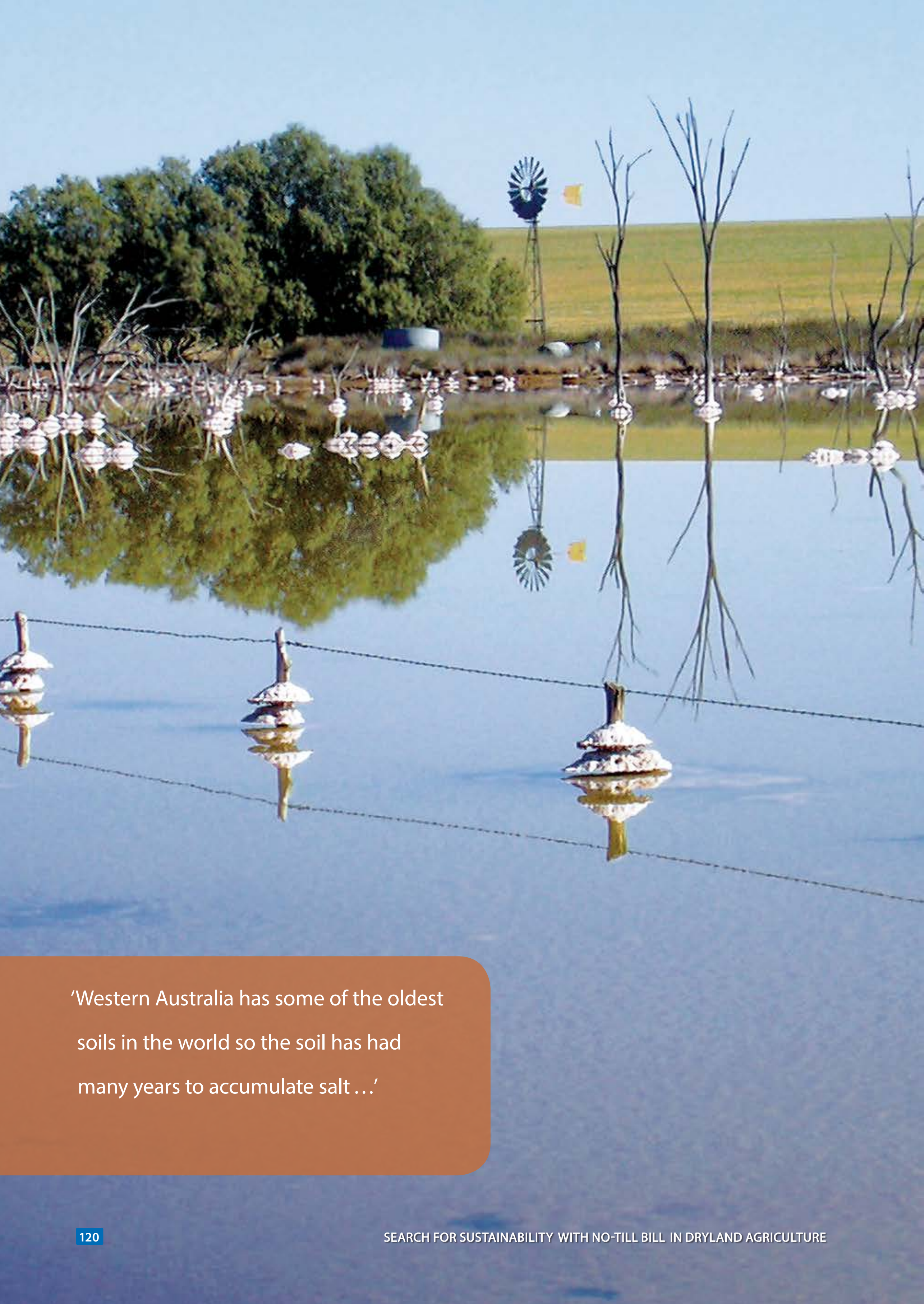
Three generations of claying communicators from South Australia. Daniel Morgan (left), Roger Groocock (centre) and Clem Obst.
Most recently, Roger has introduced the new spader clay incorporator.

## 18.3 Naturally occurring soils with severe acidity

Large areas of Western Australia have a soil type typified by a pH of 3.8–4.2 (in $CaCl_2$) with strong ionic strength and 8–15% clay. This is called 'wodgil' soil and is associated with a variety of Acacia species, but especially the Wodgil, *Acacia resinimarginea*. These soils are only mildly responsive to high rates of lime without tillage. Research in the past has shown that tillage with liming is beneficial when trying to increase these soils pH to depth.

Research needs to be done in WA to determine if the South American approach of liming with black oats will work in our environments (as discussed in this book). If this technique could work in Australia it would save on the need to physically mix lime to depth with tillage. Some trials were conducted but due to technical challenges the results were not reliable. Research by Chris Gazey from the Department of Agriculture of Western Australia has shown that lime can be slotted to depth in these wodgil soils with some effect.

Lupins growing well on wodgil soils.
PHOTOGRAPH COURTESY OF WAYNE SMITH.



‘Western Australia has some of the oldest soils in the world so the soil has had many years to accumulate salt …’

CHAPTER 19:

# Salinity in Western Australia

**SINCE** the start of clearing of native vegetation in WA about 5% of land has been lost to salinity. This is predicted to more than double in the next 30 years. But WA is not alone with this problem. Salinisation of agricultural land occurs all over the globe. The cause is salt (most commonly sodium chloride) that is carried over the land from the oceans via the winds and rain. Western Australia has some of the oldest soils in the world and as such the soil has had many years to accumulate salt.

The amount of salt that blows in from the ocean can be up to 75 kg/ha per year close to the coast in southern Australia. On the south coast of Western Australia scientists have estimated that 4000 t of salt is stored in 1 hectare of land to a depth of 40 m.

LEFT: While there were many naturally salty lakes in WA agriculture has caused more lakes to become salty.

RIGHT: Once prime agricultural land now gone salty.

Salt comes to the surface and kills many annual plant species.

## 19.1 Result of removing perennials

Given this large amount of salt stored in our soils, the second part of the problem is the removal of trees and other deep-rooted perennials and their replacement with shallow-rooted annual species. These annuals are not capable of using all the water that falls over the full 12 months of the year. Hence some of the rainfall leaches through the soil profile, raising the water table. The water table 'leaks' into the landscape at certain locations—often in valley floors—and brings the stored salts with it. Damage is typically observed about 30 years after the clearing of native vegetation.

Much of WA was cleared during the late 1950's and 1960's. In the late 1980's there was great concern in Western Australia as increasing areas of land were being lost to salinity annually. This expansion has slowed in recent years perhaps due to the drier than normal seasons (in 2000–2007). However, WA farmers realise that they need to manage salinity in susceptible areas.

A multi-faceted management approach is necessary to slow salinisation. But for widespread adoption any tools must also have a direct benefit to farmers. Trees are not yet a reliable income source for farmers—though perhaps this will change with carbon credits as currently being discussed. The agricultural community is constantly searching for new options. Oil mallee (*Eucalyptus* spp. with high oil content) has been the most widely adopted agroforestry option in the wheatbelt, but is still not a reliable income earner.

## 19.2 Greater water use needed

Improved crop water use with no-till is possible as farmers are able to sow crops earlier and have them actively growing when more of the rain is falling. Their roots are able to access more of the soil's stored water due to a softer soil profile. The soil in the rooting zone is also able to store more water. Essentially the crop has a bigger 'bucket' of water from which to draw. Deeper rooting depth comes from the softened subsoil due to less traffic, less tillage and increased soil biological activity.

Using no-till farming practices, a grower is able to help combat water recharge on the paddock, and at the same time help to somewhat drought-proof crops. More water will be held in the rooting zone for the use of crops, and may not travel further into the profile. However, if there is large amounts of rain over a short period of time it is possible with no-till that more water may leak through the soil profile and contribute to more salinity pressure. No-till farmers always observe that after a few years of no-till the dams do not catch as much water from the paddocks' run-off as they used to.

The growing of crops or pastures that use more water will also assist in minimising recharge. It may be possible for warm season crops to fit the system here with water use at depth in wet years or drought-tolerant perennials for drier areas. For a similar reason the use of lucerne may also have a role. However, lucerne growing has not persisted in the dry regions of WA and has had limited success in fitting into profitable dryland farming systems.

## 19.3 Deep drains

Engineering solutions will likely be part of any approach to the management of salinity in appropriate soil environments. Deep drains have shown, at several locations throughout the WA grain belt, that they are capable of drawing water from distances and discharging it into already salty river systems. The permeability of the subsoil and the existence of ancient drainage channels can greatly assist the rate of water movement into the drains. The salt came from the ocean and should one day return to the ocean. Drains are the only tools that can accomplish this.

This drainage solution has been used globally, particularly in the Netherlands, but moving such salty water into creeks and then the ocean is hindered by issues of technical ability, cost, mixed landholders and governmental support and the negative impact on rivers in the short term.

A deep drain as used at Esperance is having a positive effect on removing salt.

‘It doesn’t take much to undo all the good soil structural improvements that can take years to create …’

CHAPTER 20:

# Stock and their fit with no-tillage

**DURING THE** 1950's it was said that Australia rode on the sheep's back. They have been a valuable income source for farms, both from the wool and the meat, for over a century. The decline in the value of wool since the demise of the floor price in 1988 has seen many farmers in the wool industry switch to meat sheep while others have left the sheep industry altogether.

There is a general view that sheep have a greater impact on soil structure and soil cover than cows. Sheep do wander, seemingly meaninglessly, all over a paddock, and because of this excessive traffic their feet have a great impact on soil. Their feet loosen sandy soil and remove organic matter cover over the soil, which then exposes the soil to the elements and increase the risk of soil erosion. There is tension amongst farmers when there is discussion about sheep and their fit with sustainable broadacre farming practices.

Merino sheep are often walking across paddocks for no apparent reason. Such traffic breaks organic matter and loosens soil.

LEFT: Heavy soil can easily be structurally damaged without soil cover and by raindrop impact alone. Here a precision no-till seeder still enabled even emergence before the soil sealed over from drying.

## 20.1 Sheep and light soil

Light soil is the preferred camping ground for sheep. These camps can become focus points for erosion by wind, are more water repellent and have an accumulation of urine and faeces. To guard against wind erosion farmers need to take sheep off the land when surface organic matter declines below 1 t/ha.

No-till farmers who retain stubble and have no sheep have virtually no soil erosion problems. For them wind and water erosion are mostly in the past. The absence of sheep brings financial challenges in years where frost, flood or drought prevails. Without sheep in their farming systems no-till farmers are totally dependent on herbicides to manage summer weeds.

## 20.2 Sheep remove soil cover

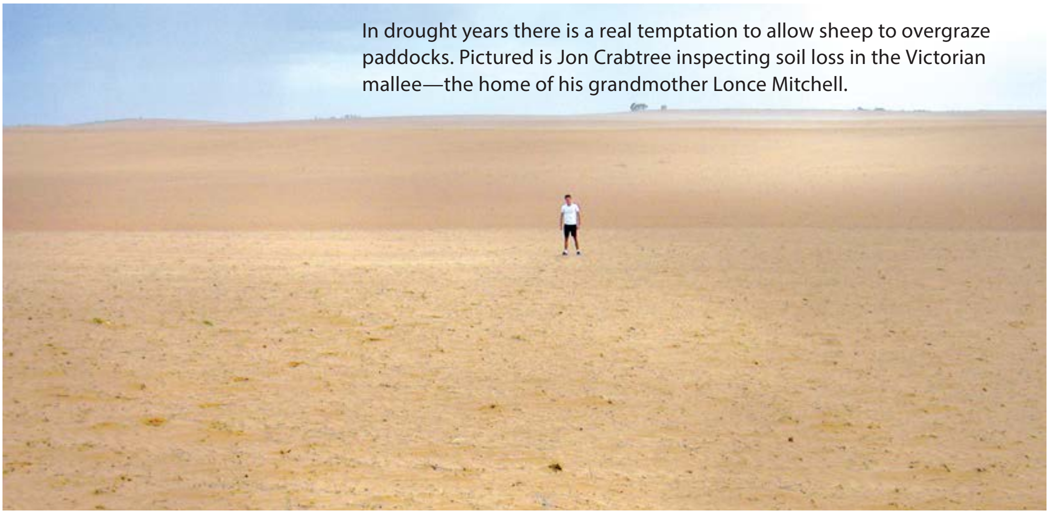
There is no escaping the fact that sheep remove soil cover, as discussed before. Soil cover promotes the better retention of soil moisture in marginal conditions. Sheep limit the ability of the soil to soften and improve its microbial activity. For these reasons it is likely that no-till farmers in perhaps 10 year's time will use more feedlots to keep sheep off paddocks— or perhaps they will have no sheep at all.

## 20.3 Sheep and heavy soil

When heavy soils are wet the sheep's hooves pug the soil. This removes its structure and so the soil sets hard when it dries. A long-term tillage trial at Merredin Research Station showed that a soil's structure had improved greatly with least tillage through time *(see Chapter 9)*. All the improvements in soil structure to a depth of 8 cm were lost on one wet weekend by locking a large number of sheep into a small trial area just before and during a summer thunderstorm. The moral of the story—it doesn't take much to undo all the good soil structural improvements that can take years to create.

Loamy soils when wet can be easily compacted and damaged by stock movement.

My own farming experience is worth relating here. At my Morawa farm there was no soil cover after a string of droughts. In February 2008 I had several strong summer rainfall events and much of this rain ran off the bare, heavy soil. I grew a reasonable crop in 2008 and again I had similar heavy rains in February 2009. The stubble that was retained and not grazed held the water up in the landscape, allowing the water to penetrate deep as a reserve to finish the crop in September 2009. This is one of the many benefits of soil cover.


In drought years there is a real temptation to allow sheep to overgraze paddocks. Pictured is Jon Crabtree inspecting soil loss in the Victorian mallee—the home of his grandmother Lonce Mitchell.


Contrast the above with no-till farming: here the stubble protects the crop from the elements.


James Crabtree (Bill's father) enjoying the fruit of our labour.

'No-till has been a key component of an economic revolution for Western Australia …'

CHAPTER 21:

# Economics of no-tillage

**THERE IS** no doubt that no-till has been a powerful tool for improving crop production in recent years. Farmers do not embrace a technology that helps them lose money. They either adopt new technology or do not remain financially viable. Some farmers, however, are slower than others to realise the benefits of new technology and adopt it.

WA's crop production, or water use efficiency, has lifted 30–50 per cent since the widespread adoption of no-tillage. This adoption has been made possible with modern herbicide technology. This yield improvement equates to an extra 32 Mt of grain over 10 years as a result of farmer adoption of no-till. Without this adoption many farmers could not have survived the recent long string of droughts.

There are also the seen and unseen benefits of saving topsoil from being washed and blown off paddocks, as well as all the other benefits previously mentioned. No-till has been a key component of an economic revolution for Western Australia.

Previously there was a reluctance by some agriculturalists and researchers to give due credit to the impact of no-till. Many farmers acknowledge that, in drier areas, half of their cropping program would not have been sown if any tillage was used. Neighbouring farmers who employ conventional tillage practices often experience 10–50% less grain yield during drought conditions. No-till has often doubled water use efficiency. The proof of this is in the strong and continued adoption of the technology.

No-till farmers regularly report that their water use efficiency has nearly doubled after 10 years of no-till. Applying good crop agronomy in marginal moisture environments without no-till can still give a poor result. Often good crop agronomy is just not possible without no-till.

The 'whole system' farm benefits that WA farmers have experienced with no-till in recent years deserves widespread public acknowledgement. These no-till agronomic gains eclipse any other form of agricultural gain, including plant breeding. Those who are keen to promote tillage and burning for short-term weed, disease and insect control should carefully consider the long-term impacts of these practices. Leading long-term no-till farmers consistently see continuous soil improvements with more time in the no-till system.

Data collected for a land use audit by David Stephens (*pers. comm.*) shows that WA has lifted wheat production more than any other Australian State. State average wheat yields climbing from 1.45 to 1.90 t/ha in the period 1992 to 2002. This corresponded to a phase of rapid farmer adoption of no-till. Grain grown and delivered supports this data.

## 21.1 Short-term economic paddock comparison

Here is a brief comparison of a tillage and a no-till system where pre-sowing herbicides are compared to tillage.

Soils that are tilled when moist can forfeit 15–20 mm of moisture; lose organic carbon; have continued weed emergence in crop; become less trafficable; are physically damaged; have problems with surface sealing; have less effective soil-active herbicides; and many other problems mentioned throughout this book. These effects are not always apparent in the first year and their effects can compound over consecutive years. However, these long-term effects are not factored into this analysis, but the earlier time of sowing advantage of no-tillage is used. The following general assumptions are used in the analysis:

- Wheat is grown.
- Grain yields for no-till is assumed to be 2.2 t/ha.
- Early 2007 costs and returns are used (more typical than 2008 or 2009).
- There is 350 mm annual rainfall.
- The land is leased.
- An air-seeder is converted to a no-till seeder.
- An extra 20 kg/ha of urea is used with no-till—due to less N released in no-till (which is observed in the first few years of no-till and changes with time).
- The no-till yield is increased by 0.2 t/ha due to earlier sowing time of 10 days.
- An extra yield of 0.18 t/ha occurs with no-till due to:
  - more efficient weed control;
  - less soil water evaporation;
  - more precise fertiliser placement; and
  - controlled water harvesting.

Large efficient machinery like the Seed Hawk® helps farmers manage more land with less time.
PHOTO COURTESY OF VÄDERSTAD®.

| **No-Tillage economics** | | **Rate (kg or L/ha)** | **No-Till Costs ($/ha)** | **Tillage economics** | **Tillage Costs $/ha** |
|---|---|---|---|---|---|
| **Inputs** | **Type** | | | **Difference** | |
| Fertiliser | DAP with seed | 70 | 42.00 | | 42.00 |
| | N as urea | 110 | 55.00 | 90 kg/ha | 44.00 |
| Fungicide | Flutriafol 250 | 0.4 | 14.40 | | 14.40 |
| Herbicide #1 | Glyphosate 520 | 0.8 | 4.64 | Not used | – |
| | 2,4-D Ester 80% | 0.4 | 3.80 | Not used | – |
| | Spray oil | 1% | 0.29 | Not used | – |
| Herbicide #2 | Glyphosate 520 | 0.8 | 4.64 | | 4.64 |
| | Trifluralin 480 | 1.5 | 8.80 | Not used | – |
| | Triasulfuron 750 | 35 g | 4.55 | | 4.55 |
| Herbicide #3 | Diflufenican | 0.02 | 1.32 | | 1.32 |
| | MCPA-LVE | 0.35 | 3.00 | | 3.00 |
| | Spray oil | 1% | 0.29 | | 0.29 |
| | Wetter | 0.25% | 0.60 | | 0.60 |
| Fungicide | Propiconazole 250 | 0.25 | 6.00 | | 6.00 |
| Operations | 4 sprayings | $6/time | 24.00 | 3 sprayings | 18.00 |
| | Treat seed | | 2.00 | | 2.00 |
| | Topdress urea | x 2 | 12.00 | | 12.00 |
| | Seeding | | 35.00 | | 35.00 |
| | Harvest | | 45.00 | | 45.00 |
| | Tillage and fuel | | – | Applied | 40.00 |
| Finance | Interest on finance | 6 months at 8% | 9.00 | | 9.00 |
| | Depreciation | | 24.00 | $11/ha more | 35.00 |
| | Land lease | | 40.00 | | 40.00 |
| **Total** | | | 340.33 | | 356.80 |
| **Returns** | Wheat at 2.2 t/ha at $A210/t | | 462.00 | $1.82 t/ha | 382.20 |
| **Profit** | | | **$121.67** | | **$25.40** |

The benefits of no-till in this analysis are $96/ha higher than a tillage-based system. These results help to explain why there is such a high adoption of no-till in Western Australia.

Hydraulic tynes enable dry seeding which has become important during recent Australia-wide drought.
PHOTO COURTESY OF VÄDERSTAD®.

## 21.2 Long-term economic benefits

There are also significant long-term implications for the practices of no-till and stubble retention. The tendency of heavy soil to soften without tillage (or sheep hooves in the wet) and with retaining stubble has led to clear improvements in soil structure. Soils that farmers could not establish crops on 15 years ago are now some of their most productive soils after many years of no-till. Cereal crop yields of 4–6 t/ha are now common in 450 mm rainfall areas.

As mentioned earlier, the amplified biological activity from the no-till system also has positive nutrient implications. The cycling of nutrients—in particular N, S, K and C—after 5 years of no-till leads to more robust and healthy plants. The free-living N-fixing bacteria become apparent in long-term no-tilled fields, which decreases the need for applied inorganic N.

Earthworms are a good indicator of soil health—these are always more common with no-till and stubble retention.

In drought years, and in sandy soils, the benefits of no-till have been obvious. Farmers have been able to establish crops on small rainfall events and at the opportune time without soil erosion. No-till seeders have been able to penetrate dry soil and place seed into marginal soil moisture. The seed has been able to germinate and survive until more rain falls. With no-till, early crop growth is slower than with full tillage, but this is an advantage in dry starts to the season as the crop uses the water more efficiently than a crop grown in a cultivated, fully mineralised soil.

Here, no-till in the eastern wheatbelt is suffering from two year's drought. This is without sheep but after a poor lupin stubble.

No-till with stubble retention can be a biologically robust system—with no erosion.

‘I can see significant benefits to the soil and other areas from farmers adopting guidance systems …’

CHAPTER 22:

# Where to next?

**LEADING** farmer groups are constantly looking for the next research or extension idea to take them forward. Some believe it will be with discs and cover crops, some think it will come from controlled traffic, precision agriculture, variable rate and guidance, while others say it will be with shielded spraying and wide rows. Some, myself included, believe that GM crops will provide the next quantum leap in profitable and sustainable farming. Then there will be ideas of which no-one has yet even thought.

It is likely that all these ideas will contribute somehow towards building a more sustainable farming system. Cover crops have already been briefly covered, so other issues are discussed below.

The sun never sets on an evolving agriculture, but we must try and minimise our footprint while we feed the world.

LEFT: Soil here at Bencubbin can be seen to be compacted by harvesting during wet weather—a strong argument for controlled traffic when soils are wet.

## 22.1 Controlled traffic

Soil compaction has been shown to restrict grain yield in some soils by up to 50% in controlled deep ripping trials. In contrast, the more typical sandy or sandy, gravel, duplex soils with fine sands of Western Australia, that contain 1–5% clay, seem to be unresponsive to deep ripping. These soils are hard to compact.

Loamy sands often give a 25–40% grain yield response to 30 cm deep ripping and they have been shown to compact naturally. Even without traffic these soils will give a ripping response. On most soils no-till alone will soften the soil, especially when crop residues are left ungrazed and the soil microbes, earthworms and soil insects are encouraged to be active.

So which soils will respond significantly to controlled traffic? Some advocates say all soils will, but this is not my experience. Certainly controlled traffic will be of benefit where large tillage responses or significant soil compaction do occur. Similarly, it will be of benefit where poor crop growth is observable after heavy traffic.

Research in the northern agricultural regions of WA and throughout Queensland has shown large yield improvements with the adoption of controlled traffic. Similarly some regions do not have appeared to benefit from the adoption of controlled traffic. One consistent observation on all soils, however, is that vehicle trafficability has been improved with controlled traffic and this is invaluable in wet seasons.

A challenge has occurred where wheel ruts have deepened with controlled traffic, allowing water to pond. However, if the soil has become softer and freer draining to depth in the inter-row then this water ponding seems to be less persistent. Leading farmers are now contemplating ways to fill these ruts in, perhaps with gravel or gypsum. If this is not done then tilling to pull nearby soil into these ruts may have to be an option.

There has been a strong push for farmers to adopt raised beds in southern WA. However, the recent string of droughts has made this intensive drainage approach not so rewarding. Perhaps wide raised beds that interfere less with vehicle traffic and take longer for the water to drain off the crop area will be adequate in this apparently drier era of farming in these traditionally wet areas.Despite these soil improvements with no-till I can see significant benefits to the soil and other areas from farmers adopting guidance systems. Most farmers are now using some form of guidance with the technology becoming more affordable.

## 22.2 Variable rate agriculture

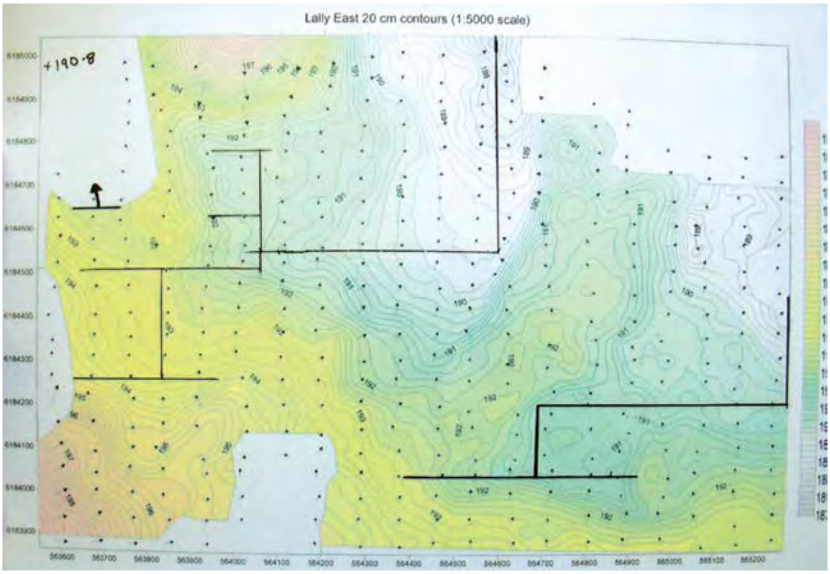
About 15 years ago there was great optimism that precision agriculture would herald a new and powerful set of tools to make farming more efficient. While a great idea, variable rate seems not to have been realised to the degree we had all hoped it would. The idea is that nutrients and pesticides could be applied at predetermined, variable rates across a field and would be automated through GPS satellite guidance systems. Farmers and agronomists map fields on the computer for the requirement of all variables. These mapped areas would then be imported into geographic information systems and rates would automatically vary across the field without manual intervention by the farmer.

Many trials have shown that we cannot predict accurately what the economic optimal rates of various macronutrient inputs are that will give the most economic returns at sowing time. There are, however, some trials that have shown useful economic returns from managing inputs in this manner (Chris McDonough, *pers. comm.*)

Garren Knell's three-year GRDC-supported study in WA with N and P rates across a range of soil types is one example of a variable result. Here Garren compared low, medium, high and recommended inputs across soil zones that were shown to be of low, medium or high likely yield potential. Rarely did the recommended rate perform as the most economical treatment, which is what it was intended to be.

In contrast, work conducted by Precision Agronomics with the EM38 (portable conductivity meter) has given more encouraging results. This model works with resistance numbers being generated on wide swathe widths and then the range of results is divided into about 9 soil sections. These sections are intensively tested to about 1.5 m depth at 10 cm intervals for soil chemistry. This chemical data is then correlated back to the EM38 data to show how the paddock varies. This tool is still new but shows a lot of promise for wide-scale use.

Yield mapping was quite exciting when it was first launched. A lot of data has been generated, but again how is it to be used and interpreted? Trying to manage these programs and data in a way that makes farming more profitable is still a challenge. This information, in conjunction with accurate autosteer, does make large trial work and data more reliable and will be useful for testing all types of ideas.




Accurate mapping for water drainage has been a useful precision tool in wet areas.

The use of smart photo imagery to determine areas of growth is just beginning to have an impact. This data, along with yield monitoring data, will be quite powerful. The monitoring tells us what the potential is while the yield monitor tells us what has happened. The challenge then is to work out why it happened, is it reproducible and predictable—and then devise a reliable variable rate strategy.

## 22.3 GPS guidance

Perhaps the most enthusiastically embraced part of precision agriculture is GPS-guided autosteer. This technology stops overlap and therefore eliminates extra pesticide and fertiliser use. It guarantees that operators can achieve controlled traffic while freeing up their hands to allow them to better monitor other controls and to oversee the whole farm operation. It also helps them be less tired at the end of a day's driving—a health and safety bonus.

There are about three levels of guidance accuracy with the autosteer systems. These are the sub-metre accuracy from marine beacon or crude correction signals; the sub-20 cm systems based on more accurate correction signals; and the sub-2 cm accuracy system which requires a base station with strong correction signal located on or near the farm. This technology is changing at a rapid rate and there are likely to be increasing options for autosteer with time.

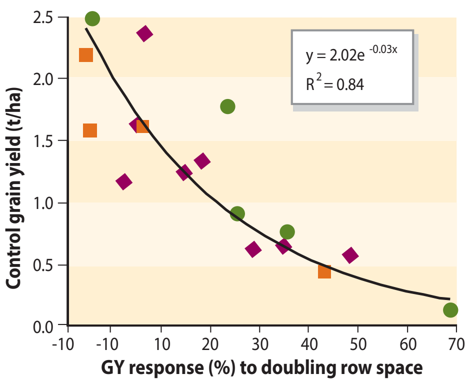
The more accurate the system the more expensive they become. However, since their release on the market in the late 1990's the cost of the technology, in real terms, has greatly reduced and further reductions are yet still likely.

There are 25 American satellites orbiting the earth and all software GPS systems use these. There are also 17 Russian satellites that are available to some GPS companies. Some companies use only the US satellites (John Deere and Auto-Farm) while Farmscan, Topcon and KEE can use the Russian satellites as well. By 2010–2011 there will also be the Galileo satellite system from the EU and, again, some systems will be able to tap into these.

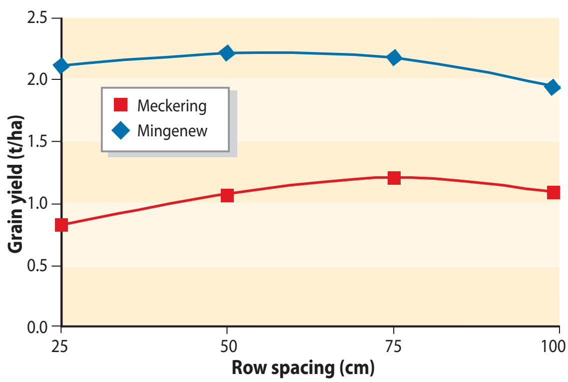
## 22.4 Wide row technology and shields

Farmers in Queensland have been using wide rows on chickpeas and faba beans since the early 1980's. They have observed 0–25% yield increase by using no-till and widening rows from 30 cm to 75 cm. Yield penalties for wide rows in these crops usually only occur with late sowing, while yield increases are common in dry years with earlier sowings and in lower yield potential situations (see graph). Their success with wide rows encouraged southern Australian farmers to mimic their work in the late 1990's with lupins, faba beans and chickpeas. Such trials have shown similar success with wide rows.

**Lupin response to doubling row space from 2000–2002 across WA**




**Lupin response to two row spacing trials in 2002 (WANTFA trial, Meckering and Mingenew)**



These wide rows have several agronomic implications. When used in conjunction with full stubble retention they allow easy seeding through thick cereal stubble. Wide row crops means less soil disturbance and less weeds stimulated to germinate and emerge. It also allows triazine herbicides to work more effectively.

Wide rows can conserve soil moisture in the inter-row, allowing the crop to better tolerate a dry period. Wide rows have been shown to give taller pod set which allows the farmer to harvest more of the grain. Wide rows have consistently given a higher harvest index where more grain is harvested for less plant growth. This does mean that less N is fixed or released to the soil with wide rows and more grain (or N) is harvested from the paddock. This will result in less residual N being available for crops following wide row lupins.

These wide rows allow for creative weed control strategies. Shields can be used to spray knockdown herbicides in between the row of crop. Typically farmers use glyphosate or Spray.Seed® with some atrazine to give full weed control and manage weeds that might be resistant to group A and group B herbicides. High rates of expensive herbicides can then be used in the furrow to improve control. This technology is time-consuming and absolute precision is essential to minimise crop damage.

Shields being used to make lupins 'Roundup® Ready', by spraying glyphosate in between the rows.

## 22.5 Perennial plants

Integrating trees, annual pastures, perennial pastures and crops into agriculture is seen by many as a balanced and sustainable approach to take. While this may well be the case for many reasons it is not my preference. I have seen these systems work quite well.

In very dryland agriculture I have seen few perennials that can cope with droughts and give good production while keeping the soil covered to stop soil erosion. If such a perennial plant exists I cannot see how it would be harvested without stock and the consequent erosion risks as they randomly traverse the land.

I am aware of the STIPA group in NSW and the Evergreen Group in WA who are integrating perennials into farming systems. I wish them the best and hope that they can develop an environmental and economical mix that leads to improved agricultural dryland sustainability. My brief personal exposure to this approach has not been overly successful however, and I feel it is limited to some agro-ecological zones.

Trees may well grow adequately and give many benefits to agriculture. But to date, I see little financial reward for them—perhaps this is still to come. Trees do reduce ground water recharge, beautify the landscape, fix carbon dioxide, provide habitat for wildlife, are greatly appreciated by the public in general—and more. They also use soil water that could have gone to the crop, create a focus for erosion and they harbour vermin—particularly rabbits.

## 22.6 GM crops

The impact of GM crops on southern Australian agriculture will be significant. While there is currently only one GM crop type available for commercial release in southern Australia (herbicide-tolerant canola) there will be many more to come over the next 8 years. I have calculated that the value of GM canola per typical farm (see Chapter 26) to be $60,000.

*See Scott's Day work with GM crops in the next section.*

Farmers in the USA, Canada, Brasil and Argentina have had a rapid and profound uptake of GM crops. In particular Roundup® Ready (RR) soy, Bt corn, RR and Bt cotton and RR and LibertyLink® canola. In these countries the adoption of these GM traits is between 60–100% since 1995. Farmer adoption has been fuelled by excellent and cheap weed control options, timeliness of sowing and weed control and excellent insect control.

While these are the big four exporting countries that Australia competes with there are many other significant GM countries also. These include China and India. The Philippines have also released over 41 different GM crops for their farmers to use. Monsanto is now placing 8 stacked genes into corn for better yield traits: these will be available from 2011 onwards.

Australian researchers have been world leaders in this technology. Both the CSIRO and universities across many states, as well as some companies, have developed useful GM traits. However, their inventions have not been able to be commercialised, largely because of state governments.

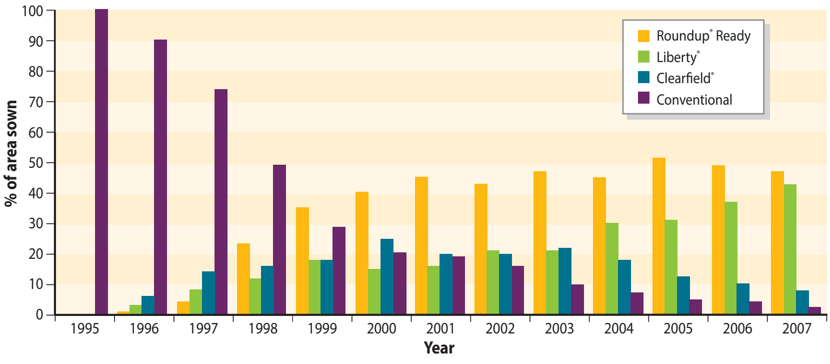
We have a difficult challenge ahead with the stifling of GM crop release. Since the public demand strict regulation of GM technology the costs of bringing these traits to market are in the ten of millions of dollars. Yet with conventional breeding a new line can be developed for less than $10,000 by randomly and chaotically damaging or altering DNA with either radiation or an acid bath. These 'non-GM' tools used in traditional breeding of new crop lines are crude and imprecise, and can carry a lot of unwanted and possibly undesirable DNA with them, yet this is readily approved. In contrast, GM is the precise cutting and pasting of only one gene and this occurs without undesirable DNA. The position of the gene placement cannot be predetermined, however, and plant performance data is required to ensure the placement is adequate.

So how does this affect our small lupin industry? Lupins are now being overlooked in Western Australia as feed companies can purchase GM soy from South America cheaper than lupins can be grown in Western Australia. However, to make lupins Roundup® Ready through GM technology, might cost $10 million. Monsanto arguably cannot justify the expense on a crop that is only 0.5–0.9 Mt annually and declining. Without glyphosate tolerance, and other beneficial genes (like increased methionine, virus tolerance and reduced allergenicity), I believe the day of the lupin plant, being a local breeding success story, is limited. Sadly, there are many other similar examples.

With GM crops farmers have a public relations challenge. While the technology has been proved as safe, if not safer, than conventional plant breeding, the uninformed and perhaps often indifferent public have been scared by a small, vocal anti-GM minority. The technology has proven that it benefits the farmers as, when given a choice, they mostly choose GM crops to grow. Many studies have shown the value of the technology through reducing pesticide use, and other farmer costs as well as managing some challenging agronomic issues.

Canadian farmers grow all the same crops as southern Australian farmers and this makes them a valid comparison for the potential impact of GM crops on Australian farming systems. In 1995—before they had access to GM canola—Canadian farmers were second only to Australian farmers for the level of herbicide resistance in their fields. Now they do not have a resistance problem while we maintain our title as world leaders with herbicide resistance. It is disappointing that politicians are sometimes more interested in being popular than in doing the right thing and allowing free market forces to sort contentious issues out for themselves.

**Canola types as percentage sown in Canada**



‘The key to successful farming in my part of the world is a no-till seeding program with a diverse system and a judicious use of inputs. . . .’

Search for sustainability with No-Till Bill's friends

CHAPTER 23:

# No-till on the prairies

## Scott Day

Manitoba, Canada

**MY NAME** is Scott Day and I farm, work and live at Deloraine, Manitoba, Canada with my wife Ann, our daughter Alex, and my parents David and Claire Day. My sister and her family have a separate farm nearby and Ann's family have farms close by as well. Farming for us is definitely a family affair.

Treelane Farms is the name of our farm and it is a partnership between my parents and me. We are located in the Southwest corner of Manitoba, 70 km east of the Saskatchewan border and 40 km north of the North Dakota border (just above the 49th parallel). This puts us in the very centre of North America.


LEFT: The Day family in their Liberty Link canola, July 2004.

RIGHT: Claire and David Day beside the farm sign, in the autumn of 2006.

The original 'Day' farm where my grandfather was born is 2 km south of our farm. Our relatives on the original homestead sustain a legacy of over 100 years of farming by the Day family. The late 1880's was when most of this region was opened up to farming. My grandfather purchased our home farm in 1936—the driest year during the Great Depression.

After finishing university in 1961 my father returned home to farm. That year was the driest year ever recorded on the Canadian Prairies. In 1989 after travelling and working abroad I returned home to farm. And yes, you guessed it! 1989 was the worst drought we had ever seen since 1961. These epic droughts that corresponded with each generation's start in farming have left us with a very cautious nature and a great respect for conservation.

## 23.1 The climate in brief

Weather is the universal topic of farmer conversation anywhere in the world. However, when you farm on the Prairies of Canada the weather ends up defining you. Being in the centre of such a large land mass and so far from a stabilising ocean, our weather presents great extremes. In fact, our region sees some of the greatest weather extremes of anywhere on earth, certainly anywhere where food is produced.

Many visitors here are amazed that all pipes associated with water and sewers have to be buried 2.5 metres in the ground to avoid freezing in winter. Despite the weather there is no other place I would rather live. Our weather makes us tough and it always gives us something to talk about.

There are positive aspects to our extreme weather as well. A long cold winter is a great steriliser when it comes to many crop production problems. Unfortunately cold winters don't solve all our problems. Despite our cold winters if you get an early thick layer of snow, which can provide tremendous insulation, you can have all manner of fragile plants surviving the winter. I have seen tiny, sensitive volunteer canola and wheat plants still alive when the snow starts to melt in the spring.

As a rule, the Canadian Prairies get drier as you head west from Manitoba to the Rockies in Alberta, and they get wetter as you head upwards from the US border to the parkland regions in the north. Our precipitation averages about 450 mm of water equivalent a year. For our region you have to convert the snowfall to a water equivalent to compare precipitation to non-snowfall regions.

Regardless of the precipitation amount we rarely see an average year. We can have rainstorms that will drop 100 mm in an hour while at other times we can go three months without any precipitation. Our ground is completely frozen for at least 5 months of the year and most of the precipitation that falls during this time is stored as snow to hopefully be released all at once in April just prior to seeding. That is why we can produce very good yields even if we only have 150 mm of well-timed rain (and snow and ice and sleet) during the growing period.

Despite temperatures of –40°C during winter, the winter wheat is green and alive under the snow.

It is also important to store as much autumn moisture as possible until it is needed in the spring. No-till farming allows us to catch as much snow as possible to help replenish soil moisture in the spring. In the past, when fields were tilled, all of the stubble would be knocked down or incorporated into the soil. This left a flat smooth field surface that allowed the snow to blow off of the fields into the ditches and trees.

Now the standing stubble in no-till acts like thousands of tiny trees catching snow evenly all across a field (see photo). The standing stubble in no-till also reduces evaporation on the soil surface because of the insulating and protecting effect from the straw. If you are going to survive in a dryland farming system then you must maximise the use of that moisture from the entire year.

## 23.2 The soils in brief

There are five soil zones in Canada and they follow these changes in precipitation and are named in accordance with the base colour of the soil. The greater the precipitation, the higher the organic matter, the darker the soil, except for the gray soil zone along the northern regions which were developed under forest conditions rather than grasslands that formed the rest of the Prairies.

Our soils are relatively new—glaciers covered our land only 10,000 years ago. Their activity was the dominant influence on our landscape. There are small depressions that dot our farm called pot-holes; they were caused by gigantic chunks of the 2 km thick ice, falling off as the glacier retreated. These potholes create significant headaches for farming with large modern equipment.

Another legacy from the glaciers are the rocks and boulders that can show up just about anywhere. Some of these are as big as a car, but most of these big ones have been removed in the 100 years of farming. However, every year a few more emerge as the freeze-thaw action in the soil each winter brings new rocks to the surface. The good thing about this annual freeze-thaw action is that it reduces compaction problems in our soil. In fact 'deep ripping' or 'subsoiling' is usually a waste of time with our soils.

We farm in the 'black soil' zone in Southwest Manitoba. We call it the 'thin black' zone as our top soil is shallower than what you find further east or north, but it does provide a reasonably good base to grow most crops. This thin black layer of top soil is a clay/loam about 10 cm thick. Below this layer we usually have heavier clay that gets lighter in colour as you get deeper.

With the youth of our soils we don't have many deficiencies when it comes to most nutrients or organic matter. The grinding up of all those rocks by the glaciers has left us with a good quality soil that usually only needs about 65 units of N and 12 units of P to produce average yields with most crops like wheat, barley and oats.

Some farmers will add a little K but that is often not necessary. Other farmers will play around by adding micronutrients but on our clay loam soils there is very little reputable research to support their need for the majority of our crops. For us the best way to test for fertiliser requirements is to sample the top 15 cm of soil for all important nutrients and then test the next 15–55 cm separately for N.


The first field we seeded with our new Väderstad Seed Hawk®/ Morris. Seeding LibertyLink® canola in May 2002.

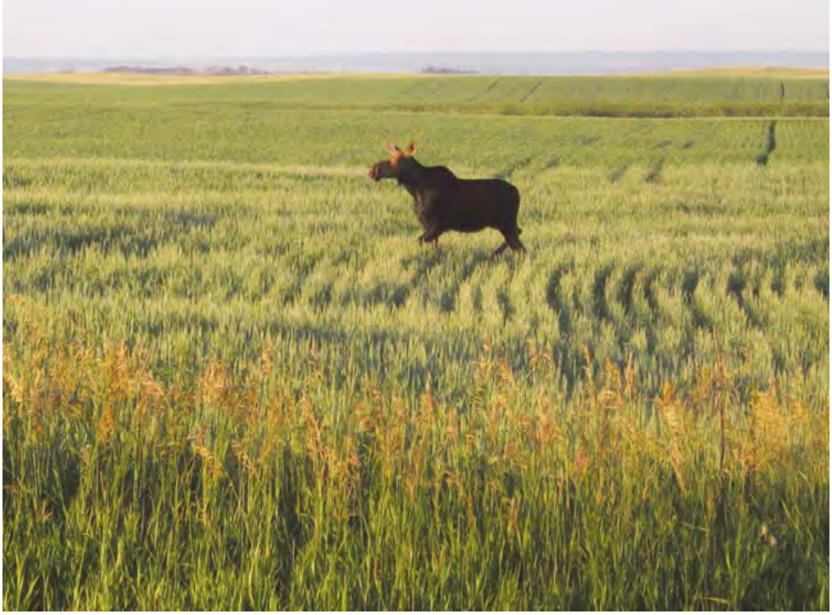
Sulphur rarely shows deficient in our soil tests but we will apply 10–15 kgS/ha as ammonium sulphate when we plant canola. This is because S can be extremely variable across the landscape and that small amount applied with the canola will often be enough to maximise yields. Elemental S will not break down fast enough to adequately supply a crop in the year of application: several years of application and planning need to pass for elemental S to become fully available in our soils and climate.

Our soil pH values run in the range 7.5 to 8.0 and with the highly calcareous nature of our soils we have tremendous buffering capacity. In fact, it would take many generations of continuous application of acidic fertilisers to create any noticeable change to the soil pH. Our organic matter runs around the 3.5–4.0% range. However, that is much lower than when the soil was first cultivated over 100 years ago.

Across the Prairies, generations of ploughing, and the erosion that comes with ploughing, reduced the organic matter to almost half of their initial values. Our farm was once a sea of grass. Like most of the Prairies, every single tree on our farm was planted. When the native grass was ploughed to make way for crops a very sensitive layer of topsoil was left exposed to the elements. Over 45 years ago my grandfather and my father made a concerted effort to do whatever they could to protect this thin layer of topsoil.

## 23.3 Wildlife on the farm

Pot-holes, which can hold water year round, are a magnet for all kinds of wildlife, especially waterfowl. Therefore, we are in a very important ecological region of North America. On any given day you can see all manner of wildlife on or near our farm; moose, elk, deer, wolves, coyotes, badger, fox, plus just about everything else you can think of from North America.



A moose in the wheat on the east side of our farm, July 2007.

See http://www.melitamb.ca

We have bald eagles, hawks, owls, prairie chicken, plus hundreds of song and shore birds and thousands upon thousands of geese and ducks during their seasonal migration. I have observed over 100 hectares of solid snow geese grazing in our stubble, wing to wing, during their migration. Our region is identified by the phrase 'Grasslands Bird Capital of Manitoba'.

Needless to say hunting is an important activity and industry in our region, but despite this we are seeing more and more wildlife every year. In fact the wildlife has become a nuisance at times. Birdwatching is an industry that continues to grow in our area.

It is hard to say why we are seeing this increase in some species; perhaps partly more no-till? Less farmers, so more abandoned farmyards for habitat? Whatever the reason our modern farming methods do not seem to be having any detrimental affect on wildlife, but we have to be aware of this delicate balance and maintain suitable habitat whenever possible.

## 23.4 Hogs complemented grain for 45 years

In the 1960's our farm was like most others on the Canadian Prairies; it was less than 640 acres (one section), we had a small herd of cattle, and some pigs as well. This was when my father decided that our farm was best suited to being a hog operation with grain production geared towards feeding our livestock first, and producing cash crops second. The cattle were sold at that time.

For the next 35 years we had a 50 sow 'farrow to finish' operation with our own feed processing mill on the farm. Then for the last 10 years we have simply been finishing pigs with our weanlings coming from another farm. Commercial hog farming was never common in our region so our farm has always been a little unique. As of December 2007 we got out of the hog business as markets had become very poor, inputs were getting very expensive and my father wanted to retire from the daily responsibility of livestock.

That decision to go into hogs over 45 years ago was an excellent move for our farm. It meant a lot of extra work for our family but it provided stability and cashflow to a small family farm that would not have survived on grain alone. The manure from the hogs also helped replace much of the organic matter and nutrients that were lost in the generations of tillage prior to the changes made by my family. With our livestock operation being relatively small we were able to concentrate the manure application to the hilltops around the farm. This has helped our fields produce more evenly than if the soil on those hills had not been replenished.

One other aspect that the hog operation afforded us was the ability to take greater risks with our grain production. On the other hand our small grain farm did not warrant the investment in the latest expensive equipment so we had to be very careful in our machinery purchases. Thankfully our local Conservation District had no-till seeding equipment that we could rent before we made the decision on what system was best for our farm.

## 23.5 Weed concern with no-till

It is interesting to note how many of the concerns that we associate with change often turn out the exact opposite to what was expected. For instance: one of the major concerns we had with reducing tillage was that we would have a lot more weeds, quackgrass in particular. As we reduced tillage in the early 1990's we seemed to get more and more of this perennial rhizobious weed, all over the farm.

We felt if we made the jump to complete no-till then this weed would get completely out of hand. Many other farmers felt the exact same way as us. However, a farmer I admired that was a director with the Manitoba–North Dakota No-till Farmers' Association told me at that time that simply reducing tillage numbers without eliminating pre-seeding tillage gives you the worst of both worlds. You still get the problems associated with soil disturbance and you don't have all the benefits of no-till.

He said that if you cut out tillage altogether then this particularly difficult weed will eventually go away because you would simply stop dragging the roots around the fields. This was the exact opposite of what we expected but it turned out to be true. As we moved to no-till, quackgrass seemed to disappear. Effective glyphosate applications were important, along with the no-till, but today quackgrass is thankfully not a problem on our farm.

After university I worked on farms in Ireland and Australia for a year and a half. I returned home at the beginning of 1989 and soon afterwards I purchased the 320 acres (half section) directly north of our farm yard. My plan was to make grain production a more significant part of the farm. The same day that I got the loan for the land I was also offered the job as a local extension agronomist (Ag Rep) for Manitoba Agriculture. I have remained an extension specialist ever since.

This has presented the interesting challenge of balancing my career with Manitoba Agriculture while still being a full partner in our family farm. Thankfully, these jobs complement each other very well. I learn a great deal from the farmers I work with and I can identify with them by often experiencing the same problems they do as well.

## 23.6 An organic experience

One very interesting aspect of this land that I purchased in 1989 was that it had always been farmed organically. It was probably one of the very few pieces of commercial grain land in Western Canada that had always been farmed organically. Most of today's organic operations are farms that have switched from conventional methods in recent years.

The previous farmer of this land had never used commercial fertilisers or pesticides in his lifetime of farming. He had been one of the pioneers of organic farming in modern times. He used legumes such as clover along with fish parts and other natural products whenever possible to try and replenish nutrients.

He used tillage and summer fallow to control weeds, but he did this as sparingly as possible. However, this land was in very poor condition compared to our home farm across the fence. The organic matter was only two-thirds the level of our home farm, and weeds were rampant across every acre.

The P level in my first soil test on this land was extremely low at only 1 kg/ha of available P. In fact the P level was so low that the soils lab asked where I had found that soil; it was the lowest level they had ever observed. I quickly made the decision that this type of organic farming was not the best for our land or my family and we planted the first crop on this land with commercial fertiliser and herbicides.

Another interesting aspect from this first year was that the nitrate level was actually quite high on this 'organic' land. The probable reason being that the summerfallow and legumes would have helped build N levels but, without adding other nutrients like P or S, crop production would have been eventually held back to the point that the N was accumulating.

This land was a good test case for the long-term effects of organic grain farming in our region. After almost 20 years of our careful stewardship this 'organic' land is still not up to the qualities of our home farm right beside it. I know that I will be challenged over this but I think that this land shows that eventually this type of farming will run out of steam and is ultimately not sustainable. It is as simple as mathematics: you can't remove nutrients without eventually having to replace them. This also reinforced the message that tillage is not the way to go.

## 23.7 Sustainable agriculture requires no-till

So what do I think is the key to maximising potential in a rain-fed cropping system in my part of the world? Well for me it is a no-till system with a diverse rotation and a judicious use of inputs. What are the specific benefits of no-till? First and foremost you reduce soil erosion to almost nil.

When I was young the sky would at times turn dark with blowing soil, that sight is now history for most of the Prairies. Tillage does not occur in nature so it only makes sense that the best method to utilize our soil is to do so without tillage. As mentioned earlier you can trap more snow and reduce evaporation

A one tonne/acre crop of LibertyLink® canola.

AC Barrie sown into bean stubble—sold to the most premium wheat market in Europe.

with no-till but you also allow the soil to develop greater internal permeability by not cultivating.

Originally we felt that no-till would decrease water permeability into the soil but once again the opposite was true—it has improved this soil quality. Now when we get a deluge of rain, the water will soak into the soil profile better than when we used to till.

No-till provides much greater efficiencies when it comes to machine and fuel use. Without the need of cultivators, disks or ploughs you need less equipment as well. A no-tilled field provides a very firm and moist seedbed to get your crop off to a good start. No-till helps reduce certain weeds and can have a negative effect on other pests. Many of the good soil organisms like earthworms thrive in no-till, and no-till provides better wildlife habitat for ground nesting birds and other wildlife. As you can imagine no-till is a very important part of our dryland farming system.

## 23.8 Drawbacks to no-till

So what are the drawbacks of no-till? Well, this greater water retention can create problems in very wet years and in very heavy soils. Salinity can be reduced with no-till in most situations while in others the extra moisture in no-till can accelerate this problem. Water management and rotation is the key to minimise these concerns.

84 foot Väderstad Seed Hawk® being used west of Regina, Canada.

With the entire crop residue retained on the surface it can host diseases and other pests longer than with tillage. This thick residue layer can also cause problems with drill performance and with soil temperature, but good rotations and proper equipment can address these concerns as well. Overall the benefits far outweigh the problems and that is why we are now joined by at least 90% of the farmers in our area with direct seeding or no-till farming.

## 23.9 Evolving no-till system

When my father and grandfather started to reduce their tillage they did so by getting rid of the plough and going to a shank cultivator. Then the 'disker' seeder was dropped in favour of a lower disturbance double disc drill. Summer fallow was dropped in favour of continuous cropping.

In 1993, after trying out those seeder options through the local Conservation District, we purchased a used 5000 Flexi-Coil air drill. We put narrow carbide-tipped Atom Jet hoe openers on the air drill set at 16 cm spacing. We applied all of our N through our heavy duty cultivator in a separate pass as anhydrous ammonia ($NH_3$). This was also retrofitted with narrow carbide-tipped knives.

This basic type of system quickly became one of the most popular seeding systems on the Canadian Prairies at that time. The $NH_3$ would usually be applied in the early spring and we would seed immediately afterwards, with the remaining nutrients going down the seed tube. Farmers that had lots of acres to cover would apply their $NH_3$ late in the fall and just go and seed in the spring.

For many years experts said that you could not seed within 5 days of applying $NH_3$ to the soil. This was still an official recommendation until the 1990's. As people wanted to seed and fertilise closer together they looked at the research to support this claim. It turned out there never was any research to support this delay and many farmers had already proved it to be unnecessary. Now most seeders on the Prairies are applying $NH_3$, urea, or liquid N while they are seeding. This just goes to show that you shouldn't simply accept recommendations without proper research.

In 2001 we made the switch to a true one pass no-till seeding system. We purchased a Väderstad Seed Hawk® with 23 cm row spacing along with a $NH_3$ tank and auto rate applicator mounted right on the drill (see photo). This drill places the seed in one furrow with a very narrow knife, on a shelf usually about 1.5 cm into the ground, and then there is a second knife equally as thin that places fertiliser 4 cm to the side of the seed row and 4 cm deep into the ground.

We don't have rhizoctonia to deal with, like they do in Australia, so we don't need to rip a deep furrow in the soil while seeding (the occasional rock would make this difficult as well). Our unit allows us to seed and fertilise our entire 2000 acres of crop with only 140 hours on our 225 hp tractor each year. This also greatly reduces our fuel use compared to our old tillage days as well.

It is hard to imagine a more efficient seeding system at this time. This type of seeding unit has become very popular in the last few years throughout the Northern Great Plains. In fact many of the larger machinery manufacturers are now copying the Väderstad Seed Hawk® or Seed Master™ lead with their own parallel link, independent, seeding openers (see photograph).

BELOW: Our 2388 harvesting AC Coupland two row malt barley.

INSET: Our combine in action in HRSW wheat destined for the premium market in Britain.

On the Canadian Prairies you have very tight timelines in which to maximise your crop potential—there are few exceptions. You have to get most of your crop planted within the first week of May. Even waiting until the second week in May usually causes a small yield reduction. Once you are seeding in June, yields can really drop off, although you can still insure most crops if they are seeded before the middle of June.

Later seeded crops have less yield potential because they are more susceptible to the heat and drought that often occurs in the later part of our summers. As a result once seeding starts you ideally want to seed 10% of your acres each day, no matter what the size of your farm. This ability coupled with the usual weather delays at seeding means that getting your spring seeding completed in two weeks is about as good as you can expect.

## 23.10 Hoe openers predominate

The short warm summers leave little room for error when it comes to seeding. The soil can be quite cool in the spring and that is part of the reason why the hoe (knife) opener has remained very popular even with low disturbance seeding systems. You can't always wait until the soil gets to the perfect temperature or you might end up seeding too late.

With a seeding hoe or tine creating a narrow ribbon of exposed black earth you can gain a few extra degrees and move the growing process along faster. As many of us were moving to direct seeding systems in the early 1990's there were several air disc drills that were purchased. In theory their low draft and low disturbance capability seemed to be the ideal in a no-till seeding system. However, despite some farmers desperately trying to make the disc seeders work, very few of them are still around.

In talking with former owners they have told me that the disc drills worked fine 80–90% of the time. Then, every once and a while, they simply did not work and there you were searching to find another seeder at the busiest time of the year. At certain times disc openers would not penetrate heavy wet straw, despite different attempts with 'trash managers' and the like. Remember that our crop residue breaks down slowly because it is frozen 6 months of each year.

We found that disc units needed considerable maintenance as they got older and they just didn't work in certain soils. There are only a couple of farmers still successfully using disc drills in my area but they are using them on unique soils and in specialised farming systems. Disc drills gain in popularity as you move south and west, to drier and warmer regions. I think disc drills have the potential for a return to our area; we just don't have the proper technology available at this time.

This aspect of very low disturbance as a way to control weeds has very good merit but Mother Nature has a way of adapting to every good theory and turning it upside down. This is especially true if you don't add variability to your system. While weeds like quackgrass have become less of a problem in a low disturbance system, other weeds that have always been there have moved to the front of the line and taken their place.

My opinion is that no-till has less overall weeds, but we still have weeds. Weeds with tiny seeds seem to be the biggest problem, like dandelion, thistle, kochia, and foxtail barley, to name a few. Some of these weeds were a problem


Our Väderstad Seed Hawk® direct seeding winter wheat into pinto bean stubble.

in tillage systems but they have also become problems in our no-till systems as well.

If you just let a field sit with absolutely no disturbance it could still be covered with these weeds by the middle of the summer. As you can see, using no or low disturbance seeding as a way to control weeds is only effective on some weeds and in certain situations.

## 23.11 Harvest is a priority

Harvest is equally a busy time although the urgency is not the same as in the spring. Most crops will mature in about 90–100 days. With our Northern latitude we have the advantage of long daylight hours in the summer. Our last spring frost is usually in the middle of May and our first fall frost is often in the middle of September.

Two-row Harrington barley matures in about 90 days on the Prairies but that same variety, when grown in Western Australia, would take 30–40 days longer to mature. This is because of the different length of daylight and because it was being grown in the Australian winter as opposed to the warmer Canadian summer.

We believe that harvest capacity with machinery should be at least 5% of the acres per day with 7.5% being better. Very large farms are able to stretch their harvest capacity over a greater area by growing crops that have different harvest periods such as winter wheat and peas at the start of harvest and sunflowers at the end of harvest.

Harvesting the 1 tonne/acre LibertyLink® canola crop, October 2006.

Our significant distance to major export markets means that most of our farms must have the ability to store all their production on the farm. That is why you will see so many grain bins on Prairie Farms; this storage aspect is also considered when we are looking at overall harvest capacity and efficiency.

## 23.12 The herbicide tolerant and GM canola systems

One of the most important tools in our ability to no-till effectively has been GM canola. I worked with this technology as a research assistant in 1987 and we adopted the technology on our farm as soon as it was available in the mid 90's. With 20 years of positive experience with this technology I have been telling my story with GMOs in many different places around the globe.

We started growing GM canola with the Clearfield® (Imi resistant) system in the mid-1990's. Then we grew the Roundup® Ready system for a few years but moved to the LibertyLink® system when they started to develop superior hybrids. We have stuck with the LibertyLink® system ever since. Here is a quick summary of my opinions of each system.

The Clearfield system isn't a transgenic canola; it is a mutagenic where existing genes within the plant were mutated to provide new desirable traits. This is technically not considered a GMO but it obviously has experienced gene modification. Clearfield canolas have always been a good choice in certain situations.

The herbicides that can be used on Clearfield canola are persistent in the soil and this helps keep fields clean for the whole season and often longer. However, these same products don't kill all weeds effectively and this is a drawback compared to the Liberty or Roundup® Ready systems.

In the last few years the 'imi's', have developed resistance issues. In our particular area all of the kochia (that weed I mentioned above that didn't need disturbance) is now resistant to this group of herbicides. We also want to maintain as much variability in our system as possible, but there are other ‘imi’ herbicides that we would like to use on our other crops as well, such as wheat and peas.

Liberty® and Roundup® are not used on other crops for the most part in Western Canada so they provide more variability to your system. We now have Clearfield wheat in Western Canada so growing Clearfield canola on the same farm as Clearfield wheat would require careful attention. Considering all of that, Clearfield can still be the best choice under certain situations and it is the least expensive system to use.

Roundup® Ready (RR) Canola covers the most acres of canola in western Canada by a narrow margin. The two transgenic GMO systems of Liberty® resistant and Roundup® resistant canola’s now account for over 83% of the canola acres in Western Canada. ‘Transgenic’ means that a gene(s) was inserted into the canola. Our adoption of GMO technology was one of the fastest acceptances of any new farming technology, ever.

We wanted the technology sooner but RR canola’s introduction was delayed because the original RR variety (which was the most popular variety in Canada at the time) developed an extreme susceptibility to Blackleg. Consequently they had to start over and insert the resistant gene into a new variety. Most of our farms in Western Canada use a considerable amount of glyphosate (Roundup®) already. This herbicide is the key to our environmentally friendly no-till farming systems, as it is anywhere in the world.

Many people don’t realise that by having the opportunity to use glyphosate on a growing crop you are actually adding variability to its use. Many Prairie farmers are not necessarily using more Roundup® because they are now growing Roundup® Ready canola they are simply applying the Roundup® at a different point in the growing season with RR canola. This variability is possibly delaying resistance to Roundup® by other plants.

Applying Roundup® ‘in crop’ means the product is being applied at a totally new time of the year. The RR system, like other ‘in crop’ herbicides, allows crop competition to play a role in weed control as well. The other times you use glyphosate, such as pre-seeding or post harvest, the crop is not being competitive to the weeds.

With RR canola even if the glyphosate doesn’t kill the weed completely the aggressive growing crop of canola may help finish it off. By applying glyphosate to an aggressive RR crop, then the crop itself creates a situation that is like tank mixing a unique herbicide in with the glyphosate. This adds further variability to your system especially if you are already using glyphosate on your farm.

Swathing that 1 tonne/acre LibertyLink® canola crop in September 2006.

When you look at the fact that Western Canada is yet to develop a glyphosate resistant weed of any significance, but Australia has been dealing with glyphosate resistant weeds for years, while not having a RR crop, is an interesting observation. It goes without saying that if you have more than one type of RR crop on your farm then RR volunteers can become a significant issue. For most of the Prairies this is not an issue as RR corn and RR soybean is not the rotation.

The LibertyLink®(LL) system is a great tool to add herbicide variability to your system. We use this product on no other crops or situations beyond Liberty® Resistant canola. It has a different mode of action and speed of action (fast) to any other herbicide that we might use on our farms. LibertyLink® (LL) canolas now cover almost the same amount of acres as the RR system and it is the number one system in Manitoba.

The yield potential with the Hybrid LibertyLink® canola's was superior for many years and the disease package was usually good as well. These reasons were why we switched to only LibertyLink® varieties a number of years ago and have stayed with them ever since. Today many of the Roundup® Ready hybrids have the same yield potential as the LibertyLink® hybrids and the Clearfields are quite strong as well, so now there are very small yield differences between the systems.

We would go back to Roundup® Ready canola on our farm now that the genetics have caught up to the LL Canolas and if we knew we were going to have a considerable weed problem. Liberty® is not as forgiving as Roundup®; you learn to use the product only under specific conditions.

The first year of LL canola in our area was very hot and dry during the spray season and weed control was poor. Now we know to spray when growing conditions are ideal: early morning or times with higher humidity work best. You don't want to skimp on rates and you need to keep water volumes up to get good coverage, yet not use it if there is a heavy dew on the plants leaves.

Overall we have been very pleased with Liberty®'s performance but glyphosate does provide more permanent results. LibertyLink® canola allows you to spray a unique mode of action and a very effective herbicide on a field once every three or four years; this adds a tremendous amount of variability to our herbicide program. It has also made no-tilling canola much more effective and possible allowing the whole system to work better.

Now GM canola is a 'clean up' crop on our farm, because we can kill all weeds in canola and so reduce herbicide use in the crops we grow before and after canola. GM canola also allows us to seed canola earlier because we don't have to wait for the exact conditions the old conventional canola herbicides needed. This early seeding helps us finish in that ideal, yield-maximising two week period in late April and early May.

## 23.13 Herbicide resistant weeds

The first Treflan tolerant weed in the world was identified on our neighbour's farm across the road, just 1 km from our farm yard. This Treflan or trifluralin-resistant green foxtail (somewhat like Australia's troublesome ryegrass) was first identified in 1987 and this field has since become famous to weed scientists around the world. Not quite the fame we were looking for but we'll accept any publicity.

Our whole approach to weed control has changed because of the resistant population that was discovered in this location and, subsequently, many other fields across Canada as well. This field had been seeing the same herbicide to control the same weed in most of the crops in the rotation, from wheat to barley to canola. When the resistance hit it was a terrible mess, and 20 years later the green foxtail in that field is still 100% resistant to the Treflan based herbicides.

On our farm we had already made the move to reducing tillage at that time by using newer herbicides with different modes of action that didn't require tillage for incorporation. We didn't realize it at the time but that was a very good move on my Dad's part, and the few times we have used Treflan products since we have been satisfied with the control.

The introduction of GM canola has continued to add variability to our herbicide program. I know if we did not have this option with canola this resistant green foxtail would have continued to spread and plague many other farms.

## 23.14 Rotational diversity is important

Another way we add variability to our farm has been through the wide range of crops that we grow. We probably grow more different crops than is usual for a farm our size but we feel this diversity in crops can pay off in future years with reduced inputs and a more sustainable system.

This diversity can also bring cashflow when regular crops are still sitting in the bin. However, they come with greater risk and take extra work, and don't always pay off. In the last 10 years we have grown the following crops on our farm: lentils, navy beans, pinto beans, confectionary sunflowers, yellow peas, marrow-fat peas, durum wheat, winter wheat, spring wheat, prairie spring wheat, feed and malt barley, rapeseed, and all types of canola.

With all of these crops we try and get the latest and most suitable varieties for our area, once again keeping our farming system as dynamic as possible, but sticking with the ones that seem to work the best for periods of time when we can. Other crops that can be popular in our area include flax and oats but we haven't put those in our rotation recently.

Hemp is starting to be grown in our area with good success and may be a crop we consider in the future. I think that once you get a dynamic rotation that works, making dramatic changes each year because of potential market changes rarely pays long-term. In the last few years we have settled on a few key crops to provide diversity but with a little more focus.

We grow winter wheat: this is a great crop for reducing inputs and adding diversity into your cropping system. The problem with winter wheat is that it doesn't always survive our -45°C winters and is also very susceptible to disease. It can also be difficult seeding winter wheat and trying to harvest the rest of your crop at the same time. However, with its different seeding and harvest dates, its greater water use efficiency (higher yield potential) and its strong competitiveness with weeds, we are happy to include it in our rotation.

The one crop that makes our farm unique for this region is pinto beans. We grow pinto beans solid seeded direct into wheat stubble, and then we swath them prior to harvest. It is a warm season broadleaf legume, which is a rare crop in our crop rotations. This type of bean is traditionally grown in a row crop situation with high inputs and lots of tillage. We have been able to do the opposite, often with reasonable success. The following crop of wheat on this bean stubble is always one of our best.

The trouble with beans is they need heat and rain just at the right time, which is something we don't always get, and harvest is slow and difficult with beans. However, beans can be a profitable crop and it does fit into our system of no-till, lower inputs, and high diversity.

We also grow many types of wheat, the two- and six-row types of barley, and of course one-quarter to one-third of all our acres each year are GM canola. If we were to make some changes for the upcoming years we might look at growing peas again. We used to grow peas but their price became too low and pinto beans replaced them on our farm. Peas make a great rotation crop for any farm and now prices are strong again we would consider adding them back into the mix. Flax would be another consideration in the short-term. The other thing that is always in the back of our mind is steadily rising input costs.

Using a legume has become much more important than it was, even two years ago, as fertiliser prices skyrocket. While I mention peas and flax, we could grow any of the crops mentioned, at a moment's notice, if markets and conditions were appropriate. This flexibility comes from having a precise one pass seeding operation and a good deal of variability already in our system.

Each of the changes to our farm has come with a great deal of discussion and trepidation for all members of our farm but the goals remained the same. While we are quite flexible with our farm plans we do have this core goal of growing each crop without tillage.

The protection of our soil resource is paramount and with that comes better water conservation and yield potential. Thankfully, profitability is now best with zero till—but even if that was not the case we would probably still be using this system for those many other benefits I have already mentioned.

If they say we can only grow a crop with tillage then we will search for a way not to do so—like we did with pinto beans—or we simply won't grow it. Another goal is maximising diversity on our farm: different crops, different varieties, different pesticides and different markets should keep our system sustainable for quite some time.

Livestock was part of our farm diversity as is my off farm job. We will continue to look for ways to increase this aspect of diversity. We are also focused on maximising input utilisation; we precisely apply fertiliser only where and when it is needed; we use variable rate controllers, Autosteer on our tractors and GPS systems. Not necessarily the latest technology but certainly worthwhile for our small farm.

Pinto beans that were direct seeded in wheat stubble. We harvested almost 1800 pounds/acre of beans off that field in 2007 (our 2008 bean crop wasn't nearly as good).

## 23.15 Conclusion

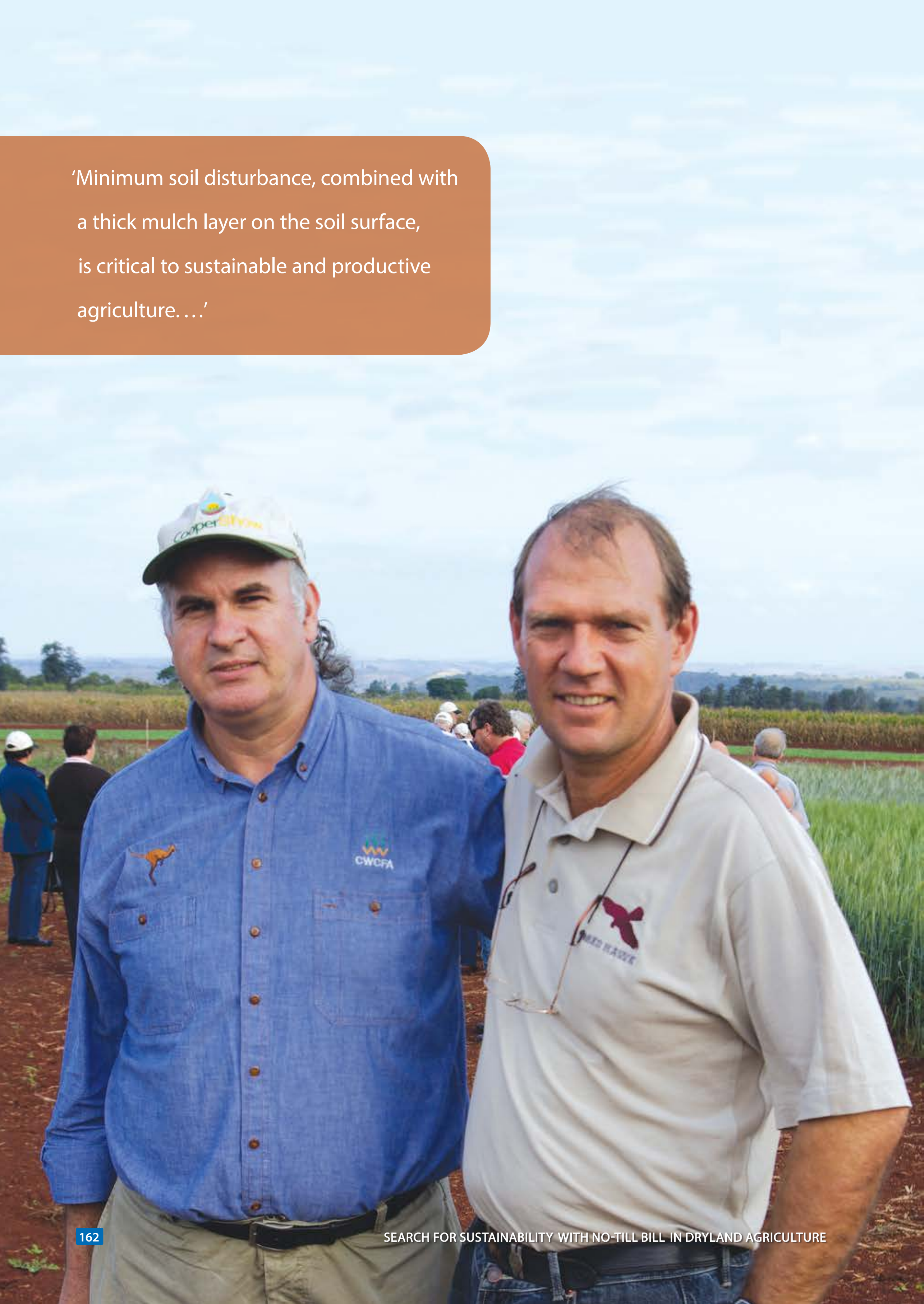
Profitability is our most important goal but it is often the most elusive. However, I am certain that if you have a strong, diverse system with its many components working positively together then profitability is sure to follow. Minimising costs while maintaining production is the most important balancing act in making your farm profitable, but with no-till, the latest affordable technology, and a wide diversity of complementary crops this balancing act is much easier to perform.

Profitability also requires finding ways to add value to our production, and this can also be an elusive quest. Livestock was one way to do this, local processing and consumption has been another. We need to continue to search for ways to add value to our production in the future.

Like I have said, the key to successful farming in my part of the world is a no-till seeding program with a diverse system and a judicious use of inputs. Look to your surrounding environment and vegetation, look to your neighbours and agricultural researchers, and look to other, similar locations around the world. I am sure you will find the inspiration and direction to make these key aspects work on your farm as well.

Unloading premium hard red spring wheat into our truck, August 2006.

‘Minimum soil disturbance, combined with a thick mulch layer on the soil surface, is critical to sustainable and productive agriculture. . . .’



CHAPTER 24:

# No-till in southern Brasil


## Ademir Calegari

Paraná  State Department of Agriculture, Brasil


**MY NAME** is Ademir Calegari and Bill has invited me to share some of my experiences with zero-till. This is my pleasure. I first met Bill in 2001 when he brought a group of Australian farmers to my region. I work as a researcher in the Paraná State Department of Agriculture and have been intimately involved in no-tillage since its beginning in 1972.

Although we have a very different climate to southern Australia, we have many similar issues in crop agronomy. It is interesting to note that disc zero-tillage is the only form of no-till that we employ in our farming systems. Please allow me to further explain our cropping systems and come with me on our search for sustainability in southern Brasil.

## 24.1 Setting the local scene

In tropical and subtropical agricultural areas of the world, where land is intensively cultivated, organic matter decomposition is quite rapid. Historically this effect has decreased the productive potential of soils—often to the point where many believed that sustainable cropping in these regions could not be achieved. This was until the zero-till revolution that has swept through the region and many neighbouring regions subsequently. More on this soon!

The process of developing Paraná State in southern Brasil started about 60–70 years ago with serious consequences of soil erosion through tillage-based agriculture. Paraná State is located between 23–26° south.

LEFT: Two no-till pioneers: Ademir Calegari and Bill Crabtree.

Soil erosion in a storm, Paraguay.

Over 90% of the forests were removed in the first 50 years (until 1984) with agriculture covering both able and marginal areas.

**Figure 1. Map of Brasil showing the subtropical southern states of Paraná (PR) and Rio Grande do Sul (RS), where Brasilian zero-till spread from to the west and north (see arrows) to Paraguay and the tropical/'cerrado' savannah region (shaded)**

In Paraná state there are nearly 7 Mha of land that grows summer species including soybean, maize, beans, cotton, rice, sugarcane, cassava, sorghum, coffee, fruits and vegetables. On 4.5 Mha of this land cool season crops of wheat, barley, oats, lupins and some canola are grown in the autumn and winter. The remaining 2.5 Mha is not sown in the autumn and winter and is prone to soil erosion, capable of weed infestations and requires extra labour and farm production costs.

## 24.2 The problem with tillage

Manuel Pereira showing improvements to his soil.

The soils of Brasil are typically deep red loams. The rainfall intensity can be severe with 200mm capable of falling in an afternoon's storm. The average annual rainfall is 1200–1600 mm and the rain falls all year round. Winter temperatures are mild, and rarely will the maximum drop below 18°C in southern Brasil. The landscape is very hilly and in this environment organic matter decomposes rapidly. Combine all these factors, with the use of ploughing for weed control, and this is a recipe for some of the most dramatic soil erosion possible.

Soil erosion was so great that many Brasilian farmers considered getting out of farming or they would be forced out by the costs of repairing the damage caused by soil erosion. So great were these erosion events that bulldozers were needed to fill in the massive erosion holes and ruts. Without this repair activity farmers could not drive across their lands. Farmer Manuel Pereira reports that it was so severe that it was either do something different or give up farming.

In Brasil the concern over preserving soil and water was not a priority until the 1970's. The dominant farming systems prior to 1970 were perennial crops and pastures, which minimise the effect and intensity of soil erosion. The availability of the tractor in the early 1970's enabled farmers to grow crops each year—this effectively doubled the crop area in the Paraná.

For many years, water erosion was considered the great environmental problem. Contour banks were considered as the main soil conservation tool, however these were largely ineffective. This realisation led growers to search for common solutions. Through time and research no-till has developed into common practice with outstanding success.

## 24.3 Evolving farming systems

During the 1960's, a significant expansion of areas growing soybean and winter wheat occurred in southern Brasil. There was intensive ploughing, disc use, residue burning and downhill seeding with these crops which exposed the bare soils to intensive rainfall, which in turn led to extensive soil erosion and economic losses throughout large areas.

These practices led to the damage of two-thirds of the land suffering some form of degradation. It was associated with the loss of organic matter, poor rainfall infiltration, structural degradation, soil compaction, reduction in plant-available water and with the pollution of waterways through runoff and erosion and even the abandonment of farms.

No-till pioneer Herbert Bartz.

No-till began in northern Paraná with pioneer farmer Herbert Bartz in Rolandia in 1972. His main objective was to control soil erosion where soybean and wheat were intensively grown in rotation. Afterwards, corn also began to be cultivated under this system and researchers began experiments to improve these various production systems.

Herbert wanted to crop and control soil erosion so visited zero-till research facilities overseas. He went to the ICI headquarters in Fenhurst, UK, and visited farmer Mr Harry Young in Kentucky, USA. Bartz returned to Brasil with a zero-till planter and planted his first zero-till soybean crop in October 1972.

Herbert's success in controlling soil erosion and reducing production costs quickly inspired some neighbours, and later farmers in other regions of Brasil. By 1984, there were 0.3 Mha of crop sown with zero-till in Paraná, being 5% of the state. Then in 1985, the zero-till area in southern Brasil covered 0.8 Mha, and now (2008) more than 24 Mha of land is sown with zero-till. Brasil is one of the world leaders in no-till with many regions having 90% adoption, with the state of Paraná having about 5.5 Mha of a possible 7 Mha in no-till.

In the 1980's, research and farmer experience showed that sustainable agriculture is not only about tillage. Rather it needed to evolve into an integrated system. There is currently a strong global desire to find the most appropriate farming systems. There is a need to improve and maintain soil fertility to good production capacity while balancing soil organic matter and preserving natural resources.

## 24.4 Soil cover is part of the system

It has been observed globally that minimum soil disturbance, combined with a thick mulch layer on the soil surface, is critical to sustainable and productive agriculture. The mulch can be comprised of growing plants or their residue. This is particularly important in warm and wet environments where microbial activity and nutrient leaching is continuous and where weeds can grow strongly all through the year. An understanding of how different crop residues influence soil nutrient recycling and chemical properties is essential to optimise the system.

The zero-till systems have now proven to be economically rewarding and ecologically sustainable. They have increased crop productivity, improved water harvesting, conserved the soil and usually recovered losses in soil fertility. In addition to this, through crop rotations, they require less N fertilisers and decrease the effects of pests and diseases.

By exploiting crop rotations and with careful planning, Brasilian farmers are able to continuously cover soil, increase soil organic matter, integrate livestock, move surface-applied lime through the soil profile, break compact soil layers and reduce their reliance on agrochemicals in a zero-till system—all under a variety of soil and climatic conditions, and range of farm sizes.

Zero-till has become progressively widespread throughout the world, most notably in Australia, Canada, Argentina, Brasil and the United States. It has expanded to an area of over 120 Mha globally. About half of the agricultural land in Brasil is estimated to be managed with zero-till. Although in southern Brasil, this figure is above 80%, or even 90% for smallholder farmers with less than 50 ha. Indeed, among the leading zero-till nations, Brasil is perhaps the only nation with both substantial zero-till in the tropics and with smallholder farmers.

Interestingly, the adoption of zero-till permanent soil cover by small farmers worldwide has generally been poor. It remains marginal outside of Brasil, Paraguay, and small parts of Central America. While the cost of labour, land and organic residues is often viewed as a stumbling block to small zero-till farmers elsewhere, in Brasil they are actually considered as main reasons for small farmers to adopt zero-till. These are reported along with erosion control, greater income, higher yields and less drudgery.

## 24.5 Benefits of cover crops with zero-till

Our experience shows that robust zero-till systems require retained crop residues on the soil for many reasons. The effect of vegetation on the surface and intact roots in the soil invokes important changes in soil properties. These include alterations to the physical, chemical and biological nature of soils. Tillage destroys the potential of biologically driven soil changes.

Zero-till allows microorganism populations to build. Retained plant organic matter, when added to the soil, effects the soil structure through microorganisms producing polysaccharides and other organic polymers that serve as linking agents to soil particles. Residue helps improve soil structure by increasing the stability of aggregates in water through the cementing action of the organic matter, polysaccharides and hypha of fungi. This increases water-holding capacity, water infiltration rates, promotes greater soil porosity, greater aeration, results in less water evaporation from the surface, and decreases the soil density because of the effects of the turnover of organic matter.

### NO-TILL SYSTEM ADVANTAGES

There are system advantages at many levels:

#### FARMERS' LEVEL:

- Reduction in labour and time.
- Reduction in cost, farm power and fuel.
- Longer lifetime and less repair of tractors.
- More reliable yields.
- Better trafficability in the field.
- Increasing yields with decreasing inputs.
- Increased profit.

#### COMMUNITY, ENVIRONMENT AND WATERSHED:

- More constant water flows in the rivers, re-emergence of dried wells.
- Cleaner water due to less erosion.
- Less flooding.
- Less impact of extreme climatic situations.
- Less cost for road and waterway maintenance.
- Better food security.

#### AT A GLOBAL LEVEL:

- Increased carbon sequestration.
- Less pollution from dust, exhaust fumes and greenhouse gas emissions.
- Less fuel use: 30–60% of energy savings.
- Less leaching, less pollution of water.
- Practically no soil erosion.
- Recharge of the aquifers.
- Food security.

## 24.6 Cover crops in more detail

During the growing stages different crops have different effects on soil properties. They are directly linked to the shoot and root biomass production, soil cover capacity, crop residue's stability on the soil surface and the residue's effects on the soil properties. Such soil properties include soil density, soil aggregates, infiltration rates and porosity.

The general functions of cover crops broadly include:

- Providing additional fodder, forage, food and secondary commercial or subsistence products for livestock and humans.
- Directly adding N to the soil through symbiotic $N_2$-fixation from the atmosphere.
- Converting otherwise unused resources, such as sunlight and residual soil moisture, into additional biomass and upon the breakdown of their residues, increasing the build-up of soil organic matter.

- Capturing and recycling easily leachable nutrients ($NO_3^-$, K, Ca, and Mg) that would otherwise be lost beyond the rooting zone of commercial crops.
- Ameliorating soil structure and buffering against compaction by creating additional root channels that differ from those of the main crops and by stimulating soil biological activity through the release of root exudates.
- Improving the management of acidic soils by releasing various products that can mobilize lime movement through the soil profile, decarboxylise organic anions, function in ligand exchange and add basic cations to the soil, including to depth.
- Facilitating weed management by competing against or smothering weeds that would otherwise become noxious in the main crop cycle.
- Breaking the cycle of certain pests and diseases that could otherwise build-up in continuous mono-cropping systems.
- Protecting the soil from erosion, temperature extremes and conserving soil moisture.

Some of the major cover crops and cover crop mixtures that are used in Brasil, together with their main advantages or functions and drawbacks, are presented in the below tables. The function of certain cover crops in terms of building organic matter, improved nutrient management, alleviating soil compaction, and facilitating soil acidity and weed management, according to the agro-ecological zones must also be considered.

### WINTER SPECIES

Black oat (*Avena strigosa* Schreb), radish (*Raphanus sativus*), Vetches (*Vicia sativa* and *Vicia villosa*), Lupin (*Lupinus* spp.), ryegrass (*Lolium multiflorum*), rye (*Secale cereale*), sweet pea (*Lathyrus sativus*), clovers (*Trifolium* spp.), sweet clover (*Medicago* spp.) Lucerne (*Medicago sativa*), serradella (*Ornithopus sativus*), Chickpea (*Cicer arietinum*).

### SUMMER SPECIES

Pigeon pea (*Cajanus cajan*), Velvetbean (*Mucuna* sp.), sunn hemp (*Crotalaria juncea*), *Crotalaria spectabilis*, cowpea (*Vigna unguiculata*), green gram (*Vigna radiata*), lablab (*Dolichos lablab*), Siratro (*Macroptilium atropurpureum*), Stylo (*Stylosanthes* spp.), *Clitoria ternatea*, jack bean (*Canavalia ensiformis*), brave bean of Ceará (*Canavalia brasiliensis*), pear millet (*Pennisetum americanum*), finger millet (*Eleusine coracana*), *Centrosema* sp., *Desmodium* spp., tropical Kudzu (*Pueraria phaseoloides*), *Tephrosia* spp., *Calopogonium mucunoides*, *Neonotonia wightii*.

**Table 1. Chemical composition of summer cover crop at the flowering stage.**

| | Nutrients (% of dry matter) | | | | | | C:N | Content (ppm) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Cover crops** | **N** | **P** | **K** | **Ca** | **Mg** | **C** | **Ratio** | **Cu** | **Zn** | **Mn** |
| *Crotalaria juncea* | 2.5 | 0.19 | 1.2 | 2.3 | 0.47 | 45.3 | 18.1 | 14 | 44 | 179 |
| *Crotalaria spectabilis* | 2.2 | 0.09 | 1.6 | 0.5 | 0.37 | 50.8 | 23.4 | 8 | 23 | 126 |
| *Cajanus cajan* | 2.6 | 0.14 | 2.6 | 1.8 | 0.45 | 56.3 | 21.6 | 7 | 22 | 87 |
| *Canavalia ensiformis* | 3.2 | 0.15 | 5.6 | 1.4 | 0.63 | 50.2 | 15.7 | 9 | 62 | 254 |
| *Canavalia brasiliensis* | 2.5 | 0.13 | 1.7 | 0.2 | 0.16 | 51.2 | 20.6 | 4 | 14 | 17 |
| *Mucuna pruriens* (grey) | 2.5 | 0.15 | 1.4 | 1.2 | 0.27 | 52.3 | 21.1 | 16 | 28 | 183 |
| *M. pruriens* (black) | 2.5 | 0.13 | 1.4 | 1.2 | 0.27 | 52.2 | 21.1 | 14 | 29 | 174 |
| *M. pruriens* (dwarf) | 3.1 | 0.19 | 4.5 | 2.1 | 0.65 | 50.8 | 16.4 | 9 | 85 | 179 |
| *Vigna radiata* | 2.1 | 0.21 | 4.9 | 1.5 | 0.75 | 52.5 | 25.1 | 10 | 78 | 127 |
| *Vigna unguiculata* | 2.6 | 0.20 | 2.8 | 0.9 | 0.28 | 45.4 | 17.3 | – | – | – |
| *Indigofera sp.* | 2.2 | 0.14 | 1.5 | 1.2 | 0.32 | 40.4 | 18.6 | 13 | 24 | 53 |
| *Calopogoniumm mucunoides* | 2.2 | 0.12 | 1.6 | 1.4 | 0.29 | 46.7 | 21.6 | 9 | 15 | 172 |
| *Pueraria phaseoloides* | 3.7 | 0.29 | 2.1 | 1.3 | 0.41 | 54.1 | 14.7 | 11 | 27 | 155 |
| *Glycine wiighti* | 2.6 | 0.23 | 2.4 | 1.0 | 0.35 | 45.0 | 17.3 | 8 | 32 | 102 |
| *Centrosema pubescens* | 2.3 | 0.23 | 1.2 | 0.7 | 0.45 | 47.6 | 20.3 | 10 | 32 | 67 |

**Table 2. Chemical composition of winter cover crops at the flowering stage.**

| | Dry matter % | | | | | | | C/N | Content (ppm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cover crop** | **N** | **P** | **K** | **Ca** | **Mg** | **C** | **Protein** | **Ratio** | **Zn** | **Cu** | **Mn** |
| Hairy vetch | 3.8 | 0.30 | 2.0 | 0.8 | 0.27 | 38 | 24 | 10 | 26 | 9 | 61 |
| Common vetch | 2.9 | 0.23 | 2.9 | 1.1 | 0.41 | 37 | 18 | 13 | 24 | 9 | 87 |
| Ornithopus sativus | 1.8 | 0.14 | 3.6 | 1.1 | 0.45 | 40 | 11 | 22 | 59 | 13 | 97 |
| Radish | 2.7 | 0.17 | 2.8 | 1.5 | 0.76 | 39 | 17 | 14 | 49 | 8 | 84 |
| White lupin | 3.2 | 0.09 | 2.7 | 0.5 | 0.38 | 47 | 20 | 15 | 57 | 12 | 330 |
| Yellow lupin | 2.9 | 0.16 | 2.5 | 0.6 | 0.39 | 42 | 18 | 14 | 66 | 14 | 359 |
| Blue lupin | 3.2 | 0.19 | 2.3 | 1.2 | 0.49 | 38 | 20 | 12 | 24 | 13 | 230 |
| Sweet blue lupin | 2.3 | 0.10 | 1.8 | 0.6 | 0.42 | 38 | 14 | 17 | 32 | 16 | 147 |
| Field pea | 2.1 | 0.12 | 1.5 | 0.7 | 0.20 | 40 | 13 | 19 | 8 | 22 | 52 |
| Wheat | 0.8 | 0.06 | 1.2 | 0.2 | 0.10 | 40 | 5 | 53 | – | – | – |
| Sweet pea | 2.2 | 0.10 | 2.9 | 0.4 | 0.19 | 42 | 14 | 19 | 22 | 11 | 52 |
| Black oat | 1.9 | 0.28 | 2.2 | 0.4 | 0.21 | 40 | 12 | 21 | 11 | 7 | 102 |
| White oat | 0.8 | 0.05 | 2.4 | 0.2 | 0.17 | 39 | 5 | 48 | 9 | 6 | 138 |
| Ryegrass | 1.3 | 0.07 | 2.6 | 0.4 | 0.22 | 59 | 8 | 44 | 23 | 9 | 214 |
| Rye | 1.2 | 0.08 | 1.4 | 0.2 | 0.14 | 45 | 8 | 37 | 15 | 6 | 53 |
| Sunflower | 1.8 | 0.15 | 2.4 | 1.6 | 0.62 | 40 | 11 | 22 | 31 | 18 | 96 |
| Corn spurrey | 2.1 | 0.22 | 3.5 | 0.5 | 0.77 | 42 | 13 | 13 | 44 | 11 | 136 |

The most suitable crop sequence will likely comprise plants that present different growing habits, and water and nutrient needs. For example: horticultural crops that are leafy typically require more N, while horticultural crops that grow roots, bulbs, and rhizomes typically require more K, and the legume crops normally get more P from the soil.

It is not recommended to repeat the same crop or plants with similar characteristics, or from the same species or family every season, but to look for a diverse crop rotation. Monocropping often causes infestations of nematodes that can impede crop development. In this case including a break cover crop with the ability to decrease the nematode populations would be appropriate.

## 24.7 Cover crops in the tropical Cerrado (Savannah) region

Much of the Cerrado region is an agricultural frontier with large and mechanised farms. This contrasts with southern Brasil that has a variety of farm sizes and levels of mechanisation. The seasonality of rainfall in the Cerrado often does not allow continuous cropping without irrigation.

It is common for farmers to establish fast-growing, drought-tolerant cover crops immediately after harvest of the main crop. Their aim is to grow a cover crop to produce some biomass on the residual stored soil moisture under the mulch layer. The most common cover crop is millet, but other drought-tolerant cereals or pasture and forage species are also used. Some innovative farmers will plant millet at the beginning of the rainy season, rather than at the end, desiccating the millet with glyphosate 45–80 days later and planting soybeans into the millet residues.

Frank Djikstra explains cover crops and no-till to his neighbours in the early 1990s.

The advantage of this system compared to planting soybean first is that the millet grows more rapidly than soybean. The millet's roots can extend at a rate of 3 cm a day to a depth of about 1.5–2.4 m. This allows the millet to pump the nutrients from depth, thereby capturing nitrates, which would otherwise be lost to leaching after soil wetting and drying cycles, at the break of the season. This increases biomass and adds a different rooting pattern to the cropping system.

Another progressive option is to continuously zero-till with sequences of cover crops that remain alive throughout the 3–5 month dry season. These crop types can re-grow rapidly after the first rains of the following rainy season, or after sporadic dry season rain, thereby ensuring a permanent soil cover. This may include soybean, rain-fed rice, maize or common beans which are grown during the rainy season and followed by a second crop of fast-growing cereals or cover crops (millet, maize, sorghum, finger millet or sunn hemp) and intercropped with forages.

At the end of the rainy season, the forage species can then be managed with glyphosate and later controlled with selective herbicides before or after planting the next commercial crop. This approach gives the crop a competitive edge while ensuring continuous undergrowth or 'carpet' of forages. Alternatively, the forage species can be terminated with glyphosate before the seeding of the commercial crop.

Such combinations of cereals and forage species planted at the end of the rainy season allow receding soil moisture, as well as sunlight to be used efficiently during the dry season, while at the same time producing large bulk which can be grazed or used as green manure.

Under irrigation or in wetter areas, of greater than 1500 mm per year, the total above and below ground annual dry matter production increased from 4–8 t/ha, with a single annual crop, to near 30 t/ha in the most efficient zero-till systems. Some farmers, with large livestock herds and large farms, leave part of their land as pasture for 3–4 years, before a 3–4 year cycle of zero-tilled crops. This minimises the re-establishment costs of the pasture and the need for selective herbicides, while allowing organic matter build-up.

## 24.8 Soil and yield changes with long-term zero-till rotational systems

Crop and cover crop rotations are complicated in Brasil compared to the Australian rotations. Many different crops can be grown and typically five crops are grown over a two year period. Such diversity makes it hard to give a simple picture or explain the common rotations. The most common cash crops in southern Brasil are soy, corn, wheat, bean, barley, white oat, cassava and potato.

A cover crop is often grown as every fifth crop or sometimes more often than this, depending on the soil, weather and economic considerations. Cover crops can be grown more often than one in five crops and sometimes are terminated mid-way through their life cycle. Popular winter cover crops include black oats, beans, lupins, field peas and vetch; while popular summer cover crops include sunn hemp and millet.

Without cover crops weeds can proliferate and complicate the ability to rotate between plant types. This rotation creates a cleaning effect and some rotations give strong increases in crop yields. This follows the philosophy that the soil must to be covered for all the time that is possible during the year.

It is important to have organic residues constantly added to the soil's surface. This also creates root effects, which relate directly to the population dynamics of soil organisms. The result is that complementary effects occur with macro, meso and microorganisms and these contribute to create a vibrant root zone on the first layer of the soil. The organic residues and also root exudates are the main source of energy for the soil organisms, thus the availability of these compounds is crucial to the organisms' activities as the dynamics of population increase.

There is evidence (Séguy *et al.*, 1995) that savannah soils gave higher soil organic matter after six years with zero-till (see Table 3). The savannah region generally have well defined dry and rain season and soils with low clay content, high temperatures and fast organic matter mineralisation process.

**Table 3. Organic matter in different tillage systems and crop rotation, after 6 years (1986–92) in savannah soils in centre north of Brasil**

| Tillage and crop rotation | Soil depth (cm) | Soil organic matter (%) |
|---|---|---|
| Heavy discs on soybean mono-crop | 0–10 | 1.0 |
| | 10–20 | 1.0 |
| | 20–30 | 1.0 |
| Ploughed by discs on soybean–corn rotation | 0–10 | 1.5 |
| | 10–20 | 1.3 |
| | 20–30 | 1.3 |
| Zero-tillage on soybean–corn rotation | 0–10 | 3.8 |
| | 10–20 | 3.4 |
| | 20–30 | 2.0 |

SOURCE: SÉGUY *et al.*, 1995.

When the soils are disturbed to sow annual crops, soil organic matter decreases. The data shows that after 6 years, a rotation of corn and soya increases a soil's organic content to depth, but not as much as if the corn soya rotation was zero tilled. Here soil organic level was increased three-fold as opposed to a 35% increase with a rotation change only.

Paraná growers who use green manure cover crops and zero-till typically experience corn yield increases as measured by Calegari and Alexander, 1998, (Table 4). The data shows that legume crops, when grown before corn, can provide large quantities of N.

**Table 4. Corn yield (t/ha) after winter crops at Pato Branco-PR exp station**

| Winter cover crop | Zero-tillage | | Conventional tillage | |
|---|---|---|---|---|
| | Rate (kg/N/ha$^{-1}$) | | Rate (kg/N/ha$^{-1}$) | |
| | 0 | 90 | 0 | 90 |
| Common vetch | 7.34 | 7.64 | 6.09 | 6.44 |
| Hairy vetch | 6.88 | 7.34 | 5.61 | 5.77 |
| Blue lupin | 6.87 | 6.42 | 5.92 | 6.30 |
| Ornithopus | 6.76 | 7.36 | 5.01 | 5.86 |
| Sweet pea | 6.42 | 7.56 | 4.74 | 5.34 |
| Radish | 5.75 | 6.99 | 5.57 | 6.18 |
| Corn spurrey | 5.45 | 6.92 | 5.66 | 6.43 |
| Wheat | 5.00 | 5.99 | 4.77 | 5.33 |
| Black oat | 4.59 | 6.84 | 5.44 | 6.13 |
| **Fallow** | **4.44** | **5.99** | **4.83** | **5.94** |
| Rye | 4.29 | 6.67 | 3.86 | 5.33 |
| Raygrás | 4.28 | 6.98 | 5.72 | 6.02 |

SOURCE: CALEGARI AND ALEXANDER, 1998.

## 24.9 Weed management

One of the major tools in Brasilian integrated weed management under zero-till is the use of cover crops. The different cover crops species are important in weed management as they compete with weeds during their development, and their mulch can also suppress weed emergence. Several winter and summer cover crops have been shown to suppress weeds through their fast growth pattern.

Weed biomass reductions of 22–96% have been observed by using summer cover crops according to plant species in southern Brasil. A similar result has been observed in the Savannah region (Cerrado) where it was possible to eliminate the use of a selective maize herbicide.

The effects of soil covering—whether it be shading or an allelopathic effect, or perhaps both effects working together—can properly control many weeds in field conditions. Normally the effects are strongly linked to the amount and quality of the mulch produced and remaining on the soil's surface.

A study of an integrated weed management program on 58 farms in Paraná showed that after three years with adequate weed management, weed control costs decreased on average costs by 35% with herbicide reductions of 25%.

## 24.10 Nematodes managed with plant species

According to many researchers in Brasil, the presence of crop residues on the soil will stimulate the soil's microflora and microfauna. Their formation and growth contributes to higher biodiversity and includes antagonistic organisms that collaborate to lower the phyto-parasite nematode populations.

The amount of crop residues accumulated on the soil surface in the zero-till system will increase soil organic matter and biological activity. This increases the number of species, avoiding the predominance of one isolated species and results in a higher environmental equilibrium.

In some regions of Brasil, there are problems with cereal fungi that provoke root disease. These include *B. sorokiniana* and *Gaeumannomyces graminis* var. *tritici*. The crop rotation that includes black oat and rye are more resistant than wheat and barley (Reis and Bayer, 1983). These effects are primarily because in a rhizosphere zone the soil pH is lowered a little and this gives disease depression.

Many oat varieties can decrease the nematode populations of *Meloidogyne* sp., and also suppress some soil fungi, including *Fusarium* sp., *Rhizoctonia* sp. The soybean sown after black oats is less affected by rhizoctonia and sclerotinia. In the same manner, wheat is less affected by root diseases when sown after oats (Santos *et al.*, 1990). The table on the following page shows how different cover crops species have a different effect on nematode population suppression.

**Table 5. Cover crops species and their effect on different nematode populations**

| Nematodes species | Antagonistic cover crops |
|---|---|
| *Pratylenchus brachyurus* | *Crotalaria juncea*, *Crotalaria spectabilis*, *Cajanus cajan*, *Stylosanthes* spp., *Psophocarpus palustris*, *Centrosema pubescens*, *Pueraria phaseoloides*, *Raphanus sativus*, and other *cruciferae* plants |
| *Pratylenchus zeae* | *Crotalaria* spp. |
| *Helicotylenchus* | *Crotalaria juncea*, *Crotalaria spectabilis*, *Cajanus cajan*, *Mucuna pruriens*, *Avena strigosa*, *Ricinus communis* |
| *Rotylenchulus reniformis* | *Mucuna pruriens* (black), *Pennisetum americanum*, *Sorghum bicollor*, *Crotalaria* spp., some maize varieties, *Arachis hypogaea*, *Brassica* spp. |
| *Meloidogyne javanica* | *Arachis hypogaea*, *Crotalaria* spp., *Mucuna* spp., *Cajanus cajan*, *Medicago sativa*, *Ornithopus sativus*, *Spergula arvensis*, *Avena* spp., *Secale cereale*, *Lolium multiflorum*, *Hordeum vulgare*, *Arachis pintoi* |
| *Meloidogyne incognita* | *Arachis hypogaea*, *Setaria italica*, *Crotalaria* spp., *Mucuna pruriens*, *Cajanus cajan*, *Avena strigosa*, *Secale cereale*, *Lolium multiflorum*, *Phacelia tanacetifolia*, *Ornithopus sativus*, *Medicago sativa*, *Trifolium pratense*, *Arachis pintoi* |
| *Meloydogine incognita* race 3 | *Crotalaria* spp., *Mucuna* spp., *Cajanus cajan* (dwarf), *Arachis hypogaea*, *Medicago sativa*, *Ornithopus sativus*, *Spergula arvensis*, *Avena* spp., *Secale cereale*, *Lolium multiflorum*, *Hordeum vulgare* |
| *Meloydogine incognita* race 1, 2, 3, 4 | *Crotalaria spectabilis*, *Crotalaria juncea*, *Mucuna* spp., *Arachis hypogaea*, *Cajanus cajan* (dwarf), *Avena sativa* (cv. IAC-7). |
| *Xiphinema rivesi* | Mucuna, pearl millet, pigeon pea, and pigeon pea + millet + cowpea, presented stronger effects on diminish the number |

ADAPTED BY: CALEGARI *et al*., 1993, BOLLIGER *et al*., 2006, SANTOS & RUANO, 1987; QUESENBERRY *et al*., 1989, CALEGARI AND PEÑALVA, 1999, KRZYZANOWSKI, 2000.

## 24.11 Conclusions

We have learnt through 35 years of farmer experience and field research, in south Brasil and beyond, that zero-till combined with appropriate crop rotations are very economical and sustainable. Such robust systems ensure soil erosion control, provide higher soil water storage, enhance soil fertility and give excellent crop productivity.

We have learnt to grow cash crops in conjunction with cover crops in a sensible manner. In addition to this, these cover crops in rotation save on N fertiliser, give superior weed control by the mulch effects, give a greater biological balance in the soil, promote higher soil biodiversity, decreases pests and disease occurrence, saving labour and fuel from the mechanised agriculture, so decreasing production costs. All of this is representing a sustainable way to farm.

The area under the zero-till systems continues to increase every year. Many different crops are being planted (soybean, maize, beans, cotton, sorghum, millet, sunflower, wheat, barley, rye, oat, lupins, rape, groundnuts, vegetable crops), with improved profitability. This has been a period of rapid improvement in agriculture in Brasil—a most exciting time!

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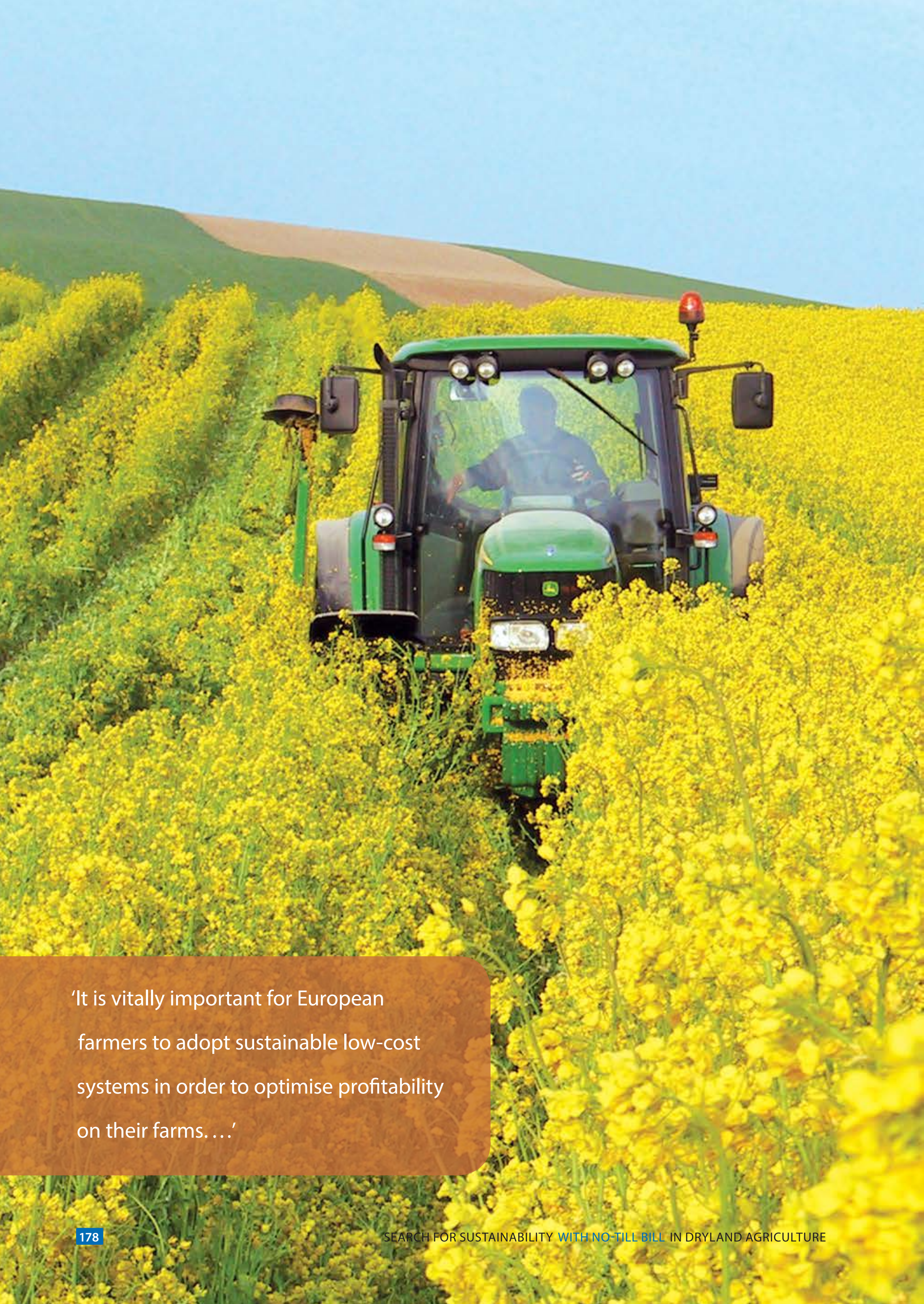

'It is vitally important for European farmers to adopt sustainable low-cost systems in order to optimise profitability on their farms. . . .'

CHAPTER 25:

# No-Tillage in Europe — State of the Art: Constraints and Perspectives

Jana Epperlein, Gottlieb Basch, John Geraghty, Bernhard Streit and Wolfgang G. Sturny

## Abstract

**'NO-TILLAGE IN EUROPE'** contains a brief review of agricultural developments over the last three decades beginning in the late 1960s. Reasons for attempts to introduce this soil conserving production method are outlined and obstacles affecting the widespread uptake of no-tillage throughout Europe are identified. Contemporary data are provided for the uptake of both conservation tillage and no-tillage in the member countries of the European Conservation Agriculture Federation.

Further aspects surrounding the low uptake of no-tillage and conservation tillage when compared with other regions in the world are explored. European conditions whether natural, human or political are identified as possible explanations for low levels of adoption of no-tillage in Europe. Despite these issues, increased awareness that soils are a non-renewable resource among farmers, politicians and society as a whole is leading to a gradual change in the overall approach to soil conservation. The implementation of a European Soils Directive is considered to be an important step towards the recognition that conservation tillage and no-tillage are both economical and ecological sustainable methods for agricultural production. It is anticipated that this development will promote the concept of Conservation Agriculture and increase adoption levels throughout Europe.

## 25.1 Review of no-tillage development in Europe

Early uptake of no-tillage in Europe was voluntary and driven by the need to reduce crop establishment costs. Tillage farmers did not identify soil erosion or degradation as a major concern (Kuipers, 1970). In large parts of Europe there is a cool and wet climate which induces relatively stable weather conditions in contrast to other parts of the world where heavy rainfall and severe windstorms regularly cause soil erosion. In addition, negative effects of repeated tillage

LEFT: Corn being no-tilled into flowering turnip rape.

Corn being directly planted into killed grass/clover on a farm in Rubigen, near Berne.

by the mouldboard plough such as compaction in plough pans, reduced pore volume in topsoil and sealing of the soil surface have been masked by the ongoing development of more powerful implements used for soil tillage.

It is no small irony that some of the leading pioneers of no-tillage from South America observed and studied developments in Europe in the late 1960s and early 1970s. At this stage Imperial Chemical Industries (ICI) were pioneering direct-drilling techniques in the UK using paraquat herbicide to control weeds. Heavy residue was being burned—a technique that, while well intentioned, proved detrimental to maintaining and improving soil quality (Crovetto, 2006). The increase of grass weeds like annual meadow grass *(Poa annua L.)* and sterile brome *(Bromus sterilis L.)* proved problematic as there were few herbicides available for in-crop weed control. In many cases short term no-tillage research was conducted under unfavourable soil conditions with little crop rotation, using inappropriate drills or planters. It is understandable therefore that negative conclusions were made about the suitability of no-tillage systems under European conditions.

The development of a market support system through the Common Agriculture Policy (CAP), while ensuring strong market prices, also hampered efforts to identify solutions to problems encountered using no-tillage techniques from the early 1970s. Many of the early adopters of no-tillage reverted to plough based production once produce prices strengthened. Meanwhile farmers in numerous regions of South America, exposed to world market price fluctuations, had little option but to find solutions to the same problems their European counterparts were experiencing such as weed control and residue management (Geraghty, 2006). It is likely that a combination of these events prompted the development of no-tillage in favour of the Americas from the seventies to the present day. Furthermore, in both North and South America, agricultural machinery manufacturers have since developed a wide range of no-tillage drills and planters appropriate for local conditions.

By contrast, in Europe, there are a limited number of manufacturers producing no-tillage equipment specifically designed for crop production in temperate climates which is characterised by high yields and associated high residue levels.

## 25.2 The current state of no-tillage in Europe

While over fifteen per cent of the total arable area in the member countries of the European Conservation Agriculture Federation (ECAF) is under conservation tillage of one form or another (Lane *et al.*, 2006), the area devoted specifically to no-tillage is just over one per cent (Table 1). The situation is in stark contrast to adoption trends in Australia and in North and South America in particular. The challenge now is to encourage farmers to move from conservation tillage to no-tillage systems and encourage the adoption of conservation tillage over conventional practices.

**Table 1. Area of arable land under conservation tillage (CT) and no-tillage (NT) in member countries of the European Conservation Agriculture Federation (2005)**

| Country | CT (incl. NT) (1000 ha) | No-Till only (1000 ha) | Arable Land (1000 ha)[1] | % in CT | % in NT |
|---|---|---|---|---|---|
| Belgium | 140 | 0 | 815 | 17.2 | 0.0 |
| Denmark | 230 | 0 | 2276 | 10.1 | 0.0 |
| Finland | 1150 | 150 | 2199 | 52.3 | 6.8 |
| France | 3870 | 150 | 18,449 | 21.0 | 0.8 |
| Germany | 2500 | 200 | 11,791 | 21.2 | 1.7 |
| Greece | 430 | 200 | 2717 | 15.8 | 7.4 |
| Hungary | 500 | 10 | 4614 | 10.8 | 0.2 |
| Ireland[2] | 10 | 0 | 401 | 2.5 | 0.0 |
| Italy | 560 | 80 | 8287 | 76.8 | 1.0 |
| Portugal | 418 | 80 | 1990 | 21.1 | 4.0 |
| Russia | 15,500 | 500 | 123,465 | 12.6 | 0.4 |
| Slovak Rep. | 179 | 37 | 1433 | 12.6 | 2.6 |
| Spain | 2400 | 600 | 13,738 | 18.0 | 4.4 |
| Switzerland | 102 | 12 | 409 | 25.4 | 2.9 |
| UK | 2680 | 180 | 5,753 | 45.6 | 3.1 |
| | **30,669** | **2199** | **198,337** | **15.5** | **1.1** |

## 25.3 From conservation tillage to no-tillage

Farmers traditionally love working with soil. There is an inherent belief that by cultivating and working soil we are doing a lot of good by burying weed seeds, mineralising nutrients, breaking soil compaction, aerating soil and creating a suitably loose seedbed for sowing a variety of crops. While some of these assertions may be individually true, especially when soil is regularly cultivated, collectively they lead to an overall depletion in soil quality that is unsustainable in the medium to long term, both from an economic and environmental point of view. Therefore, the successful adoption of a no-tillage system is dependent on convincing a farmer of the benefits associated with developing a cropping system that requires little soil disturbance. The photographs over the page show one example of no-tillage farming in Switzerland involving turnip grown as a winter cover crop followed by maize as a cash crop.

Increasing farmer awareness and education about the damage one can do to soils through excessive tillage has proven difficult. There is a cultural barrier to overcome with different languages and traditions throughout Europe. Agriculture infrastructure and farm practices vary greatly between different countries. Whereas the principles of no-tillage are the same for all conditions, the adaptation of crop management to local conditions is crucial (Lane *et al.*, 2006). There is, broadly speaking, poor state support for specific research and education initiatives in this regard. Many voluntary organisations at a national level are solely dependent on farmer subscriptions to conduct research and

[1] FAO Statistics 2003 on http://faostat.fao.org

[2] Government Statistics (2005) and data supplied by Conservation Agriculture Ireland Survey (2007).

Maize planted directly into a flowering turnip cover crop in Switzerland. The green manure plants are then sprayed off with a non-selective herbicide to provide a favourable microclimate for the maize seedlings and also to protect against erosion, pesticide run-off, nitrate leaching, among others.

PHOTOGRAPHS COURTESY OF WOLFGANG G. STURNY.

extension work with occasional sponsorship from the commercial sector (Geraghty, 2006). Coupled with these issues there are strongly held views opposing the adoption of no-tillage on a widespread scale in Europe.

## 25.4 Popular arguments against no-tillage in Europe

There is much skepticism in Europe about the suitability of no-tillage for our climate conditions and cropping systems. Many opponents of no-tillage point to the wide variety of soil types throughout the continent, the perceived high cost of no-tillage equipment and the intensive hands-on management required in comparison with the relative ease and familiarity associated with tried and trusted plough-based techniques. Diverse crop rotations including cereals, legumes and other broadleaved crops are an important feature of successful no-tillage systems. In many regions of Europe, however, arable production has been focused on growing a limited number of crops—mainly cereals or maize. Agronomic issues surrounding weed, pest and disease management have also provoked much debate and discussion among farmers, extension personnel and researchers alike.

It is firmly ingrained in farmer and researcher psyche that weed control is best achieved by a combination of thorough soil inversion and herbicide use. Indeed one of the main setbacks to no-tillage adoption was the proliferation of grass weed species that occurred three decades ago, problems still vividly remembered by farmers and extension workers today. It is frequently noted that the move from ploughing to conservation tillage and no-tillage will increase dependence on herbicides. It is also argued that savings in fuel, time and labour are offset by the increased cost of the extra herbicide application for weed control. Practical experience at farm level has found these observations to be untrue. International research experience also notes that, while there is an initial increase in herbicide use during the adoption phase of no-tillage, overall herbicide usage decreases once all aspects of the system are being practiced (Landers *et al*., 2002 & Wolf *et al*., 2003). Two further issues are causing concern for supporters of no-tillage. Tighter regulation within the EU in recent years has led to the withdrawal of herbicides in some countries (e.g. atrazine, simazine and isoproturon) resulting in fewer efficient weed control options. A strong environmentalist lobby is now demanding the withdrawal of other herbicides that are vital for weed management in no-tillage (e.g. glyphosate in France).

Due to the cool, wet climate in parts of Europe mollusc pests called slugs are an important species in a variety of crops. The practice of leaving crop residues on the soil surface has encouraged the idea that slug numbers will increase beyond acceptable levels under no-tillage. Significant costs would result from associated crop damage or extra pesticide control measures. While these are commonly held beliefs, farmer experience has often been the opposite. In many cases slug control no longer requires the use of pesticide and slug levels have been adequately managed by increased predator populations, such as ground beetles. It appears however that a slug population can recover within the growing season and may re-establish faster in no-tillage systems (Bieri *et al*., 2007).

In recent years there has been much criticism of conservation tillage and no-tillage due to the increased incidence of head blight disease (*Fusarium* spp.) recorded in wheat and to a lesser extent in maize. This has occurred mainly in Germany, France and Switzerland. The threat of this disease is greatest when wheat is grown after maize and during moist–humid summers at anthesis stage. There is strong evidence that choosing the least susceptible wheat variety along with fine chopping of maize residues leads to lower head blight incidence and reduced deoxynivalenol contents with less mycotoxin contamination (Vogelgsang *et al*., 2005). Further research is looking at different ways to reduce disease levels such as maize residue management, selection of fusarium resistant wheat varieties, and fungicide control.

Considering the above issues, proponents of no-tillage in Europe often find themselves in a situation not unlike that encountered in the 1970s in South America, the 1980s in North America and the 1990s in Australia. A significant amount of time is spent explaining or defending the system to officials in research and extension agencies and at government levels. Against this backdrop it has proven difficult to convince farmers of the practical and economic benefits resulting from no-tillage adoption. Much valuable research work was carried out under the EU-Life Project (2000–2003) to establish accurate information and investigate some of these agronomic issues with very positive results. However, further funding has not been available to continue much needed research and extension initiatives on a Europe-wide basis.

## 25.5 Common Agriculture Policy (CAP) Development

The European CAP has been subject to ongoing reform since it was implemented in the second half of the last century. There has also been a concerted effort since the early 1990s to link agricultural and environmental policy. More recent developments include a transition from production-linked subsidies to a farm payment system that is separate from production. Presently, farm subsidies are also subject to deductions called modulation whereby increased percentages of a farmer's overall payment are redirected towards alternative rural development and environmentally sensitive initiatives. Coupled with annual inflation, the net value of farm subsidies is decreasing annually. After 2013 it is highly likely that any future payments will be strongly linked towards environmental protection. Even outside EU Member States other national governments on mainland Europe are placing increased emphasis on environmentally sensitive practices and climate change strategies and are willing to fund such initiatives with public money (Table 2).

**Table 2. Incentive program detailing contributions towards a 5-year transition period from conservation tillage to no-tillage in the Canton of Berne, Switzerland (1996 to date).[3] Plough-based tillage is a breach of contract and will be fined.**

| | Conservation Tillage Transition [€*ha$^{-1}$y$^{-1}$] | No-Tillage Target [€*ha$^{-1}$y$^{-1}$] |
|---|---|---|
| **Crops** | **Years 1–5** | **Years 1–5** |
| Cereals | 102 | 204 |
| Oilseed rape | 204 | 340 |
| Maize (strip tillage) | 306 | – |
| Maize | 204 | 340 |
| Sugar beet | 238 | 374 |
| Peas and beans | 170 | 272 |
| Sunflowers | 204 | 340 |

## 25.6 New legislation for the protection of soils

After three years of widespread public consultation the Soil Thematic Strategy was ratified by the European Commission on September 22, 2006.

[3] At least two main crops, other than cover crops, must be no-tilled during the first five years.

*'It creates a common legal framework to ensure that EU soils stay healthy for future generations and remain capable of supporting the ecosystems on which our economic activities and our well-being depend.'*

EU Commission, 2006

The strategy aims to address soil degradation throughout 27 EU Member States under the following parameters: erosion, organic matter decline, salinisation, compaction, sealing, contamination, flooding and landslides and biodiversity decline. Despite the fact that nine Member States have specific soil protection legislation there has been a significant increase in soil degradation processes in recent decades.

Water and wind erosion affects 157 million ha of Europe's total land area (cited in Tebrügge, 2001). Approximately 90 per cent of soils in Europe have low to medium organic matter levels, 45 per cent of these with less than two per cent organic carbon and a further 45 per cent with between two and six per cent organic carbon (EU Commission, 2006). Decline in organic matter is an important issue in Southern Europe but regions further north have also recorded significant losses in soil organic matter levels over the last thirty years particularly on land where continuous tillage has taken place. Compaction affects up to 36 per cent of subsoils while 3.8 million hectares are affected by the accumulation of soluble salts. Several of the parameters surrounding soil degradation are further exacerbated in recent years by the effects of climate change such as increases in temperature, rainfall amounts and extreme weather events. The Commission now estimates that soil degradation could be costing the EU up to €38 billion annually.


Direct seeding of winter wheat into standing cover crop.

The strategy will be adopted as a Soil Directive by the EU parliament in spring 2009.

The Directive places emphasis on the following areas:

- Identification of risk areas at appropriate levels within five years of adoption.
- Use of common criteria (e.g. soil type, texture, density, hydraulic properties, topography, land cover, land use, climate, etc).
- Use of empirical evidence or modelling.
- Findings to be made public and reviewed every ten years.

## 25.7 Key factors for the successful adoption of no-tillage

The implementation of a Soil Directive will have far-reaching consequences for the development of no-tillage in Europe. Over fifty per cent of agricultural land throughout the EU is devoted to crop production. The vast majority of this area is still prepared using traditional mouldboard plough-based systems leading to an increased risk of soil degradation (Garcia-Torres *et al*., 2001). The widespread adoption of no-tillage would guarantee the realisation of many of the objectives set out in the Soil Thematic Strategy especially on our most vulnerable soils. It is therefore in every Member State's interest to initiate new, and improve existing, education and research initiatives targeted at accelerating the uptake of no-tillage at farm level using **pull factors** such as:

- Effective knowledge and technology transfer using scientific and practical expertise from a range of climatic regions across Europe—already a priority among ECAF's 15 National Associations.
- Extend "incentive programs" for conservation and no-tillage under existing agro-environmental measures.
- Establish a network of no-tillage demonstration farms with special focus on crop rotation, cover crops and plant protection measures.
- Field events including practical hands-on farmer demonstrations (e.g. annual national festival for non-inversion and no-tillage in France and Switzerland).
- Develop and introduce appropriate no-tillage drills and planters to handle field conditions found in Europe.
- Long-term research projects with continuous no-tillage systems at both farm and research levels.
- Extension services with specialised no-tillage advisers skilled in "farmer to farmer' knowledge transfer resulting in a multiplier effect in the sector.
- Active involvement of stakeholders including administrative authorities, political agencies, farmer organisations, food and agricultural engineering industries and consumer organisations.
- Establish a market for carbon credit trading based on soil carbon sequestration.

Wide-ranging benefits to society would accrue with no-tillage adoption resulting in a significant reduction in energy consumption, thereby reducing production costs by introducing farming practice that enhances soil, water and air quality.

## 25.8 Future trends

The replacement of production-oriented subsidies with a single farm payment has refocused farmers' minds on the economic sustainability of the production systems they operate. Some farmers will consolidate their production system by sharing management inputs with neighbouring farmers or by using contractor services in an effort to reduce fixed costs. Others, deciding that their land area is inadequate to realise a sustainable income, will leave the arable sector in the coming years. This will provide an opportunity for those who are committed to farming and who wish to expand their arable area. Under either scenario, expansion or consolidation will necessitate the adoption of more efficient farm management practices. In Eastern Europe, low-cost agricultural production will decide the success or failure not only of individual farms but the overall agricultural sector in these countries. The adoption of no-tillage systems would facilitate positive developments in all these instances.

While recent trends show a strengthening of commodity prices it is noteworthy that subsidies to European farmers are declining in value each year and any future payments made to producers will be strongly linked to environmentally sensitive practices. New soils legislation throughout Europe will ensure that soil protection becomes a legal responsibility within each Member State. Further emphasis on conservation practices in agriculture would necessitate the adoption and development of no-tillage systems.

No-tillage is a sustainable agricultural system that meets the economic needs of farmers, addresses the concerns of consumers and minimises the impact on the environment. It is vitally important for European farmers to adopt sustainable low-cost systems in order to optimise profitability on their farms. The ECAF has a pivotal role to play in the coming years in assisting with the promotion and adoption of no-tillage systems throughout Europe.


Stefan Minder (farmer and contractor) in the Emmental.

Sugarbeets being no-tilled into a dead cover crop.

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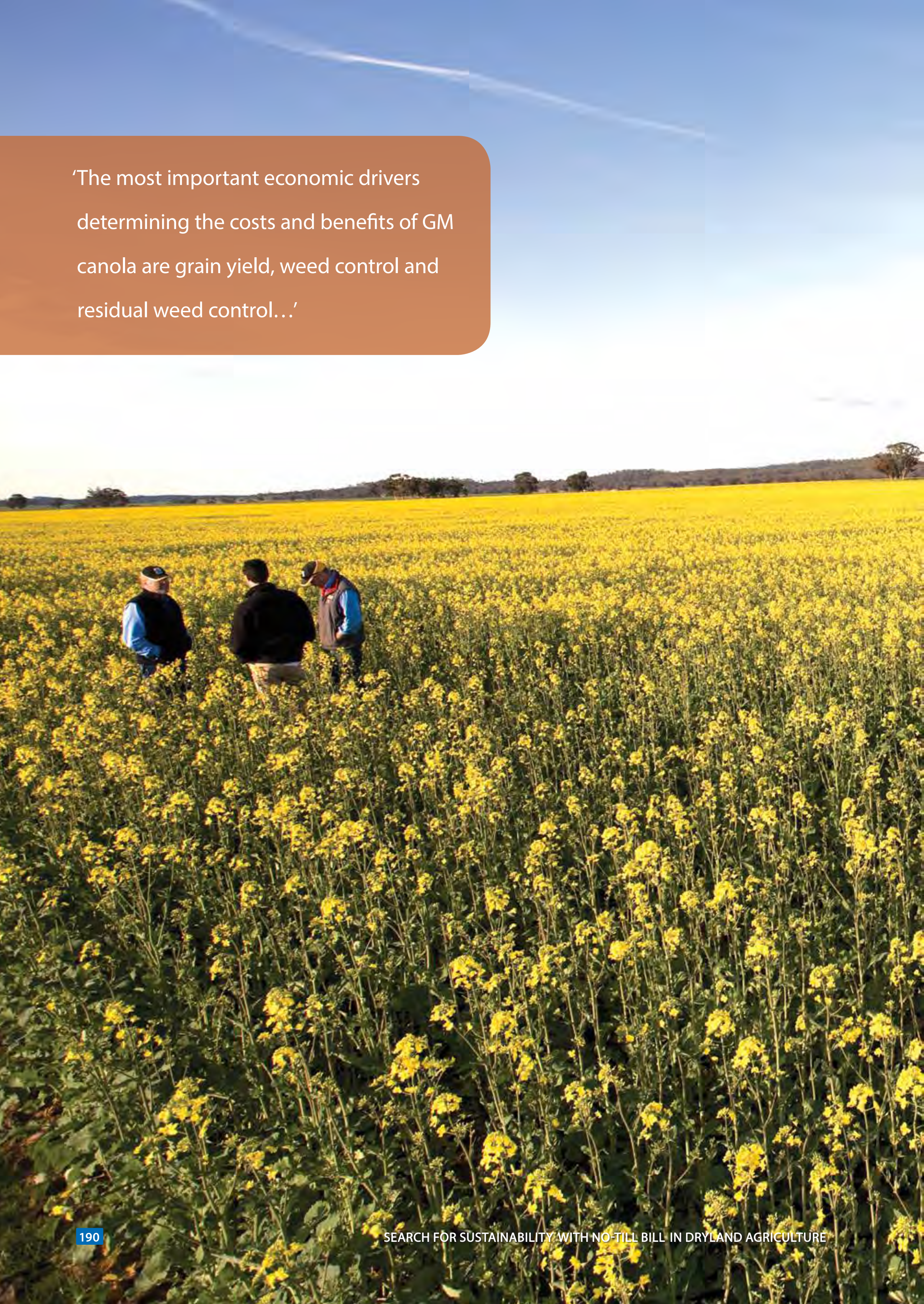
‘The most important economic drivers determining the costs and benefits of GM canola are grain yield, weed control and residual weed control…’



CHAPTER 26:

# Impact of Australia rejecting GM canola

**IN EARLY** 2003 the Federal Australian government approved the use of genetically modified (GM) canola for Australian farmers based on human health and environment grounds. All state governments except the state of Queensland then proceeded to impose bans or moratoria against the growing of GM canola due to public uncertainty with the technology. This chapter was originally written in 2005 and explores the then impact of this decision, with some updates.

For 12 months in 1996 I lived in Canada and made many good friends in agriculture. My ongoing contacts with Canadian farmers and agronomists, since then and the three Australian farmer study tours that I have taken to Canada since has lead me to conclude that there are six main reasons why Canadians have wholeheartedly embraced GM canola.

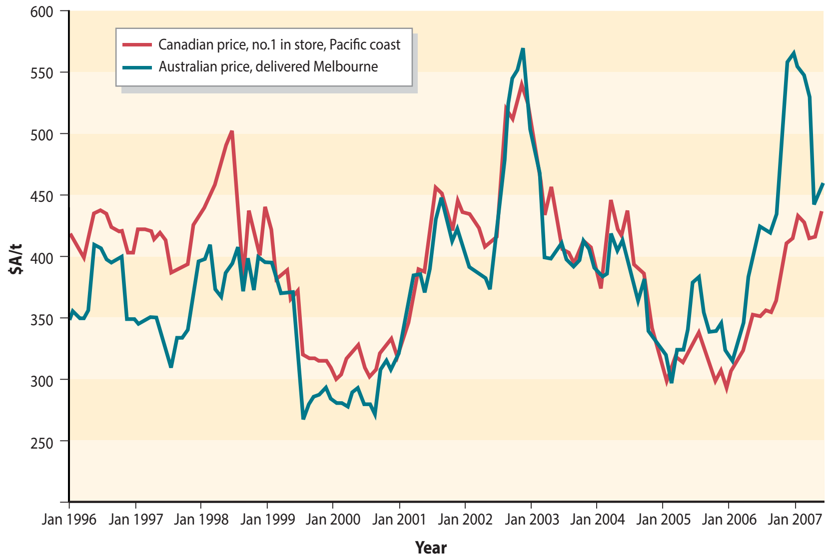
REASONS FOR GROWING GM CANOLA

1. Superior weed control;
2. Management of herbicide resistant weed populations;
3. Potentially better yield;
4. Earlier time of sowing with more return-and so more profit;
5. Reduced input costs; and
6. Ease of management.

## 26.1 All markets accept GM canola oil

There is very little discrimination against GM canola since its introduction in 1995. Even the EU is accepting crushed GM canola oil and has been for several years. Japan accepts GM canola but also purchases some non-GM canola where the threshold of GM admixture is 5%. This full GM market acceptance explains why Australian canola prices are the same as the Canadian canola prices (except of course during a period of Australian-wide drought in 2006—see graph on next page: the red line is Canadian and the green is Australian).

**Canola domestic price comparisons**
**Canada vs Australia (Australian dollars), ABARE**




This data set covers the full period of time that Canadian canola was sold as GM canola. Canadian farmers have no problems selling their record 9 Mt of GM canola produced in 2005, 2006 and 2007. In 2008 they produced 12.6 Mt and it demands the same market value as non-GM Australian canola. They export to the same markets as Australia does, with our small tonnage of about 1 mt of canola. These countries include Japan, Pakistan, China, Korea, Mexico and USA.

Why would Australia reject GM canola when it has been the bread-winning crop for most Canadian prairie farmers since 1998? I believe it is due to fear and misinformation fed to the media—who seem to have enjoyed the interesting stories. The hysteria being whipped up by anti-GM people is subtly anti-scientific.

Patrick Moore, co-founding Member and Former President of Greenpeace recently said "I believe the campaign of fear now waged against genetic modification is largely based on fantasy… and a complete lack of respect for science and logic", and "In the balance it is clear the real benefits of genetic modification far out weigh the hypothetical and sometimes contrived risks claimed by its detractors."


Dr Patrick Moore now heads up Greenspirit.

*See www.greenspiritstrategies.com*

## 26.2 GM canola trial data

The most important economic drivers determining the costs and benefits of GM canola are grain yield, weed control and residual weed control. Trials conducted in Western Australia in 2003, as published in the *2003 Crop Updates* (conducted by independent researcher, Mike Lamond), show GM canola consistently yielded 200 kg/ha more than triazine tolerant (TT) canola varieties. This is a conservative result, as can be seen in more recent trial data of non TT lines when they are compared to the 'would-be' GM canola lines.

The full yield potential of local GM material has not yet been realised in WA.

In our recent drought years of 2000, 2001 and 2002, independent trial results (by Lamond) showed that our current TT varieties typically yielded between 0.4–0.6 t/ha, while the 'would be' GM varieties yielded around 1.0 t/ha. This is a 500 kg/ha increase in yield—in drought years, an outstanding result!

With these new canola varieties the canola could be a profitable crop for WA farmers, not just in the wetter or southern areas of the state. Canola could become as important a crop statewide as it is for Canadian farmers and this could in turn reduce our current over-reliance on wheat or barley.

## 26.3 Problems with TT canola

There are two major problems we have with TT canola varieties. Firstly, TTs are physiologically inefficient converters of sunlight energy to sugar, which greatly restricts their grain yield potential; and secondly, any new TT lines which are adapted to WA conditions take time to breed. In contrast, there are many new and good conventional canola lines adapted to WA conditions with high grain yields. However, due to a lack of broadleaf herbicides available in canola crops, we cannot afford to grow these widely.

## 26.4 Economic assumptions

Monsanto, the company who hold the license for the Roundup Ready technology plan to charge farmers about $10.80/t as an end point royalty payment. This means that if farmers have a crop failure for any reason then there will be no end point royalty payment required. Conversely, if the farmer grows 1 t/ha then the fee will be $10.80/ha plus the cost of the seed which is likely to be similar to other new canola varieties. Farmers will be allowed to use any glyphosate that is registered for Roundup Ready crops. There are no assumptions calculated about improved yields from GM LibertyLink® canola, nor the benefit this crop brings to the farming system in ryegrass resistance management.

The ability of farmers to grow a weed free crop at low cost will alter farming risk particularly in dry areas where they are in search for sustainable agriculture. A clean canola crop with retained stubble creates an opportunity for early dry-sowing of wheat for the following year. This lifts the yield potential of the subsequent wheat crop and makes the wheat a less risky crop to grow.

The following data shows a $170 million loss for Western Australia rejecting GM canola. This figure is based on four main effects, and are listed in the Table 1 as:

1. Canola issues at $40,608,800;
2. Wheat issues at $25,200,000;
3. More canola grown at $81,000,000;
4. More wheat from new canola crop at $24,300,000; and
5. Calculations made in 2005.

The calculations can be followed in Table 1. Note letters down the left hand column. The figure assumes:

(a) Canola is worth $380/t – 5 years' average (2000–2005).

(b) 200 kg/ha grain yield increase is applied to GM canola.

(c) A full adoption of GM canola on 460,000 ha (WA's 5-year average canola cropped area).

(d) GM canola is $10/ha cheaper to grow with less herbicide use and greater seed cost.

(e) A 2% higher grain oil level over TT canola, worth a 3% price premium.

(f) Noodle wheat is $A180/t.

(g) 200 kg/ha more wheat is grown after canola than after wheat.

(h) There are 4.5 million hectares of wheat grown each year in WA.

(i) 10% of wheat is grown after clean GM canola.

(j) The wheat grown after GM canola needs $20/ha less herbicide cost.

(k) As in Canada, paddocks with a high grass weed burden are sown to canola, worth $120/ha more than a paddock left as sheep feed only.

(l) GM canola is grown rather than green manure crops, dirty pastures or lupins in dry regions.

(m) There is no conservation value assumed, but it would greatly reduce stubble burning and sheep induced soil erosion.

(n) The following wheat crop yields 300 kg/ha more than when grown after a grassy pasture.

This brief economic analysis shows how large the gains might be for WA farmers. This GM technology would afford more northern farmers significant and powerful crop diversity.

**Table 1: Financial analysis table of GM canola for Western Australia in 2004**

| | | |
|---|---|---|
| **1. Canola issues** | | |
| a | $380 | value ($/t) of grain delivered |
| b | 0.200 | extra grain yield from GM canola (independent 2003 trials) |
| c | 460,000 | ha grown in 2003 |
| | 92,000 | extra tonnes grown from GM lines |
| | $34,960,000 | extra $ generated from GM lines |
| d | $4,600,000 | saved $10/ha = $35/ha for less herbicides - $25/ha for GM seed and EPR |
| e | $1,048,800 | 3% more grain value from 2% more oil |
| | **$40,608,800** | Extra income from GM canola crop |
| **2. Wheat issues (this assumes wheat and GM canola are equally profitable)** | | |
| f | 180 | value ($/t) of grain delivered |
| g | 0.2 | extra yield from growing wheat after canola rather than wheat |
| h | 4,500,000 | ha grown annually |
| i | 10% | % of wheat that might be grown after clean canola |
| | 90,000 | extra tonnes of wheat grown |
| | $16,200,000 | extra $ generated |
| j | $20 | per hectare less herbicide required for 15% of wheat |
| | $9,000,000 | less herbicide costs from sowing into clean GM stubble |
| | **$25,200,000** | Extra wheat income from GM canola |
| **3. More canola grown on dirty pastures; and 4. better subsequent wheat crop** | | |
| k | $120 | $ difference between grassy pasture sprayed out versus GM canola |
| l | $81,000,000 | Canola grown on 'clean-up' paddocks (another 15% of land) |
| m | $x | Less wind erosion on sprayed pastures + more moisture trapped |
| n | 0.3 | t/ha more wheat after clean canola rather than grassy pasture |
| | **$24,300,000** | Extra wheat from more GM canola stubble |
| | **$171,108,800** | Extra potential income from GM canola package |

Given that a 500 kg/ha GM canola yield increase in drought years in dry regions of WA is possible this would increase the value of GM canola. Then we could change assumption (b) to 500 kg/ha and assumption (k) to $360 and this would lift the benefits of GM canola to a massive $338 million a year.

## 26.5 Dry wheatbelt needs crop diversity

The ability to sow GM canola dry and then remove the weeds easily and cheaply will have a profound impact on economic sustainability in dry regions. This also then creates the option to dry seed the following wheat crop into clean canola stubble which can capture summer rain more than grazed paddocks with minimal stubble. In northern regions where frost risk is low this will enable much more sustainable and economic farming systems at lower costs.

Similarly, farmers in low rainfall areas are nervous about planting wheat into thick legume stubbles following a modest year. This is because they have produced lots of organic nitrogen that will promote rapid early wheat growth. This extra growth can cause the wheat crop to excessively dry the soil and 'hay-off' the crop. GM canola would not create this 'excess N' potential risk and farmers can then regulate the N supply to the crop with post-sowing N applications in the following wheat crop.

GM canola would increase canola production in WA. There is a strong need for wheatbelt farmers to have greater crop diversity for weed, disease and insect management and for market risk and time management. The adoption of GM canola would enable less herbicide use, better herbicide resistant weed management, less stubble burning, greater crop diversity and it could even be as profitable as wheat growing in its own right.

We know that in dry areas, time of sowing is critical for canola, and marginal soil moisture at seeding makes this decision challenging, as TT weed control will be compromised without good following rains. GM canola crops eliminate this problem.

Brasilians can sow straight into GM soya as it is weed free. Their rapid adoption of new technology is leaving the 'clever country' Australia behind.
PHOTOGRAPH COURTESY ADEMIR CALEGARI.

## 26.6 Some real GM concerns

The Canadian experience has taught us that it is a challenge to keep different canola lines pure. This has meant that the organic canola growers were unable to remain 100% GM free. By definition GM free means no detectable traces of GM: this is not possible in Australia. The non-GM term is less than 0.9% levels of GM for most countries (Australia and the EU included) while it is 5% for Japan. If the organic industry were prepared to have their GM-free products at the 0.5% level then co-existence at this level would be possible.

The Canadians did not try to segregate their canola and they found a 0.25% level of contamination was common in their studies. However, Canadian farmers, after 13 years of GM canola, believe that if they wanted to revert to non-GM canola that they could. GM canolas are easily killed by many herbicides from Groups B, C, I, F and L.

The technology use agreement (TUA) has been the most uncomfortable part of Roundup® Ready (RR) canola. However, hybrids are now available in RR canola, as they have been with LibertyLink® canola for a long time and hybrids reduce the need for a stringent TUA as the seed has to be purchased every year for extra yield. Governmental researchers in Canadian have shown there is a 15% yield boost with hybrids of which 80% of this yield boost is lost if the seed is kept and reused.

Another concern over GM canola is that many multinational companies will lose their large herbicide markets. Consequently, farmers will be applying less herbicides to their crops and this may reduce R&D by these companies. A typical TT canola requires about 2.8 kg/ha of herbicides, mostly Atrazine, while a GM canola crop might require 1.2 kg/ha of herbicide.

## 26.7 Summary

It is with great relief that in 2009 most state governments across Australia are moving towards lifting the Moratoriums against the growing of GM crops. These governments have listened to the experience of Canada, USA and South America who have had outstanding success with this technology. I think GM crops will soon become the sought after crop by consumers as they learn that we are dealing with precise technology that can provide safer foods in a more timely manner than conventional plant breeding.

This GM technology, once allowed to be sensibly developed and with restrictions made less draconian, will lesson our footprint on the earth. It will enable another step forward in reducing pesticide use, reducing fuel use, reducing fertiliser use and it will create time for even more sustainable farming to be developed.


Roundup
Ready™
CANOLA

'In 1998 I initiated the WANTFA R&D site which was and remains WA's premier agronomic sustainable agricultural spring Field Day site …'

CHAPTER 27:

# How did I get into no-tillage?

**WHILE** studying for a Bachelor of Science in Agriculture at the University of Western Australia (1980–1984), I would regularly return home to the family farm to plough the land. This had severe consequences as the years 1980, 1981 and 1982 were dry and windy and resulted in horrific wind erosion. Therefore, perhaps my greatest qualification was developed then, being a desire for sustainable agriculture, as I saw our freshly ploughed land blow away as a result of my own action.

Near the end of these studies I conducted a research project called 'The effect of cultivation on soil fertility'. This was a study of soils from the home farm. The photograph below is taken from this thesis—it shows how severe the soil erosion was at the time.

From 1985–1987 I conducted a Project with the Jerramungup Department of Agriculture called "Minimum tillage for wind erosion prone south coast sandy soils of Western Australia." This work showed that less tillage could result in crop grain yields equal to tillage farming.

From 1988–1996 I worked as an extension officer with the Department of Agriculture at Esperance and Jerramungup and took 18 months study leave to begin a M.Sci. through the UWA in 1990–1991. This I completed in 2002 with a focus on managing water repellent soils.

In 1996 I had the great experience of working in Canada for 12 months with the Manitoba North Dakota Zero Tillage Farmers' Association. While their agriculture is so different to ours it is amazing how similar the essentials of agronomy are and how no-tillage works similarly in both regions. During this time I had the privilege of co-editing the book called "Advancing the Art of No-Tillage" which has gained wide applause for its scope and usefulness to no-tillers and agronomists.

In 1997 I accepted a position as Scientific Officer with the Western Australian No-Till Farmers' Association (GRDC-funded WAN3 Project). During this five year project I made 20,000 contacts with farmers and scientists in groups throughout WA and Australia.

Over the five years with WANTFA I organised Conferences and Seminars that attracted 6580 people, and field days that have attracted 3710. I also conducted at least 70 radio interviews and spoke at other non-WANTFA events where 9110 people attended. In 1998 I initiated the Meckering WANTFA R&D site which was and remains WA's premier agronomic sustainable agricultural spring Field Day site.

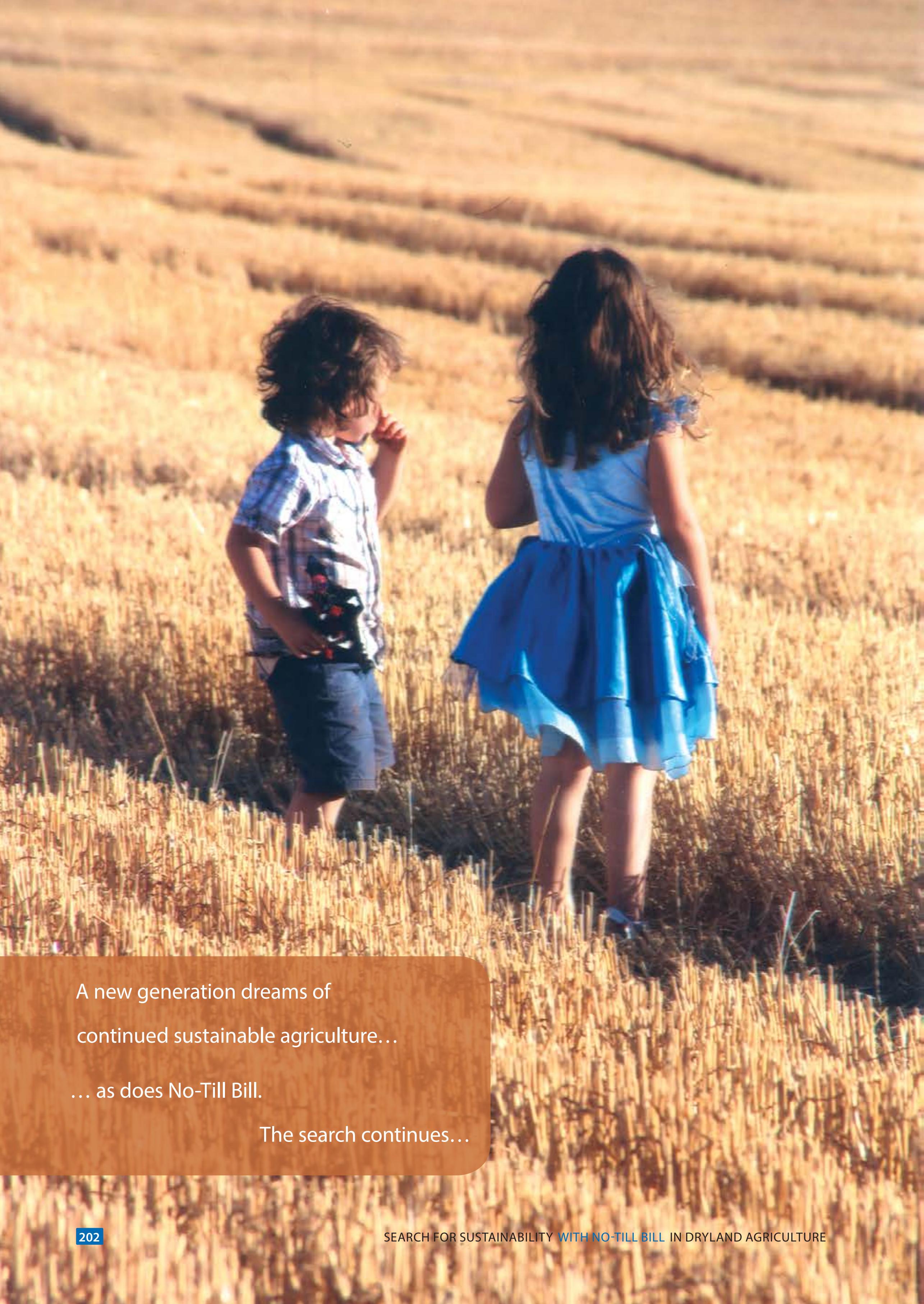
At the Meckering R&D site: Bill speaking to the crowd about canola agronomy

ABOVE: The WANTFA Meckering R&D site from the air.

ABOVE: One of the many trials at Meckering that Bill has supervised. Here the Canadian precision no-till seeder (left) is compared with the standard knife point and press wheels (right). The Väderstad Seed Hawk® gives excellent precise seed placement onto firm undisturbed soil.

WANTFA membership during this project rose from 600 to 1370 as of September 2002. During this time relations with Department of Agriculture staff were strengthened, with DAFWA now mostly adopting no-till as their common form of crop establishment.

In recognition of this work with WANTFA I was awarded honorary Life Membership (presented here by WANTFA Past President Geoffrey Marshall—pictured left) in March 2003 and the GRDC's Western Panel 'Seed of Light Award' in February 2006 for excellence in communication. As a consultant I now continue to carry the title of 'No-Till Bill' and 'The No-Till Specialist'.



A new generation dreams of

continued sustainable agriculture…

… as does No-Till Bill.

The search continues…

CHAPTER 28:

# Crabtree publications

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## 'NO-TILL BILL' CRABTREE

This book is for those who would like to know where no-till has been, where it is going and how to do it on your farm. Whether you are a newcomer to no-till or an experienced practitioner this book has something for you.

Bill Crabtree has been researching and extending no-tillage for 25 years and is well respected for his work throughout Australia and the world.

'In the early days, many people associated with no-till, be it farmers, researchers or extension advisors, would hit a problem and conclude "no-till doesn't work" or "doesn't work here". However, it was very refreshing to experience the steely determination of 'No-till Bill', who had the attitude of "Well, what is wrong with the system, and how can we get around it to make no-till work better?"

Having been involved in many robust group discussions with Bill, I have appreciated his in-depth technical knowledge and widespread hands-on experience, his ability to think outside the square and to take on new challenges to find honest answers.

Bill has played an important role as South Australian farmers followed the lead of Western Australian no-till farmers, speaking at field days, providing key information, hosting tours to WA, and generally lifting our vision as to what was possible.

I have appreciated his enthusiasm, his humour, and even his musical ability as we have performed songs together about no-till at field days. I'm sure this book will see many no-till enthusiasts studying the information, looking for that gem that might just make things click into place for them—and they won't be disappointed.

Bill, you're an ornament to the game!'

**Chris McDonough**

Department of Primary Industries and Resources of South Australia (PIRSA)

'Bill has produced and written a book I couldn't put down. Farmers, consultants and lovers of the land will find this book a 'must have' in their pursuit of sustainable food production via no-till farming. Bill writes in his wonderful punchy manner of getting straight to the point and covers the remarkable history of no-till adoption and adoption around the world and how it was almost always farmer-lead, not researcher-lead. No-till has been a saviour for so many areas of the agricultural world and this book is an excellent tool in spreading this superior method of farming.

It is a great read for anyone wanting to get into no-till farming.'

**Wayne Smith**

Independent Agronomist and fellow no-till pioneer | www.agronomy.com.au

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