Grass 2 Crop

- Project background
- Research programme - what did we do?
- Key points and guidelines - moving from grass to the cropping phase
  - Rotational and soil type considerations
  - Crop yields
  - Grass sward destruction
  - Crop establishment
  - Crop growth
  - Soil nitrogen (N) availability and phosphorus (P) distribution
  - Weed control in crops following grass
  - Soil Carbon
  - Economics
- Grower case studies
- 2011 Cropping Sequence Survey results
Introduction
The Grass 2 Crop project was set up to research and demonstrate the most effective ways of harnessing the key benefits of the grass phase for the successive cropping phase. This FAR Focus outlines the results of the three year project and some of the key guidelines that emerged during the course of the study.

The project was funded by the MAF Sustainable Farming Fund and the FAR levy and was a successful collaboration between Plant & Food Research (PFR), FAR, NZ Arable and key growers on the steering group. The skills brought together in the work programme have ensured that the project addressed the topic at a number of levels from in depth science monitoring through to practical case studies of farmer practice.

I hope you find the booklet both informative and interesting.

Nick Poole
Research Co-ordinator, Foundation for Arable Research
May 2012
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1. Project background and objectives
Project background and objectives

In New Zealand arable cropping systems involve a grass phase of various durations, ranging from six months under continuous cropping to up to six years or longer in the mixed arable cropping system. The benefits of the grass phase (e.g. soil quality and disease management) are well understood, however converting that grass back into cropping, or “breaking” grass, presents a number of problems:

- The 2006 MAF SFF, FAR and Crop & Food Research (now Plant & Food Research (PFR)) Cropping Sequence Survey (approximately 400 returns) revealed that in both the North and South Islands the most intensive cultivation (plough) used on cropping farms was to go from the grass phase back into cropping. Thus following the primary means of restoring the health of New Zealand cropping soils, the most intensive cultivation system is used.

- Intensive cultivation has detrimental effects on soil quality by increasing the rate of organic matter decomposition, resulting in a breakdown of soil structure.

- Cultivation of grass can cause the release of large amounts of mineral nitrogen into the soil which, if not properly managed, is both a waste for the grower and an emission to the environment.

- There are a number of issues associated with going from grass to the cropping phase with less intensive cultivation. Some of these problems include key pests such as grass grub or argentine stem weevil, less invasion of the soil also results in greater grass weed pressure in the following crop and greater dependence on agrichemicals. Another key issue is the matted nature of the root systems in grass which make it more difficult to lightly cultivate.

Grass 2 Crop was set up to research and demonstrate the most effective ways of harnessing the key benefits of the grass phase for the successive cropping phase, whilst minimising the release of nutrients to the ground water and maximising soil carbon retention.

The project funded by the MAF Sustainable Farming Fund and FAR has been a collaboration involving a number of organisations, each playing a crucial role in the key outputs. Erin Lawrence-Smith and Paul Johnstone led the teams at The New Zealand Institute for Plant & Food Research (Plant & Food Research) who conducted the work on nutrient release (in particular nitrogen), biomass accumulation, phosphorus and soil carbon levels. Bede McCloy and his team at NZ Arable and Kevin Sinclair (Plant & Food Research), together with FAR conducted crop structure assessments and gathered harvest yield data. The host farmers and contractors, not only hosted individual trial sites but also helped with establishing crops and overall trial management.

The trial results that are the foundation for this booklet were conducted over the three years from 2008 - 2010; these included; three long term trials that were superimposed on the same trial site for all three years (and which have been continued by FAR for another two years), each following a grass phase of different lengths (>30 years, 4.5 years and 2.5 years). The other eight trials were conducted for one year only following grass phases of between one and two years and were not subject to the same level of assessment and analysis.

In a number of sections of this booklet I acknowledge that FAR has inserted specific text and charts directly from Plant & Food Research Report No. 5857 by EJ Lawrence-Smith et al (August 2011). If you are a FAR levy payer and wish to receive a copy of the full report and/or the 2011 Cropping Sequence Survey (Plant & Food Research Report No. 6057) by PM Fraser and EJ Lawrence-Smith please contact the FAR office.

The other aspect of the booklet that I would like to draw your attention to are the individual case studies where some of our project steering group growers and others were asked to comment on how they moved from grass to crop on their property. It’s never easy explaining your own approach and in effect “laying bare” your farming approach, so my sincere thanks go to those growers who undertook an interview.

Finally, it is hoped that this FAR Focus will be read in conjunction with issue 1 from this series ‘Non - Inversion Agronomy - Guidelines for successful reduced tillage’, which covers FAR’s other recent research on reduced tillage.

Nick Poole
Research Co-ordinator, Foundation for Arable Research
May 2012

Author’s definitions used in this FAR Focus issue

Conventional tillage (Plough) - Tillage where the primary cultivation is carried out by the plough.

Non-inversion - Non-inversion is crop establishment without the use of the plough.

Top work (Min till) - Non-Inversion establishment with the use of multiple cultivation passes. This is also referred to on occasions as minimal tillage, although to be minimal the number and cost of passes needs to be considered.

Direct drilling or no tillage establishment (Direct) - Crop established in one pass with soil surface disturbance limited to within or from the seed row.

Sub tillage or deep rip - Cultivation carried out at depth below the normal working depth of top work cultivation or ploughing. In trials conducted in this project sub tillage has been used at 25 - 30 cm depth.

Strip tillage - Cultivation strip for planting the crop where only a proportion of the soil surface is cultivated at varying depths with powered or non-powered cultivator legs.

Broadcasting - Broadcasting is crop establishment without the use of a seed drill.
2. Research programme - what did we do?

- Trial programme 2008 - 2011
- 2011 MAF Sustainable Farming Fund/FAR/Plant & Food Research Cropping Sequence Survey
**Trial programme 2008 - 2011**
The aim of the Grass 2 Crop project was to investigate whether farmers can obtain benefits from using direct drilling or minimum-tillage establishment practices instead of conventional cultivation (based on the plough) after grass. Specific parameters of interest were:

1. Net amount and timing of N released through soil mineralisation.
2. Amount and distribution of carbon (C), nitrogen (N) and other nutrients in the soil profile.
3. Crop structure, management, yield and quality of crops produced.

The programme of 11 trials was split into two series; three long term trials that were superimposed on the same trial site for all three years of the project, each trial following an initial grass phase of a different duration from over 30 years down to 2.5 years. The other series, which was not subject to the same level of assessment and analysis, was based on eight trials that were conducted for one year only, each following grass phases of between one and two years.

Plant & Food Research (PFR) was contracted by FAR to carry out soil-related measurements at the three long term trials of the Grass 2 Crop project. These trials were located in Waikato (Site 1), Rangitikei (Site 2) and Methven, Canterbury (Site 3); each trial paddock had been in pasture for various durations (>30, 4.5 and 2.5 years respectively) prior to the implementation of the cultivation treatments (see page 6 for details).

**2011 MAF Sustainable Farming Fund/FAR/Plant & Food Research Cropping Sequence Survey**
The end of project survey was sent to all FAR levy payers in May 2011 with the aim of defining the shift in cultivation systems and cropping sequences in New Zealand since 2006. Four hundred surveys were returned to FAR and subsequently analysed by Plant & Food Research (Cropping Sequence Survey, PM Fraser & EJ Lawrence-Smith, Plant & Food Research Report No. 6057, September 2011). This booklet contains only a small sample of the results from the survey. If you are a FAR levy payer and would like a copy of the full report please contact the FAR office. This survey was formatted in a very similar way to the 2006 survey which enables change, in tillage practices to be defined over the last five years in New Zealand cropping systems (see section 4.0).

**Grower case studies**
To ensure that this FAR Focus represents a range of views on moving from grass to crop, a number of cropping farmers were asked to comment on their own establishment strategies and how they moved from the grass to the cropping phase on their property; these are a must read for the farmers.
## Summary of trial location and design, including experimental treatments and important agronomic details by site for all years of the Grass 2 Crop trials

<table>
<thead>
<tr>
<th>Details</th>
<th>Site 1 - Waikato</th>
<th>Site 2 - Rangitikei</th>
<th>Site 3 - Canterbury</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Soil type</strong></td>
<td>Otorohanga silt loam</td>
<td>Marton clay loam</td>
<td>Mayfield/Hororata silt loam</td>
</tr>
<tr>
<td><strong>Duration in permanent pasture prior to trial initiation in 2008-09</strong></td>
<td>&gt;30 years</td>
<td>4.5 years</td>
<td>2.5 years</td>
</tr>
<tr>
<td><strong>Cultivation treatments</strong></td>
<td>Conventional (CT)</td>
<td>Plough (PL)</td>
<td>Plough (PL)</td>
</tr>
<tr>
<td></td>
<td>Strip tillage (ST)</td>
<td>Top Work (TW)</td>
<td>Top Work (TW)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Direct Drill (DD)</td>
<td>Direct Drill (DD)</td>
</tr>
<tr>
<td><strong>Year 1 (2008-09) crop sown</strong></td>
<td>Maize silage (36M28)</td>
<td>Spring Barley cv Putney</td>
<td>Radish (White-stemmed <em>Raphanus sativus</em>)</td>
</tr>
<tr>
<td><strong>Sowing date</strong></td>
<td>18 Nov 08</td>
<td>11 Nov 08</td>
<td>19 Sept 08</td>
</tr>
<tr>
<td><strong>Harvest date</strong></td>
<td>26 Mar 09</td>
<td>12 Mar 09</td>
<td>18 Feb 09</td>
</tr>
<tr>
<td><strong>Base fertiliser</strong></td>
<td>450 kg/ha potassium chloride</td>
<td>Nil</td>
<td>150 kg/ha Cropmaster 15, 100 kg/ha Kieserite, 50 kg/ha potassium chloride, 20 kg/ha Borate46</td>
</tr>
<tr>
<td></td>
<td>100 kg/ha super phosphate</td>
<td>Nil</td>
<td>175 kg/ha Urea (18 Nov 08)</td>
</tr>
<tr>
<td></td>
<td>66 kg/ha Kieserite</td>
<td>Nil</td>
<td></td>
</tr>
<tr>
<td></td>
<td>58 kg/ha magnesium oxide</td>
<td>Nil</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11 kg/ha Borate</td>
<td>Nil</td>
<td></td>
</tr>
<tr>
<td><strong>Starter fertiliser applied to sampling areas</strong></td>
<td>Nil</td>
<td>Nil</td>
<td>150 kg/ha Cropmaster 15, 100 kg/ha Kieserite, 50 kg/ha potassium chloride, 20 kg/ha Borate46</td>
</tr>
<tr>
<td><strong>In-season fertiliser applied to sampling areas</strong></td>
<td>Nil</td>
<td>Nil</td>
<td>175 kg/ha Urea (18 Nov 08)</td>
</tr>
<tr>
<td><strong>2009 winter crop and management</strong></td>
<td>Perennial grass/chicory mix, direct drilled, sown with 200 kg/ha DAP, 1 x grazing with yearlings (late Sept), Silage cut and bailed (late Oct).</td>
<td>Winter grass, light surface cultivation across all treatments followed by drilling. Crop grazed with sheep (set stocked).</td>
<td>Sown into autumn wheat</td>
</tr>
<tr>
<td><strong>Year 2 (2009-10) crop</strong></td>
<td>Maize silage (34B23)</td>
<td>Spring Barley cv Putney</td>
<td>Autumn wheat (cv. ‘Phoenix’)</td>
</tr>
<tr>
<td><strong>Sowing date</strong></td>
<td>3 Nov 09</td>
<td>2 Nov 09</td>
<td>6 April 09</td>
</tr>
<tr>
<td><strong>Harvest date</strong></td>
<td>24 Mar 10</td>
<td>5 Mar 10</td>
<td>21 Feb 10</td>
</tr>
<tr>
<td><strong>Base fertiliser</strong></td>
<td>500 kg/ha of 50% potassic serpentine super</td>
<td>Nil</td>
<td>Nil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nil</td>
<td>300 kg/ha superphosphate</td>
</tr>
<tr>
<td><strong>Starter fertiliser applied to sampling areas</strong></td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
</tr>
<tr>
<td><strong>In-season fertiliser applied to sampling areas</strong></td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
</tr>
<tr>
<td><strong>2010 winter crop and management</strong></td>
<td>Perennial grass/chicory mix, direct drilled. Site was heavily grazed (visual pugging damage). 200 kg/ha of DAP was applied.</td>
<td>Winter grass, light surface cultivation across all treatments followed by drilling. 150 kg/ha of Cropmaster 15 applied at sowing, followed by 85 kg/ha Urea in May. Crop grazed with sheep (set stocked).</td>
<td>Sown into Cocksfoot</td>
</tr>
<tr>
<td><strong>Year 3 (2010-11) crop</strong></td>
<td>Maize silage (38H20)</td>
<td>Spring Barley cv Putney</td>
<td>Cocksfoot cv Kara</td>
</tr>
<tr>
<td><strong>Sowing date</strong></td>
<td>26 Oct 10</td>
<td>3 Nov 10</td>
<td>27 Feb 10</td>
</tr>
<tr>
<td><strong>Harvest date</strong></td>
<td>24 Feb 11</td>
<td>1 March 11</td>
<td>11 Jan 11</td>
</tr>
<tr>
<td><strong>Base fertiliser</strong></td>
<td>600 kg/ha of potassic super mag</td>
<td>Nil</td>
<td>Nil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nil</td>
<td>150 kg/ha Cropmaster 20 (9 April 2010)</td>
</tr>
<tr>
<td><strong>Starter fertiliser applied to sampling areas</strong></td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
</tr>
</tbody>
</table>
3. Key Points and guidelines - moving from grass to the cropping phase

3.1 Rotational and soil type considerations
3.2 Crop yields
3.3 Grass sward destruction
3.4 Crop establishment
3.5 Crop growth
3.6 Soil nitrogen (N) availability and phosphorus (P) distribution
3.7 Weed control in crops following grass
3.8 Soil carbon (C)
3.9 Economics
### 3.1 Rotational and soil type considerations

#### Starting Point Guidelines following grass:

- Know your seedbed characteristics, how much clay is in your soil? What is its water holding capacity and how wet is it at the stage when you wish to establish the crop?
- The fibrous nature of the root mass from the grass and the good soil crumb structure following grass can be particularly advantageous in establishing small seeded crops that may be susceptible to compaction. When direct drilling following grass the desiccated grass residue acts as an excellent weed mulch which confers good broad leaf weed control. This is particularly important where specialist broad leaf crops have few safe herbicide options.
- Generally autumn seedbeds provide a much better platform from which to reduce cultivation intensity. These seedbeds, irrespective of soil type, are moving from a dry phase to a wet phase.
- In the spring, soils are moving from a wet phase to a dry phase. It is easy to be impatient and damage soil structure by moving soil too early and, though the more fibrous nature of the grass root mass affords some protection against compaction, seedbeds still need to be dry enough for field operations. Paddocks to be direct drilled are likely to be cooler due to higher water content and may therefore take slightly longer to dry.
- Aeration may aid crop establishment on soils with heavy clay contents in the spring. In autumn aeration may not be important due to self-regulation - the process by which clays crack and fissure over summer as a result of shrinkage.

#### Autumn versus spring establishment following grass

In this project, wheat crops on a Wakanui silt loam in Mid Canterbury, established better and were higher yielding when direct drilled in autumn (following a 14 month grass seed crop) than in the spring (following an 18 month grass phase (including a grass seed crop)). This was due to poorer plant establishment in the direct drilled blocks in the spring compared to the autumn. The reduction in plant establishment did not appear to be related to pest issues but the inability of the seedling to reach the surface once germinated. Following a short term grass phase with less available soil nitrogen, slower initial growth of direct drilled crops (see section 3.5) could be more significant in spring sown wheat where the growing season allows less time for compensation than with autumn sown crops. Whilst the initial lag in biomass of direct drilled crops can be partly overcome with the use of “at sowing” nitrogen, the crop may not fully compensate if initial plant establishment is also reduced. When the grass phase supplies greater soil fertility, this lag in biomass from direct drilling can prevent excessive early growth and reduce late season lodging, however with short grass phases and low fertility, slow early growth is a disadvantage. Therefore fertiliser at sowing, particularly nitrogen (and phosphorus) are more important with spring sowings than with autumn sown crops after grass.

Spring sowing allows utilisation of the grass phase over winter for grazing, and is a popular option for farmers with grass seed crops. Where farmers (particularly those on heavy land) have removed livestock from the farming system, there has been an increasing desire to establish wheat early in the autumn after grass. FAR is currently evaluating March versus April sown wheat following two year grass crops in South Canterbury. Initial results indicate that grass weeds and volunteer ryegrass are more difficult to control with March sowings, but wheat yields on dryland are higher or the same when compared to April sowings.

#### Graminaceous crops (e.g. cereals, maize) versus broad leaf crops (e.g. pulses)

Many farmers use spring barley after grass in a system to establish a new pasture. Ex grass paddocks in spring are also an excellent platform for direct drilling broad leaf crops. These crops have limited herbicide options, and the glyphosated grass sward acts as an excellent mulch preventing the germination of new broad leaf weeds. There is frequently regrowth from the sward, resulting in grass volunteers in the following crop, however in broad leaf crops these are relatively easily controlled. Grass regrowth and grass weeds are more problematic in cereals following grass where herbicide options tend to be more limited (in terms of modes of action) and more expensive.

#### Wheat after grass versus wheat after spring break crop after grass?

Two milling wheat trials were set up to examine whether there was a yield benefit in a wheat crop following Chrysanthemum (following grass) versus wheat following grass directly. Both trials were established with milling wheat cv Conquest on the same day with the same establishment techniques in separate paddocks. Although not directly comparable the establishment treatments gave similar results in both trials, with a 0.6 - 0.8 t/ha yield advantage to milling wheat following Chrysanthemum (after grass) as compared to wheat following grass direct.
Influence of establishment technique - autumn versus spring wheat establishment following grass - Wakanui

<table>
<thead>
<tr>
<th>Wheat establishment method</th>
<th>Autumn sown 2009 (following 14 months' ryegrass)</th>
<th>Spring sown 2010 (following 18 months' ryegrass)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Establishment (Plants/m²)</td>
<td>Dry matter GS33 kg/ha</td>
</tr>
<tr>
<td>Plough</td>
<td>166</td>
<td>5525</td>
</tr>
<tr>
<td>Top work</td>
<td>135</td>
<td>3896</td>
</tr>
<tr>
<td>Direct (Cross Slot)</td>
<td>127</td>
<td>4250</td>
</tr>
<tr>
<td>Direct + 30 kg N at seeding</td>
<td>136</td>
<td>4390</td>
</tr>
<tr>
<td>LSD</td>
<td>22</td>
<td>1856</td>
</tr>
</tbody>
</table>

ns - no significant yield difference

Influence of establishment techniques in autumn wheat following ryegrass versus wheat following chrysanthemum (following grass) cv Conquest - Wakanui

<table>
<thead>
<tr>
<th>Wheat establishment method</th>
<th>Autumn sown 2009 (following 14 months' ryegrass)</th>
<th>Autumn sown 2009 (following chrysanthemum following 18 months' ryegrass)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Establishment (Plants/m²)</td>
<td>Dry matter GS33 kg/ha</td>
</tr>
<tr>
<td>Plough</td>
<td>166</td>
<td>1377</td>
</tr>
<tr>
<td>Top work</td>
<td>135</td>
<td>1297</td>
</tr>
<tr>
<td>Direct (Cross Slot)</td>
<td>127</td>
<td>654</td>
</tr>
<tr>
<td>Direct + 30 kg N at seeding</td>
<td>136</td>
<td>1071</td>
</tr>
<tr>
<td>LSD</td>
<td>22</td>
<td>443</td>
</tr>
</tbody>
</table>

ns - no significant yield difference

Key point guidelines

- Poorer establishment, leading to lower yields, following grass has been more pronounced in the spring than in the autumn on Wakanui Silt loams with direct drilled crops.

- Ensure that seed is vigour tested before planting where direct drilling is being undertaken, this will be particularly important when seedbeds are cold and wet in spring. If seed is low vigour or has borderline vigour do not use for direct drilling.

- Slower initial growth in direct drilled crops (relative to conventional cultivation) following short term grass swards, with lower soil fertility is more important to rectify with “at sowing” fertiliser (nitrogen and phosphorous) in spring sown wheat than with autumn sown wheat from results on Wakanui silt loams. See section 3.5 for more details on crop biomass accumulation.

- Where grass swards are grazed over winter and sprayed out prior to spring cropping, the dead grass residue is an excellent mulch for the direct establishment of broad leaf crops, particularly those where herbicide options are limited.

- Where grass swards are killed off in early spring as opposed to later in spring, land will take longer to dry, particularly on heavier soils. Early sward spray out with glyphosate means that the grass pasture cannot be used to dry out the soil, assuming it retains good ground cover after being sprayed out. Greater patience is therefore required for direct drilling in these situations to avoid smearing heavy clay soils at seeding with drill coulters. However, irrespective of spray out timing sufficient time is needed to allow for sward breakdown and pest control.
Enterprise: Growing, Harvesting and Marketing of Maize (Grain and Silage), Baleage, Hay and Cereals and Agricultural Contracting

Crop area grown: 1000ha precision planted maize

Soil type: Large range: Black Sands, River Silts to Heavy Clays

Grass phase length: 12 - 60 months depending on grass species

Establishment method: Predominantly minimum tillage top work, strip tillage with RTK GPS and ploughing

Adoption of non inversion cultivation
Maize is grown for grain as a monoculture on the Flemings’ own properties using a top work approach to cultivation of disc and tine cultivator on lighter soil types, or discing twice and a light powerharrow pass on heavier soils. Sub soiling is carried out in some seasons where conditions allow and compaction is identified. Six years ago a move was made away from ploughing to top work to reduce costs, prevent wind erosion on lighter sands and to avoid an anaerobic layer of stubble he felt was impeding crop growth. This move has reduced cultivation costs and tractor hours by 30 - 50%.

Adoption of autosteer RTK GPS tractors over the last five years has lead to the introduction of strip till cultivation. This is being used on the lighter soil types and is being trialled and adapted to heavier soil types. Strip till has the ability to reduce cultivation costs significantly but in Russell’s view there are also some negative impacts of strip till cultivation. These are that it often makes the crop more vulnerable to heavy rainfall events at germination and that the costs of slug control can offset some of the tillage savings made.

No-till maize trials are being conducted on the Flemings’ property as part of a MAF SFF/FAR project this season. As technology improves this may become a possibility for the Flemings in the future. Russell sees the biggest hurdle for no-till maize being that the Manawatu spring conditions tend to be wet most years: often there are only small windows of opportunity between rainfall events to establish crops in the Manawatu spring. Cultivation of some method gives the opportunity to dry out the soil enough to establish the crop in a timely manner, which is critical for good yields.

Moving from grass to crop
The grass to crop phase in the spring is the only time the plough is still utilised. Maize silage paddocks planted with a winter annual grass are baled and sold to avoid winter stocking of these predominantly leased properties. The plough gives the ability for a very fast turnaround from baling to sowing of less than a week. This is important to achieve maximum dry matter production and timely maize crop establishment. No pre-mowing glyphosphate is used as the risk of losing the grass crop to wet weather delays is considered too great a risk. Ploughing and post emergent herbicides are then used in combination to control the grass in the subsequent maize crop.

Future objectives - controlled traffic
Recently replacing machinery with higher horsepower tractors and auto steer technology has led to an ability to operate a controlled traffic regime. Cultivation equipment, planters, sprayers and combine harvesters can be operated on the same wheel track. The aim of this move into controlled traffic is to reduce compaction. Russell foresees that controlled traffic operations will further increase their ability to adopt reduced tillage systems to a wider range of soil types.
a) Kuhn XM Discs

b) Yetter Strip Till Unit fitted with mole knife opener

c) Overum Ploughs
3.2 Crop yields

Direct versus top work versus plough - influence of tillage on crop yield

The mean yield from all 11 trials in the project (all years) show there was a small yield advantage (4%) to plough and top work over direct drill establishment. However, in only two trials in this series was there any statistically significant difference between establishment methods.

Influence of establishment method following the grass phase in the rotation - Yield (as a % individual trial site mean) from 11 trials conducted between 2008 - 2010 at locations between South Canterbury and Rangitikei

In the two trials where there was a significant advantage (15 - 25%) to the plough and top work over direct drilling, the crop being established after grass was wheat. In one trial crop establishment with direct drilling was a factor. This was when spring sown wheat on a Wakanui silt loam followed 14 months of ryegrass in 2010 (see section 3.1) and sward destruction took place the previous autumn. In the other trial, establishment in the autumn was good but water logging over winter had a greater effect on the plant stand in direct drilled blocks than in ploughed and top worked blocks.

Without these two wheat trials there was no yield difference due to establishment method, and less variation in yields with the direct drilled blocks following grass, compared to plough or top work treatments.

Influence of establishment method following the grass phase in the rotation - Yield (as a % individual trial site mean) from 9 trials conducted between 2008 - 2010 at locations between Canterbury and Rangitikei (excluding two wheat trials where plant stand was inferior with direct drilling)

Yield results as a % site mean - Grass 2 Crop Project 2008 - 2010

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Plough</td>
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<td>102</td>
<td>98</td>
<td>102</td>
<td>n/a</td>
<td>94</td>
<td>104</td>
<td>97</td>
<td>109</td>
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<td>101</td>
<td>97</td>
<td>99</td>
<td>101</td>
<td>99</td>
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</tr>
<tr>
<td>Direct</td>
<td>101</td>
<td>98</td>
<td>102</td>
<td>101</td>
<td>100</td>
<td>101</td>
<td>100</td>
<td>100</td>
<td>87</td>
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<tr>
<td>Direct + N</td>
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<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
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<tr>
<td>Direct with deep rip (25 - 30 cm)</td>
<td>100</td>
<td>101</td>
<td>99</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
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</tr>
<tr>
<td>Site yield 100% (t/ha)</td>
<td>7.03</td>
<td>8.08</td>
<td>6.85</td>
<td>1.52</td>
<td>11.42</td>
<td>10.56</td>
<td>10.01</td>
<td>11.71</td>
<td>8.26</td>
<td>5.87</td>
<td>3.88</td>
</tr>
<tr>
<td>LSD (t/ha)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sig (0.05* 0.01** 0.001*** )</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

n/a - not available, ns - no significant yield difference.
Conventional versus Strip tillage in maize

There was no statistically significant yield differences between forage maize established with conventional intensive tillage versus strip tillage in the three years of trials following 30 years of grass pasture at the Waikato site. However in all three years there was a trend for the strip tillage to be slightly inferior (1.2 - 2.0 t/ha dry matter (DM)), a result that is likely to be related to greater soil nitrogen availability with conventional tillage. In order to assess the impact of soil nitrogen mineralisation the trials were grown with no added fertiliser, therefore it is possible this trend in dry matter might not have been evident if fertiliser had been applied.

Above ground crop biomass accumulation at site 1 (Waikato) after different tillage treatments were applied pre-sowing for three consecutive seasons.

<table>
<thead>
<tr>
<th>Tillage practice</th>
<th>Above ground biomass (t DM/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Year 1 - Maize</td>
</tr>
<tr>
<td></td>
<td>4 WAS(^1) 8 WAS 12 WAS Harvest (18 WAS)</td>
</tr>
<tr>
<td>Conventional tillage</td>
<td>0.62 8.2 18.0 28.1</td>
</tr>
<tr>
<td>Strip tillage</td>
<td>0.59 7.7 17.1 26.9</td>
</tr>
<tr>
<td>P value</td>
<td>ns(^1) ns ns ns</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>0.14 1.6 2.0 2.4</td>
</tr>
<tr>
<td></td>
<td>Year 2 - Maize</td>
</tr>
<tr>
<td></td>
<td>3 WAS 7 WAS 12 WAS Harvest (20 WAS)</td>
</tr>
<tr>
<td>Conventional tillage</td>
<td>0.03 1.4 9.0 17.9</td>
</tr>
<tr>
<td>Strip tillage</td>
<td>0.03 1.2 8.5 16.4</td>
</tr>
<tr>
<td>P value</td>
<td>ns ns ns ns</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>0.005 0.32 1.81 2.55</td>
</tr>
<tr>
<td></td>
<td>Year 3 - Maize</td>
</tr>
<tr>
<td></td>
<td>- - - Harvest (17 WAS)</td>
</tr>
<tr>
<td>Conventional tillage</td>
<td>- - - 19.24</td>
</tr>
<tr>
<td>Strip tillage</td>
<td>- - - 17.21</td>
</tr>
<tr>
<td>P value</td>
<td>- - - ns</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>- - - 2.60</td>
</tr>
</tbody>
</table>

WAS\(^1\) = week after sowing. ns\(^1\) = not statistically significant at P > 0.10.

Key point guidelines

- Establishing a range of crops (in 11 trials) following grass phases of between 6 - 54 months resulted in direct drilled crops yielding on average 4% lower than crops established with the plough.

- However, significant reductions in yields with direct drilling were associated with only two of the 11 trials and were, in one case, related to inferior establishment, and in the other, greater incidence of waterlogging over winter.

- In the other nine trials there was no significant difference in crop performance due to establishment method, though there was less variation in yield with crops established using direct drilling (yield range 98-102%).

- Forage maize yields following strip tillage or conventional tillage showed no significant difference in dry matter yields grown following 30 years of pasture in the first year or following six months grass/chicory mix in the second and third year. However in all three seasons the trend was in favour of conventional tillage.
Enterprise: Cropping farm (cereals, herbage seed, maize and leasing out land for potatoes)

Property size: 580ha

Livestock: 1200 lambs grazing

Irrigation: 450ha irrigated

Soil type: Wakanui silt loam (heavy) and Lismore silt loam (medium)

Grass phase length: 12 - 48 months depending on grass species

Establishment method: Non-inversion (top working) and conventional ploughing

Efficiency is the key when going from grass to crop

Brent and Maryn Austin operate a large 580ha arable farm 'Austin Farming Ltd', near Ashburton in Canterbury. Four years ago they moved onto the family farm to farm with Brent's parents, since then they have bought land to increase the farm area and have leased an extra 100ha. With such a large farm, time is of the essence in terms of crop establishment. Getting the crops in as efficiently and economically as possible is the aim of the crop establishment programme.

Brent prefers to be flexible with cultivation methods, doing as little or as much cultivation as is necessary in moving from grass to crop. Since attending a John Bailey (UK mechanisation expert) workshop funded by FAR, his cultivation methods have changed considerably compared to the past. Now that he has a lot more land to work he prefers to use top working (using a He-Va disc roller) in order to cover ground more quickly and cost effectively than ploughing. But after grass Brent is having recurring issues with establishment and grass weeds, so depending on the situation he will go back to the safety and confidence of using the plough.

Enterprise and rotation

Austin Farming Ltd grows milling and feed wheat, barley, oats, grass seed, maize, linseed and leases land out for potatoes. 450ha of the farm is irrigated. The irrigation system comprises of a pivot, two laterals, a roto rainer, a turbo rain and a travelling gun. The soils are mainly a heavy Wakanui silt loam and some Lismore silt loams.

Brent and Maryn's rotation consists of wheat to ryegrass and back into wheat followed by oats and then either maize, potatoes or linseed. Wheat and ryegrass are the focal points of the rotation. In the 2010 season, 300ha of wheat was grown. Of this wheat, 60% was feed wheat and 40% was milling, though the final split is dictated by the quality of the milling wheat. In the past, Brent grazed grass over winter but he now establishes all his crops following grass in the autumn. The lack of spring crop options and higher number of feed wheat contracts for dairying were the catalysts for this change. Less winter grazing also means that paddocks aren't pugged up over the winter by livestock, thus saving the need for ploughing in the spring to establish the next crop. Less intensive cultivation breaking grass can be adopted in the autumn at a lower cost provided there are herbicide options for grass weed control in the following crop. If the grass weeds can't be sprayed out in the following crop, Brent will consider ploughing, which, depending on time available, will be carried out “in house” or with the use of a contractor. Since paddocks lose yield potential with delays in sowing, Brent sees it as better to pay a contractor to cultivate the paddock as opposed to losing money by waiting until he can do the cultivation himself.

Moving from grass to crop

Generally, to go from grass to crop, Brent will spray the paddock off with glyphosate and then burn the stubble. He then runs a He-Va Disc roller across the paddock once followed with the basal fertiliser application and then depending on the seedbed conditions, he will either do another pass with the He-Va or a pass with a 6 metre grubber and harrow setup.

A John Deere 8120 200hp tractor is used to pull all cultivation equipment and a John Deere 6920 150hp tractor is used to pull the drill and roller. A GPS system is used to run the drill which is then used in the harvester at the end of the season. The drill Brent uses is a 6 m John Deere 750A disc based drill which he has owned for three seasons and which replaced a Duncan drill. Brent changed from a coulter based setup to a disc setup in order to handle more trash and to be able to do less cultivation after grass.

If Brent needs to plough, he will use the Clough 8 furrow plough followed by a roll and a pass with the grubber and harrows. The paddock may then be rolled again before receiving an application of fertiliser. The paddock then receives a pass with either the 9 metre Clough Maxi-till or discs and is rolled again after drilling. This is a timely process which was the traditional method of breaking a paddock for...
crop and now with more area, Brent prefers to use minimum tillage. Brent's general rule is that he will get each paddock ready for drilling in the most efficient way possible.

However, Brent recently purchased a 5 furrow reversible plough. The decision was made to buy this plough to bury grass weeds which were starting to show with using the disc roller and it is much quicker and easier than the old plough. 'I think it has done its job with the grass weeds as they are not showing as much as last year. It has been so good that I would like a bigger, newer plough to cover the ground quicker.'

Brent comments 'Most decisions are made thinking about the bottom line. For example, going from grass to crop, ploughing the grass under has a much higher chance of killing it than just top working. Even though using the plough is more expensive, it ends up cheaper in the long run because you don’t have to deal with the grass the following year.'
3.3 Grass sward destruction
Spraying off the grass weeds, pests and soil nutrition

Evaluating different methods of killing off the grass sward prior to establishment was not part of this research project, however there were a number of relevant observations. Most farmers wish to maximise dry matter production and utilisation of the grass phase prior to establishing the new cropping phase of the rotation. This means that in many cases they will aim to minimise the period between grass sward and new crop planting.

Where conventional or minimal cultivation is being used, a longer period between spraying and cultivation allows more time for grass residues (shoots and roots) to breakdown, which allows easier workability of the seedbed. The working of the soil also confers a degree of pest control therefore with direct drilling an agrichemical or longer fallow period may be required. When direct drilling post grass phase, the need for pest control, particularly of slugs, Argentine stem weevil, grass grub, springtails and aphids, should be considered. In these situations consider agrichemical control e.g. slug baiting shortly before sowing and or spraying insecticide with the glyphosate application when the grass is destroyed. Under high pest pressure agrichemical inputs can be split between the sward destruction and sowing. If the time between spraying and cultivating is more than approximately seven days in late spring then re-infection with new pests and new weed seed germination will result. Unless stock numbers have been high slugs can be particularly problematic in the spring when soils are moving from the wet winter phase and warming up (high stock numbers can reduce slug numbers purely by trampling).

In 2010, where spring wheat was established following an 18 month grass phase, the timing of top work treatments were compared to determine whether there was a yield advantage to spraying out the sward in the autumn and cultivating in autumn or spraying out in autumn followed by spring cultivation. The results revealed no yield difference between cultivation in autumn or spring following autumn glyphosate application. There was also no difference in the weed spectrum between the two treatments. This comparison indicates that with ex grass seed paddocks, that are only 12 - 18 months old (which are common in the Canterbury region), there is more flexibility in the approach to crop establishment, as the sward does not have a dense thatch of residue that is common in longer term leys.

Key point guidelines

- Where periods between the grass phase and following crop are minimised to maximise grazing return there are a number of effects:
  - Cultivation produces more uneven seedbeds since turfs associated with sward have less time to breakdown, this frequently results in more passes if top working is being considered.
  - Cultivation and heavy stock numbers reduce pest pressure e.g. slugs moving from the grass to the cropping phase, but increases the risk of soil compaction when the soil is still wet.
  - Direct drilled crops following grass are more dependent on agrichemical solutions to prevent pest problems from Argentine stem weevil, grass grub, slugs, spring tails and aphids. However the age of the sward is likely to be a key factor in the extent of pest problems, 12 - 18 month grass phases (ex grass seed crops) being much less problematic than longer grass phases.
  - Grass sward regrowth and grass weeds can be problematic following crop establishment into grass residues where top working or direct drilling is used.
  - Time of sward destruction has a large influence on crop sowing date, since with direct drilling early sward destruction means that the grass growth cannot be used to dry the soil profile (plant transpiration). This extra soil moisture is a benefit to the following direct sown crop, but greater patience may still be necessary in waiting for sufficient drying to avoid smearing drill slots.
  - Farmer observations would suggest that, if the ground is very wet when the grass phase is destroyed with glyphosate in the spring, it takes several more days for the glyphosate to work, as although the soil temperatures have warmed the grass is not growing actively in the high moisture conditions.
Enterprise: Mixed cropping (seed production - herbage seeds, clover, cereals)

Property size: 425ha

Livestock: All finishing - Weaner deer and lambs

Irrigation: Fully irrigated

Soil type: Lismore and Eyre Stony Silt Loams (light-medium)

Grass phase length: 12 - 30 months

Establishment method: Direct drilling (no-tillage) and small amount of top work

Time to move from Grass to Crop (mins/ha):
Year 1995 - 80 mins/ha
Year 2011 - 50 mins/ha

Growing elite grass seed crops and improving soil structure through the use of direct drilling and rotation

Radfield Farm is a 425ha mixed cropping farm near Ashburton and is owned and run by David and Hilary Ward. The business is centered on ryegrass seed production and the wintering of lambs and deer. They converted the farm to no tillage in 1995 with the exception of some surface cultivation for vegetable seed production. Their farm policy is 'to farm as profitably and as efficiently as possible, using sustainable practices and techniques, to improve soil quality and therefore increase moisture and nutrient retention.'

Soil is the focus at Radfield farm. Systems are in place to ensure the soil is in peak condition at all stages in the rotation. These key times are defined by the position of ryegrass seed crops and crops which are in high demand on the world markets. Utilisation of the grass phases is the focal point since it is not only a restoring crop for the soil (both in terms of soil quality and organic matter) but pays in terms of both seed production and forage production. David does not see other crops paying their way as well as ryegrass seed crops. Better soil conditions resulting from the rotation and no-tillage system lead to better cation exchange capacity (improved soil test results and less fertiliser application), better soil moisture conservation (saving 40 mm/ha/yr) and less labour, fuel and capital investment in machinery.

Enterprise and rotation

The soils at Radfield are medium to light Lismore and Eyre stony silt loams. They are free draining and have a moisture holding capacity of approximately 60 to 80 mm. The farm is fully irrigated using three bores and applied by two lateral irrigators, two Roto Rainer irrigators and two Briggs Linear. Radfield's machinery lineup consists of a 155hp Case Puma, 230hp John Deere 8220 pulling a 19 run Cross Slot drill, an 8080 New Holland harvester and a 2188 Axial-Flow combine harvester.

The farm comprises of 385ha of owned land and 40ha of leased land. Deer are grazed on 80ha which is also dedicated to growing Italian ryegrass to spread the risk and minimise cross contamination with perennial ryegrass seed crops on the main block. The rotation at Radfield generally goes from ryegrass for seed to spring barley back to ryegrass then into a brassica and back to ryegrass. It is important to note that the ryegrass is all the same cultivar to prevent contamination when growing high value seed crops. The rotation David has put together can also be broken with a ‘cleaning phase’ of three years. This phase consists of a wheat crop followed by greenfeed oats and then another crop of wheat. It may also include a brassica or break crop depending on the market prices. David prefers to return all harvest residues to the soil unless the value of the residue is greater baled.

Stock trading is also an important part of the business. Over the last few years, David has sown one or two specialist winter feed crops (kale and swedes) to feed deer and sheep over the winter in addition to ex white clover and ryegrass seed crops.

Moving from grass to crop

David generally breaks the grass phase and returns to crop in the spring, but this decision depends on the market; he may consider breaking the grass in the autumn in order to establish a seed crop. Breaking the grass phase in the spring fits with the large amounts of dry matter produced soon after harvest with ryegrass and clover crops, which enables early purchase of trading stock. Deer arrive mid-April and are gone in October and the Italian ryegrass crops are closed up and livestock removed on Labour weekend. The stock trading is seen as highly beneficial both in terms of manure returns to the soil but also in terms of overall income.

When going from the grass phase into a cereal, David applies one application of Roundup Transorb (2 l/ha), and a small amount of Granstar (150 ml/ha Pulse is added if it is perennial ryegrass). Immediately after direct drilling, David rolls the paddock with the Cambridge roller to achieve a flat seedbed for the pre emergence spray to achieve optimal coverage. The
only extra cost with this rotation position is an application of Twinax and Ultra which can be used for small grass weeds and or wild oats.

**Changes in cultivation practice over the last 20 years**

David has seen many benefits from changing to no-tillage back in 1995. Carbon and mineralisation levels are more desirable and in combination with improved cation exchange rates, appear to be improving soil tests and reducing the amount of fertiliser needed to obtain positive results. David has calculated that he saves 40 mm/ha/year with improved soil moisture conservation and at $2/mm this is a considerable saving. Diesel costs, man hours and capital farm investment have also been reduced with the change to no tillage, and another great advantage is increased trafficability.

With the exception of an increase in grass weed management requirement, David doesn't find that there are any real disadvantages to their system. Brome or hairgrass don't seem to be an issue but prairie grasses can sometimes pose a threat, however changing the rotation to allow easier control is the solution. The key to controlling the grass weeds is rotations and monitoring. David believes that relying on agrichemical herbicides alone is too risky as there is an increased probability of creating future resistance issues.

The Wards decided to change to no tillage for various reasons. They didn't have irrigation, didn't own all of the necessary machinery for conventional tillage and faced a number of droughts and wind blow events in the 1980's. They thought there must be a better way to increase soil moisture retention and be able to consistently crop the land in an intensive mixed cropping sequence. David found that although the no tillage crops struggled up to late tillering, the yield potential was no different. They had earlier issues with slugs and different herbicide mixes that didn't work but have since overcome these downfalls and achieved their desirable farming system. The limiting factor with the no tillage system is that the current technology is limited for small vegetable seeds; hence David uses some minimal tillage techniques for establishment of these crops.

In the future, David foresees wider use of precision planting and no tillage than is currently practiced; he also believes genetically modified crops may also play a part in the development of the cropping industry.
3.4 Crop establishment

In this trial series, four trials were established using the same drill (Cross Slot) for all establishment methods in order to avoid the confounding effects of calibrating different drills. Establishment was 6% lower with direct drilled crops compared to those crops established following ploughing. Over all 11 project trials, the difference in establishment was a 20% reduction when using direct drilling techniques after grass. Data from all trials (including those trials where a different drill was used for the plough/top work and direct drilling) showed there was no difference in establishment between crops established following top working or ploughing. Only in two trials of the 11 conducted over the three years did crop establishment of the direct drill fall below 75% of that achieved following ploughing and conventional establishment. The worst case was a direct drilled spring wheat crop established in September, on a relatively heavy soil (Wakanui Silt loam), which was 40% of the crop establishment achieved following the plough. In this case the addition of 30 kg N/ha made no improvement over the direct drilled plot without nitrogen applied.

**So why were less plants established in the direct drilled plots?**

Seed soil contact is frequently cited as a reason for the failure of plants to emerge with direct drilled crops; however in this experimentation, lack of seed soil contact did not appear to be a reason for poor establishment. The inverted T opener of the Cross Slot (a combination of disc and tine) obtained good seed soil contact. Instead in trials where crop establishment was reduced, coleoptiles appeared to be trapped and unable to push through to the surface following the germination of the seed. Two possible comments on this outcome are firstly, that the soil surface is badly compacted by livestock or harvest traffic (if used for grass seed), preventing emergence of the coleoptile. The second explanation is that the seed vigour of the seed stock being used is below optimum, a known contributory factor to these observations. In this case however, it was not possible to conclude which explanation was responsible for the poor establishment.

**Could deeper sub tillage prior to direct drilling be used to improve crop emergence and final yield?**

In three trials (spring 2008, 2009, 2010) conducted on a Marton clay loam in the Rangitikei (following 54 months of grass and two winter grass periods of six months) there was no establishment or yield benefit from using a James Aerator working at a depth of 25 - 30 cm prior to a Cross Slot direct drill. In the three trials, on the same block of land, the grass sward had been grazed with sheep in the period prior to returning to spring barley.

**Influence of primary tillage practice on crop establishment (%) following the grass phase in the rotation where the same drill (Cross Slot) was utilised for all methods of establishment - mean of four trials (2008 - 2010)**

- Direct: 94 (82 - 108)
- Top work: 107 (93 - 124)
- Plough: 100

% Crop establishment relative to plough set at 100% (4 sites)

**Influence of primary tillage practice on crop establishment (%) following the grass phase in the rotation where different drills were utilised for establishment - mean of all 11 project trials (2008 - 2010) for four of these trials the same drill was used - see above**

- Direct: 80 (39 - 108)
- Top work: 99 (81 - 124)
- Plough: 100

% Crop establishment relative to plough set at 100% (11 sites)

**Influence of deep ripping on crop establishment and yield following the grass phase prior to direct drilling spring barley - Rangitikei (site 2) Marton Clay loam - mean of three trials (2008 - 2010)**

<table>
<thead>
<tr>
<th>% Yield</th>
<th>% Crop establishment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plough</td>
<td>99</td>
</tr>
<tr>
<td>Top Work</td>
<td>100</td>
</tr>
<tr>
<td>Direct</td>
<td>100</td>
</tr>
<tr>
<td>Direct + Deep rip (25-30 cm)</td>
<td>89</td>
</tr>
</tbody>
</table>

Crop establishment | 19
Key point guidelines

- Direct drilled crops established after grass show lower crop establishment relative to those established using top work tillage or the plough. Looking at typical figures for crop establishment, the reduction in establishment for direct drilling was 10 - 20%.

- In four trials, where the same drill (Cross Slot) was used for all establishment techniques, the reduction due to direct drilling was less (6%).

- If using disc based drill coulters (openers) this reduction in establishment can often be attributed to insufficient seed soil contact, caused by the reduced ability of the opener to cut through the sward and/or forcing previous crop residue down the drill slit (referred to as “hair pinning”).

- In other cases where the inverted T was used, seed found a good environment to germinate but some seedlings did not emerge. To avoid this make sure seed vigour is good and that the soil surface is not unduly compacted.

- Small increases to seeding rate (10 - 15%) can help overcome many of these issues with direct drilling. However if seed rate increases beyond 15% are needed, then other issues such as ground conditions preventing establishment, seed vigour or the drill need to be addressed in order to improve establishment.

- Reduced costs of establishment with direct drilling have to be considered against extra costs for seed rate increases and greater need for agrichemical input for pest control (e.g. slug control).

- Providing soil constraints or disease are not a feature of the seedbed, a reduction in plant populations of 10 - 15% with direct drilled cereal crops can usually be compensated for naturally, provided plant populations don’t fall below 100 plants/m². This is particularly the case with autumn sown cereal crops where there is more time to compensate with increased tillering.

- The poorest crop establishment with direct drilled crops has been associated with spring sown cereals on heavier soils.

- Ensure that seed used for direct drilling is high vigour and that the soil surface under the grass sward is not badly surface compacted; deeper cultivation may be needed before sowing to remedy compaction.

- There was no evidence that deeper sub-tillage (25 - 30 cm) prior to direct drilling into grass that had been sheep grazed, resulted in improved crop emergence or final crop yield.
Enterprise and rotation
For the last 10 years, Eric has followed the grass phase in the rotation with specialist seed crops and pulses on his 490ha, irrigated arable farm at Wakanui, Ashburton. The grass phase is based on tall and red fescues which are grown for five years as well as perennial ryegrass which is generally grown for 15-30 months. An increase in demand for specialist seeds, particularly vegetable seeds has expanded the selection of crops available to establish following the grass phase, whilst at the same time providing good opportunities to control volunteer grass weeds. The range of vegetable seed crops Eric grows includes, spinach, radish, corn salad, red beet, pak choi along with other break crops such as phacelia. Eric also grows maize and pulses (peas and beans).

Moving from grass to crop
Eric's method of moving from the grass phase to crop depends on the grass species being grown, crop type to follow and soil type. When coming out of a five year fescue crop, normally Eric would always plough for the following crop due to the stronger nature of the turf residue, however this season he tried non inversion and was fairly pleased with the results. Non inversion cultivation techniques are used in all other situations following grass. Eric comments that he will on occasions plough to overcome grass weed problems in any part of the rotation. When considering soil type, Eric has 100ha of Rakaia stony silt loam and 390ha of Wakanui silt or clay loams. The light soil requires less top work cultivation to achieve optimum seed beds than the heavier silt and clay loams which require more attention.

When coming out of grass in the autumn using non inversion top working techniques, Eric applies two applications of glyphosate. Three days after the first glyphosate application, the grass is cut for silage. Then, following the subsequent grass re growth and grass weed strike, the second glyphosate application is made. Increasing the period after glyphosate application leads to a better break down of ryegrass turf which, when using non-inversion techniques is more desirable when going into wheat. Grass weeds in autumn sown crops are harder to control and there is less time to manage these weeds due to time constraints with weather. With the conventional system employing the plough following fescue one glyphosate application is sufficient in the autumn. In the spring only one glyphosate application is used irrespective of cultivation method.

Eric prefers to have all of his wheat crops in the ground in the autumn to chase higher yields at the end of the season. Non-inversion top working cultivation techniques give Eric the quick turnaround in the autumn when wet weather is often a restriction on his heavier land later in the autumn. Eric changed from the traditional method of ploughing in the spring for breaking the grass phase, to using non-inversion methods in both the autumn and spring. Eric's non inversion cultivation is achieved using a Simba SL (pictured) with two rows of discs, two rows of tynes and consolidating rings. When coming out of grass in the autumn using non inversion techniques, Eric applies two applications of one glyphosate application is used irrespective of cultivation method.

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On farm decisions based around specialist seed crops
Over the last 10 years, Eric and Maxine Watson have increasingly grown specialist seed crops in response to fluctuating market demands for commodity grains. The relatively broad range of possible break crops available to them has provided good opportunities to control grass weeds after the grass phase of the rotation. Over the same time period Eric has gradually adopted less intensive cultivation practices in order to improve soil quality. This has had huge benefits in terms of establishment turnaround times but has come with the niggle re-emergence of grass weeds.

Enterprise: Rangitata Holdings
Property size: 490ha
Livestock: Winter grazing of sheep
Irrigation: 97% irrigated
Soil type: Wakanui clay and silt loams (heavy) with 100ha Rakaia stony silt loam (light)
Grass phase length: Ryegrass (12 - 24 months)
Tall/red Fescue (48 - 60 months)
Establishment method: Non-inversion (top working) and conventional
Time to move from grass to crop (mins/ha):
Year 1995 - 65 mins/ha
Year 2011 - 50 mins/ha

On farm decisions based around specialist seed crops
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removes the Simba Aqueel Roller and Press and pulls a Combi Dan cultivator and Cambridge roller instead.

Following long term fescue crops, Eric uses the conventional cultivation based on the plough to break the grass due to the presence of strong turfs from the previous crop. The Challenger pulls an 8 furrow 1 way Kverneland Plough followed by the press and then 1 or 2 passes with the Combi Dan or a Maxi Till depending on soil conditions. Eric drills most of his crops with an 8m Horsch Pronto DC with 54 coulters with the exception of maize, radish, pak choi, spinach and red beet seed crops for which he employs a precision drill for establishment.

Changes in cultivation practice over the last 10 years

Eric's decision to change from a fully conventional cultivation system to a non-inversion system has been beneficial to his business. The non-inversion system has helped him to run the business with one less labour unit and tractor. But the most important change Eric appreciates is the improved soil conditions. The soil has become easier to work and requires less cultivation to get it ready for drilling. Eric has also noticed that his vegetable seed crops are yielding better under the non-inversion system. An important benefit to the improved soil quality has been the increased trafficability of the paddocks. Following wet weather, Eric has been able to drive over the paddocks sooner under the non-inversion system than the plough system.
3.5 Crop growth

Crop biomass accumulation

At the long term intensively monitored sites results showed that different tillage methods influenced the rate at which crops accumulated biomass during the growing season. In trials conducted in the absence of applied nitrogen fertiliser, direct drilling was slower to accumulate biomass in the early phase of growth (first 8 weeks of growth with spring sown crops and first 20 weeks with autumn sown cereals) compared to plough and top work treatments. However by harvest any differences in biomass were negligible or were higher in the direct drill plots.

![Graph](image)

Influence of establishment method on biomass accumulation (t/ha DM) in radish (all treatments received basal fertiliser of 150 kg Crop Master 15, 100 kg Kieserite, 50 kg Potassium Chloride and Borate 20 kg/ha) at seeding placed opposite the seed - Methven 2008.

So could the lower biomass and N uptake in direct drilled crops be offset by N fertiliser application?

In the short term trials that weren’t as intensively monitored, nitrogen fertiliser added to direct drilled crops at sowing increased early biomass, in some cases up to the level recorded in the plough and top work treatments. In four wheat trials, following 12 - 18 months of grass, applying nitrogen at seeding increased crop biomass in the early stages of growth, however where wheat was established in the autumn this increase in early growth did not increase final crop yield. Where wheat was established in the spring the increase in early biomass with 30 kg ha/N at seeding did result in a small yield increase. This result is at odds with the more intensively monitored trials where N supply was found not to be the cause of early biomass lag in direct drilled crops. More work is being undertaken to look at the reasons for biomass lag. It should be emphasised that the grass phases in the more intensively monitored trials was longer (30 - 54 months), which may have resulted in greater N supply, than those trials following 12 - 18 month grass phases. In two trials applying N at sowing increased early crop growth which increased crop competition and reduced the volunteer grass weed competition. This reduced weed pressure did not result in an increase in yield but was evident as reduced weed biomass at early stem elongation and in post-harvest stubble assessments.

So why did early growth lag behind with the direct drilled crops?

The reduced establishment in direct drilled crops explains some of the reduced biomass accumulation in the early growth stages. However the biomass lag with direct drilled crops was also observed in trials where there were no differences in the initial plant stand, suggesting that other factors influence early biomass (growth). Soil nitrogen available to the crop was consistent across all establishment treatments (see section 3.6) but lower soil temperatures in direct drilled blocks may have contributed to this early difference. In a FAR funded extension to the Grass 2 Crop project this hypothesis was tested in the 2011 season with the use of soil temperature probes. Results were inconclusive.

Reduced early growth in direct drilled crops also resulted in lower nitrogen uptake, since there was less biomass, but a similar nitrogen concentration in the crop to other establishment methods.
Influence of nitrogen (30 kg N/ha) applied at sowing on the yield of direct drilled wheat sown in autumn (a) (3 trials - mean of Temuka in 2009 and 2010 and Wakanui in 2009) and in spring (b) (1 trial in 2010 at Wakanui)

Crop structure and predisposition to lodging
In wheat or barley reductions in early growth are usually reflected in reduced tillering. Lower tiller numbers can be linked with slightly lower plant population; however tiller reductions can occur even when plant populations in direct drilled crops are the same as those established with the plough and top work treatments. In autumn wheat crops, following short grass phases (18 months or less), the lower tiller number can result in lower head number but rarely leads to a yield reduction. In spring sown cereals the reduction in tillering following short grass phases can reduce yield since there is less time to compensate for lower tiller numbers. Project trials have shown that applying N fertiliser at sowing increases biomass, increases tiller numbers and compensates in terms of yield, with direct drilled spring sowing. Exceptions occur when establishment is significantly lower.

Following longer grass phases, where livestock and or clover have increased fertility, project results showed that, particularly in wet seasons, the increased early growth associated with ploughing and top working can be a disadvantage, since it leads to a greater lodging risk in both cereals and broad leaf crops (e.g. radish). In 2008 spring barley and radish were established after 54 and 30 month grass phases respectively, direct drilled crops had significantly less lodging than crops established using the plough or top work.
Influence of tillage on plant establishment, head number and final yield of wheat - Wakanui 2009 14 month grass phase (low N fertility)

i) Winter sown wheat cv Conquest

<table>
<thead>
<tr>
<th>Tmt</th>
<th>Cultivation Drill</th>
<th>Drill</th>
<th>Padk. N</th>
<th>Nil N</th>
<th>Padk. N</th>
<th>Nil N</th>
<th>Padk. N</th>
<th>Nil N</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Plough</td>
<td>Simba</td>
<td>Horsch Pronto</td>
<td>166</td>
<td>680</td>
<td>466</td>
<td>556</td>
<td>348</td>
</tr>
<tr>
<td>2</td>
<td>Top work</td>
<td>Simba</td>
<td>Horsch Pronto</td>
<td>135</td>
<td>711</td>
<td>479</td>
<td>586</td>
<td>294</td>
</tr>
<tr>
<td>3</td>
<td>Direct drill</td>
<td>Cross Slot</td>
<td></td>
<td>127</td>
<td>561</td>
<td>350</td>
<td>518</td>
<td>324</td>
</tr>
<tr>
<td>4</td>
<td>Direct drill</td>
<td>Cross Slot</td>
<td>+ Fert</td>
<td>136</td>
<td>609</td>
<td>-</td>
<td>534</td>
<td>-</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td>141</td>
<td>640</td>
<td>432</td>
<td>548</td>
<td>322</td>
</tr>
<tr>
<td>LSD</td>
<td></td>
<td></td>
<td></td>
<td>22</td>
<td>119</td>
<td>93</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

NB. Padk. N - (Paddock N applied 368 kg N/ha)

Influence of tillage on plant establishment, head number and final yield of spring barley - Rangitikei 2008 following 54 month grass phase (high N fertility)

ii) Spring sown barley cv Putney

<table>
<thead>
<tr>
<th>Tmt</th>
<th>Cultivation Drill</th>
<th>Drill</th>
<th>Padk. N</th>
<th>Nil N</th>
<th>Padk. N</th>
<th>Nil N</th>
<th>Padk. N</th>
<th>Nil N</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Plough</td>
<td>Cross Slot</td>
<td></td>
<td>256</td>
<td>1372</td>
<td>1296</td>
<td>941</td>
<td>872</td>
</tr>
<tr>
<td>2</td>
<td>Top work</td>
<td>Cross Slot</td>
<td></td>
<td>238</td>
<td>1374</td>
<td>1190</td>
<td>986</td>
<td>909</td>
</tr>
<tr>
<td>3</td>
<td>Direct drill</td>
<td>Cross Slot</td>
<td></td>
<td>208</td>
<td>1365</td>
<td>1174</td>
<td>988</td>
<td>844</td>
</tr>
<tr>
<td>4</td>
<td>Deep rip f.b. direct drill</td>
<td>Cross Slot</td>
<td></td>
<td>208</td>
<td>1316</td>
<td>1366</td>
<td>1009</td>
<td>895</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td>228</td>
<td>1357</td>
<td>1257</td>
<td>981</td>
<td>880</td>
</tr>
<tr>
<td>LSD</td>
<td></td>
<td></td>
<td></td>
<td>30</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

NB. Padk. N - (Paddock N applied approximately 90 kg N/ha), f.b. = followed by

At the Rangitikei site, following 54 months of grass, higher fertility resulted in high tiller numbers (1350 tillers/m² where nitrogen was applied and 1250 with no nitrogen applied); there was no significant yield response to applied nitrogen. Under these circumstances the biomass lag experienced with direct drilled crops was advantageous since it led to significant delays in the onset of lodging.
Key point guidelines

- Reductions in early growth (biomass) associated with direct drilled cereals following grass is linked to lower tiller numbers/m² relative to crops established with the plough or top worked.

- Lower plant numbers where establishment was inferior with direct drilled establishment resulted in reduced early growth (nitrogen supply and lower soil temperatures).

- N fertiliser applied at sowing will boost tiller number and head numbers in direct drilled crops. N had less impact on yield with autumn sown wheat than in spring sown wheat.

- N fertiliser at sowing appears to be much more important where crops are direct drilled in the spring, particularly after short grass phases with less inherent fertility.

- Where grass phases are longer and result in higher nitrogen fertility (e.g. Rangitikei in 2008), plants produce higher tiller numbers. In these cases reductions in early tiller number and crop growth can be advantageous as it can lessen lodging risk.

- In these fertile situations growers using more intensive cultivation methods should review plant population targets and fertiliser strategies. Reducing plant population targets by 10 - 20% and reducing the proportion of N used at sowing reduces early biomass development and subsequent lodging risk but did not reduce yield.
CASE STUDY: RAB AND MAGGIE MCDOWELL
MCDOWELL MAYFIELD FARM LTD, MAYFIELD, MID CANTERBURY

Enterprise and rotation
The light to medium Lismore stony silt loam is hard on equipment but breaks down to a seedbed relatively easily. Rab and Maggie’s farm is also at a surprisingly high altitude considering they are on the Canterbury plains (261 m above sea level). Altitude at Mayfield shortens the growing season compared to lower on the plains. Despite this Rab and Maggie aim to maximise the amount of dry matter they can produce in a season.

McDowell Mayfield Farm Ltd is run as a double cropping arable farm with cereals for grain in spring/summer followed by stubble feeds in autumn/winter for lamb finishing and dairy support (cows and service bulls). The farm is currently dryland and Rab is in the process of converting 270ha to be irrigated with three centre pivots covering 90ha each. Rab follows a rotation of three cereals interspaced with greenfeed crops then a perennial/annual ryegrass pasture for 18 - 24 months. The forage break crops in the rotation are important not only to feed livestock but also for weed management. Break crops give a good opportunity to control grass weed volunteers.

The key to Rab’s farm management is the fast turnaround between crops. Barley crops, net of harvest costs, have similar value to feed crops for winter lambs or cows at 25 - 30 cents/kg/DM. Rab therefore aims to maximise the total dry matter he can produce in one season rather than one crop at the expense of the other. “We are basically dry matter farmers”.

Moving from grass to crop
Rab follows the grass phase with one of three crops. Wheat usually follows 24 months of ryegrass pasture on the heavier land and is substituted for barley where the land is lighter. Rab will also establish Kale in the spring after an 18 month grass phase.

Double Cropping for dry matter production at Mayfield
Rab and Maggie McDowell own ‘McDowell Mayfield Farm Ltd’, a 550ha mixed cropping farm at Mayfield. With cooler temperatures courtesy of higher altitudes at the back of the Canterbury Plains, Rab makes the point that cropping sequences are based on a quick turnaround time when it comes to establishment. This is particularly important bearing in mind the double cropping nature of the farming system, where crops for livestock are established immediately after harvest.

Enterprise: Mixed cropping enterprise (cereals) and dairy support forage crops (Green feed oats, pasture, kale)
Property size: 550ha
Livestock: Lamb finishing and dairy support
Irrigation: Being introduced to 270ha
Soil type: Lismore stony silt loam
Grass phase length: 18 - 36 months
Establishment method: Non-inversion (top working)
Time to move from grass to crop (mins/ha):
  Autumn Wheat - 40 mins/ha
  Kale - 35 mins/ha

Most crops are heavy rolled after emergence to bury rocks but Rab doesn’t roll the seedbed in the autumn since turf residues on the surface provide seedling shelter and protection against frost lift and wind blow.

Grass weeds are the biggest problem with autumn sown cereal crops in Rab’s rotation. When wheat follows grass Rab usually controls grass weeds with terbuthylazine (Gardoprim) applied...
early post emergence (of the crop), and then approximately five weeks later with metribuzin (Metriphar). Establishing brassica (Kale) after grass allows a better opportunity to tackle grass weeds and to keep them down to manageable levels.

**Changes in cultivation practice over the last 10 years**

Before moving to top working the soil, Rab found that ploughing lead to poor control of grass grub in autumn sown wheat, since grub were ploughed down below the insecticides applied at sowing. Grass grub would then move up through the profile damaging crops later in the winter. Top working the soil has kept grass grub near the surface, making them more susceptible to cultivation and insecticide application.

In the future Rab and Maggie hope that the introduction of irrigation will not only lead to higher cereal yields, but enable them to spend less on cultivation overall, since the later harvest of irrigated crops will allow less opportunity but also less need for double cropping to sustain overall production levels.
3.6 Soil nitrogen (N) availability and phosphorus (P) distribution

Influence of tillage on soil mineral N availability

Monitoring of soil nitrogen availability through the season showed large quantities of nitrogen were mineralised following the grass phase, but there was no significant difference in mineral N available to the crop due to tillage practice. It is uncertain whether this result is a feature of the variable nature of N distribution due to previous animal urine and manure patches, or lack of effect of cultivation on N availability; however variation in mineral N levels was high in the samples taken. Mineral N analysis did not indicate that N was limited in direct drilled crops, even though there was less N uptake in the plant during the early stages of growth. In the trials where N application at sowing has overcome the lag in early biomass with direct drilled crops, the grass phase in the rotation has been only 12 - 18 months. In the more intensively monitored trials where biomass lag has appeared to be an advantage, the grass phase has been 30 - 54 months. The higher mineral N reserves associated with longer grass phases used for grazing may mean that compensating for the lack of early growth, with nitrogen applied at sowing (in direct drill situations), is less important than it would be following short grass rotation phases.

Rangitikei site - Spring Barley

Influence of different tillage treatments on soil mineral N (kg/ha) in plots receiving no nitrogen (Note: 54 month grass phase prior to year one results and six month winter grazed grass phase (which was fertilised) prior to year two and three of the spring barley - see section 2.0 for details of winter grass fertiliser levels).

<table>
<thead>
<tr>
<th>Tillage practice</th>
<th>Soil mineral N (kg/ha), 0 - 0.6 m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Year 1, Barley Sowing 4 WAS1</td>
</tr>
<tr>
<td>Plough</td>
<td>205</td>
</tr>
<tr>
<td>Top work</td>
<td>173</td>
</tr>
<tr>
<td>Direct drill</td>
<td>149</td>
</tr>
<tr>
<td>P value</td>
<td>ns</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>64</td>
</tr>
<tr>
<td></td>
<td>Year 2, Barley Sowing 5 WAS</td>
</tr>
<tr>
<td>Plough</td>
<td>56</td>
</tr>
<tr>
<td>Top work</td>
<td>63</td>
</tr>
<tr>
<td>Direct drill</td>
<td>41</td>
</tr>
<tr>
<td>P value</td>
<td>ns</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>43.8</td>
</tr>
<tr>
<td></td>
<td>Year 3, Barley Sowing 5 WAS</td>
</tr>
<tr>
<td>Plough</td>
<td>82</td>
</tr>
<tr>
<td>Top work</td>
<td>93</td>
</tr>
<tr>
<td>Direct drill</td>
<td>75</td>
</tr>
<tr>
<td>P value</td>
<td>ns</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>17.03</td>
</tr>
</tbody>
</table>

WAS1 = weeks after sowing

Methven site - radish, first wheat and cocksfoot

Influence of different tillage treatments on soil mineral N (kg/ha) in plots receiving the same fertiliser level during year one (Note: 30 month grass phase for seed with periodic grazing) radish - year 1, Wheat - Year 2 in plots receiving no nitrogen and cocksfoot in year 3 in plots receiving no nitrogen.

<table>
<thead>
<tr>
<th>Tillage practice</th>
<th>Soil mineral N (kg/ha), 0 - 0.6 m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Year 1, Radish Baseline 8 WAS</td>
</tr>
<tr>
<td>Plough</td>
<td>124</td>
</tr>
<tr>
<td>Top work</td>
<td>131</td>
</tr>
<tr>
<td>Direct drill</td>
<td>131</td>
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</tr>
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<td>LSD (0.05)</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Year 2, Autumn Wheat Sowing 7 WAS</td>
</tr>
<tr>
<td>Plough</td>
<td>101</td>
</tr>
<tr>
<td>Top work</td>
<td>104</td>
</tr>
<tr>
<td>Direct drill</td>
<td>99</td>
</tr>
<tr>
<td>P value</td>
<td>ns</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>57.3</td>
</tr>
<tr>
<td></td>
<td>Year 3, Cocksfoot Sowing 33 WAS</td>
</tr>
<tr>
<td>Plough</td>
<td>43</td>
</tr>
<tr>
<td>Top work</td>
<td>45</td>
</tr>
<tr>
<td>Direct drill</td>
<td>43</td>
</tr>
<tr>
<td>P value</td>
<td>ns</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>4.8</td>
</tr>
</tbody>
</table>
**Calculating N balances using soil and crop N uptake results**

Soil mineral N and crop N uptake can be used to construct a N balance which illustrates the fate of N throughout the growing season. Please note that in the project there was insufficient resource to measure leaching from the system or N losses to the atmosphere. In addition, the monitoring was conducted in crops with no fertiliser N applied (with the exception of year one at Methven in radish). The following charts illustrate the fate of N between soil and the plant (through the season) in the nil nitrogen plots for sites at Rangitikei (Spring Barley), Methven (radish, winter wheat and cocksfoot) and Waikato (forage maize).

### Waikato site - Maize

**Influence of conventional tillage and strip tillage treatment on soil mineral N (kg/ha) in plots receiving no nitrogen fertiliser in all three years following a grass phase of 30 years in pasture.**

<table>
<thead>
<tr>
<th>Tillage practice</th>
<th>Soil mineral N (kg/ha), 0 - 0.6 m</th>
<th>4 WAS</th>
<th>8 WAS</th>
<th>12 WAS</th>
<th>Harvest (18 WAS)</th>
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<tbody>
<tr>
<td><strong>Year 1, Maize</strong></td>
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<tr>
<td>Strip tillage</td>
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<td>155</td>
<td>60</td>
<td>49</td>
<td>59</td>
</tr>
<tr>
<td>P value</td>
<td>0.03</td>
<td>0.08</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>38</td>
<td>48</td>
<td>19</td>
<td>8</td>
<td>21</td>
</tr>
<tr>
<td><strong>Year 2, Maize</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conventional tillage</td>
<td>32</td>
<td>60</td>
<td>61</td>
<td>47</td>
<td>24</td>
</tr>
<tr>
<td>Strip tillage</td>
<td>63</td>
<td>64</td>
<td>65</td>
<td>40</td>
<td>22</td>
</tr>
<tr>
<td>P value</td>
<td>0.011</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>7.3</td>
<td>7.8</td>
<td>17.4</td>
<td>12.1</td>
<td>4.9</td>
</tr>
<tr>
<td><strong>Year 3, Maize</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conventional tillage</td>
<td>43</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>37</td>
</tr>
<tr>
<td>Strip tillage</td>
<td>45</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>34</td>
</tr>
<tr>
<td>P value</td>
<td>ns</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>ns</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>5.2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>14.2</td>
</tr>
</tbody>
</table>

WAS¹ = weeks after sowing

---

¹WAS = weeks after sowing
Rangitikei (Spring barley - no fertiliser applied)

Year 1: 2008 following 54 months’ grass phase (grazed and fertilised) - for each sampling date: 1st bar - plough, 2nd bar - top work and 3rd bar - direct) I = LSD

The results from Rangitikei illustrated that large amounts of nitrogen were mineralised during the course of all seasons. The calculated amounts across treatments (since there was no significant difference due to tillage practice) were 120, 150, 100 kg/N/ha (for the three years of the project 2008 - 2010 respectively). These figures were calculated by subtracting the initial soil mineral N from the harvest soil mineral N plus N in the crop at harvest.

Rangitikei (Spring barley - no fertiliser applied)

Year 2: 2009 following 6 months’ winter grass phase (grazed and fertilised)

Rangitikei (Spring barley - no fertiliser applied)

Year 3: 2010 following 6 months’ winter grass phase (grazed and fertilised)
Methven (radish - fertiliser applied)

Year 1: 2008 following 30 months' grass phase (fertilised seed crop grazed in winter - for each sampling date: (1st bar - plough, 2nd bar - top work and 3rd bar - direct) I = LSD

Methven (Winter wheat)

Year 2: 2009 following radish (no fertiliser)

Methven (Cocksfoot)

Year 3: 2010 following winter wheat (fertiliser applied)
The results from Methven illustrated that **moderate amounts of nitrogen were mineralised during the course of the season.** The calculated N mineralised was 40, 120, 90 kg/N/ha (for the three years of the project 2008 - 2010 respectively). The high rainfall over winter in the growing seasons of years two (wheat) and three (cokfoot) may have resulted in nitrogen that was mineralised in the trial being lost through leaching.

Total N mineralisation was affected by tillage treatment at the Waikato site. There was more N mineralised under the conventional tillage (CT) than the strip tillage (ST) in the first two years of the trial (differences were not significant in year 3). Total net amounts of N mineralised were: year 1, CT = 288, ST = 232 kg/N/ha; year 2, CT = 125, ST = 100 kg/N/ha; year 3, CT = 175, ST 150 kg/N/ha. The greater amount of N mineralised under the CT treatment may be due to this treatment being subjected to more intensive cultivation as a whole than the ST treatment (where only 20% of the plot area is cultivated to form the strip).

**Phosphate distribution**

Phosphorus (P) varied with tillage treatment and depth through the topsoil profile. Treatments that were ploughed typically had lower P concentrations in the soil surface profile (0 - 0.25 m), but higher concentrations in the 0.15 - 0.25 m depth, reflecting the inversion effect of ploughing. By comparison, P tended to be concentrated near the soil surface under direct drilling. This was measured at both Rangitikei and Methven.

The results of this study demonstrate that tillage practice can have a strong influence on the vertical stratification of less mobile nutrients such as phosphorus. Continuous direct drilling can result in a marked stratification of immobile nutrients near the soil surface, where as ploughing tends to redistribute nutrients more evenly throughout the soil profile. It is unclear how these differences in nutrient distribution influence crop performance when arable crops are established following grass pasture. Soil testing for fertiliser recommendations under pasture is typically analysed for 0 - 7.5 cm while for cropping soils the depth is typically 0 - 15 cm. This may impact the P fertiliser recommendations.

---

**Key point guidelines**

- Large quantities of nitrogen are mineralised from the grass phase of the rotation, even after relatively short grass phases (e.g. 30 months Methven Grass 2 Crop trial).
- N balance calculations showed large amounts of N can be mineralised in the first three years following pasture phases (Site 1. 30+ years pasture; 290, 125, 175 kg N/ha for each year respectively. Site 2. 4.5 years pasture; 120, 150, 100 kg N/ha. Site 3. 2.5 years pasture; 40, 120, 90 kg N/ha). These results varied across sites due to differences in crop growth durations, soil type, climate, etc.
- The lack of early crop growth when direct drilling could not be related to lower mineral N availability in the long term trials conducted at Rangitikei and Methven, but could be in the Waikato. However spatial variation in soil mineral N due to animal urine/manure deposition makes it difficult to prove differences due to tillage.
- One year project trials established that biomass lag could be remedied or partially remedied by applying nitrogen at sowing. Therefore where dry matter (forage crop) as opposed to a grain is the focus, nitrogen at sowing can be very beneficial, to promote early growth when direct drilling is used.
- Where a spring sown grain or seed crop follow a short grass phase (18 months) fertility will usually be lower and crops benefit from N at sowing.

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Soil Olsen phosphorus (P) content (µg/ml) by depth for the Grass 2 Crop trials following the third main crop established post the grass phase (measured in autumn 2011) for the Methven site (end of year 3); LSD
CASE STUDY: 
DAVE AND ROS GRANT 
THE GLEBE, METHVEN, MID CANTERBURY

Enterprise: Cropping enterprise (cereals, herbage and vegetable seeds) with over winter grazing

Property size: 410ha and 55ha leased

Livestock: Over winter grazing dairy cows and sheep (traded before the spring)

Soil type: Mayfield stony silt loam (light - medium)

Grass phase length: 12 - 60 months depending on grass species

Establishment method: Non-inversion (top working), direct drilling and rotational ploughing

Grass to Crop (historical and current practice):
Year 1990 - plough/roll/surface work/ drill
Year 2011 - direct drill or 1 pass subsoil/direct drill

Flexibility in the rotation leads to a need to be flexible in cultivation approach

Dave and Ros Grant own ‘The Glebe’ a 410ha arable farm just south of Methven. Twenty years ago, they changed from conventional to a minimum tillage cultivation system due to extremely friable and erosion prone soils. Flexibility in their cultivation system is important and Dave did not want his flexibility in rotation impaired by a single establishment system. For this reason Dave operates using both minimum tillage and direct drilling for establishing his crops and believes that more emphasis on direct drilling could constrain his rotation.

Enterprise and rotation

On the light to medium Mayfield stony silt loam, Dave grows a variety of grasses; browntop, cocksfoot, fescues and perennial ryegrass. The perennial ryegrass is a twelve month crop and the other grasses are grown for 4 - 5 years. Dave’s rotation generally goes from grass into wheat, brassica or clover. Wheat is sown following brassica or clover. Following wheat, the paddock will go back into grass.

Moving from grass to crop

After harvest, the grass paddocks are shut up, irrigated and fertilised before being cut for silage. This silage cut depends on how good the conditions are for autumn growth. After the silage is baled and removed, the paddock is watered and fertilised again. Dave grazes all of the grass crops over the winter with dairy cows and stock that are then traded before the spring. The ability to utilise grass crops all year round and graze crops over the winter brings in good revenue and can only be done due to the forgiving soils which don’t pug very easily in wet winters.

The grass is broken in August or September following one application of glyphosate. Turf grass and browntop crops may be broken earlier in order to plant clover in the autumn. When drilling brassica after ryegrass, crops are drilled directly into the grass residues, or if following cows that have created damage to the soil structure, sub tilling will be considered prior to sowing. When following ryegrass with wheat, the paddock is ploughed, rolled, surface worked and drilled (depending on soil nitrogen levels in the following wheat, Dave applies an early spring nitrogen application to give the wheat crop a growth boost). Ploughing is used when wheat follows grass in order to combat grass weeds which tend to be more difficult to control in the following wheat. When using minimum tillage and direct drilling as the establishment method for the broad leaf crops, such as brassica or clover, an extra grass weed spray is needed in the spray programme.

Dave’s crop cultivation and establishment machinery consists of a 200hp MX200 Case, a 4 furrow Vogel Newt reversible plough, an 8 metre Cambridge roller and a grubber (tynes and harrow). He also has a 5 metre Allen direct drill.

Changes in cultivation practice and establishment method

The purchase of a Great Plains drill with double disc and press wheel assembly in the late 80s was a major breakthrough in establishment technique at the Glebe. It allowed Dave to handle the trash and clover runners which had previously forced him to plough everything. Four years ago the Grants purchased an Allen drill which is based on similar disc based openers. This drill has fluted discs in front of a row of packers followed by a double disc press wheel assembly which has allowed him to increase the amount of direct drilling he can do effectively. Approximately 20% of the farm is now direct drilled, 65% is minimum tilled and 15% is ploughed. Dave has found he gets better seed emergence and more stable seed beds under a minimum tillage scenario compared to ploughing on his soils. However with less cultivation, issues with slugs and grass weeds has increased. Hairgrass infestation has increased over the last 5 - 10 years and Dave is being forced to return to ploughing in parts of the rotation where hairgrass is building up. With the introduction of new agrichemical herbicides he may stop ploughing altogether but
for the mean time Dave is using rotational ploughing once every 5 - 6 years as a way to control the hairgrass. Dave hopes to do more direct drilling in the future when going from grass to crop but only if he has robust chemical support. He is mindful about the negatives of becoming overly reliant on a small range of chemicals and potentially building up resistance in grass weeds, therefore maintains flexibility in the farms establishment approach. Dave recalls that as research results to date show, there has been little, if any yield differences between plough, minimum tillage and direct drill, but significant differences in weed populations; this is a major issue for many farmers when going from grass to crop.

a) Allen 4 m triple disc drill

b) Grass seed crops are grazed over winter with cattle at Dave & Ros Grant’s property at Methven
3.7 Weed control in crops following grass

Grass weed populations
The downside of reduced tillage techniques in Europe and Australia has been the buildup of grass weeds in the rotation. For a number of reasons NZ growers are not currently faced with the same problem as growers on other continents. It is important that management techniques that will preserve the benefits of reduced tillage without building up grass weeds are developed and used. Grass 2 Crop project trials illustrate that a greater number of ryegrass volunteers germinate in reduced tillage (non-inversion) systems compared to ploughing following grass.

Influence of cultivation method on ryegrass volunteers (plants/m²) germinating in the following crop after a ryegrass seed crop grown for seed - FAR Grass 2 Crop Trials 2007 - 2010 (mean of 5 Canterbury trials)

<table>
<thead>
<tr>
<th>Establishment Method</th>
<th>Volunteer Ryegrass - plants/m² (mean of 5 trials)</th>
<th>Range - plants/m² (mean of 5 trials)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full inversion tillage (ploughing)</td>
<td>9</td>
<td>(3 - 19)</td>
</tr>
<tr>
<td>Top work tillage - non inversion</td>
<td>103</td>
<td>(19 - 187)</td>
</tr>
<tr>
<td>(including min till)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct drilling</td>
<td>181</td>
<td>(45 - 318)</td>
</tr>
</tbody>
</table>

Managing grass weeds is a "numbers game". The more grass weeds that germinate in your crop the greater the control required from the in-crop herbicides in order to prevent the number of seeds returning to the weed seed bank of the paddock. A benchmark of 95% control or above for in-field grass weed control has historically been set as a standard for making sure that the weed seed bank does not build up in the soil. Using the data presented above, achieving 95% control would leave less than one plant/m² with the plough, five plants/m² with top work and nine plants/m² with direct drilling.

i) Limitations of chemical (herbicide) grass weed control
Provided the agrichemical manufacturers continue to provide newer, more effective herbicide active ingredients for grass weed control it could be argued that growers need not worry about grass weeds. However, there are a number of reasons why a dependence on herbicides alone would be short sighted.

Reduced tillage encouraging more grass weeds – as already outlined reduced tillage systems result in greater grass weed numbers germinating in the crop, so the 95% control benchmark still leaves more grass weeds to set seed.

Herbicide resistance - Widespread herbicide resistant grass weeds are not currently a problem in New Zealand. In Australia, growers are having to contend with an increasing number of ryegrass, windmill grass and barnyard grass populations that are glyphosate resistant as well as managing widespread resistance to a wide range of graminicides such as trifluralin, sulfonyl ureas, fops and dims.

Lack of new modes of action - As the effectiveness of grass weed herbicide groups decline due to herbicide resistance, it increases the pressure on agrichemical manufacturers to produce new modes of action to control resistant weeds. Up to now there has been a steady increase in new herbicide products but there are few breakthroughs in terms of new modes of action. The arable market in New Zealand is small relative to others in the world with therefore proportionally greater investment in registration costs.

Legislation - There is increasing pressure on European growers to use integrated pest and integrated weed management (IPM & IWM) approaches as the number of agrichemical options is reduced. This is encouraging growers to examine non-chemical forms of weed, pest and disease management. How effective are cultural/non-chemical forms of grass weed control and which ones could New Zealand growers use to help make reduced tillage systems more sustainable into the future?

ii) How effective are non-chemical (cultural) weed control techniques?
As already demonstrated; ploughing can markedly reduce grass weed numbers germinating in the crop. If ploughing was the sole form of weed control how would it compare with other forms of non-chemical weed control and agrichemical herbicides? At the 2010 Australasian Weeds Conference, Dr Stephen Moss from Rothamsted Research Centre, UK presented a summary of trial results in which he compared different techniques in terms of their effectiveness.
Non-chemical control of blackgrass in the UK over a number of different trial comparisons - Dr. Stephen Moss 17th Australasian Weeds Conference 2010

<table>
<thead>
<tr>
<th>Method of Weed Control (No. of trial comparisons)</th>
<th>% Control achieved Mean</th>
<th>% Control achieved Range (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ploughing (25)</td>
<td>67</td>
<td>-20 to +96</td>
</tr>
<tr>
<td>Delayed sowing (16)</td>
<td>37</td>
<td>-64 to +82</td>
</tr>
<tr>
<td>Higher seed rate (15)</td>
<td>30</td>
<td>+8 to +53</td>
</tr>
<tr>
<td>Competitive cultivars (27)</td>
<td>27</td>
<td>+9 to +36</td>
</tr>
<tr>
<td>Spring cropping (2)</td>
<td>80</td>
<td>*</td>
</tr>
<tr>
<td>Fallowing (1)</td>
<td>70</td>
<td>*</td>
</tr>
</tbody>
</table>

* Insufficient data

Other non-chemical forms of grass weed control that can have an important role in New Zealand arable rotations are stubble burning and whole crop silage. FAR trials, conducted as part of the non-inversion agronomy project (2003 - 2008), illustrated that burning cereal crop residues had a key role to play in grass weed control in the following crop.

Influence of burning on grass weed control in barley (assessed as plants/m², 15 March and 29 April) and seed head numbers/m² (5 January) - mean of three trials. (F. Dastghieb & N. Poole 2005 - NZ Plant Protection Proceedings 2010)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>15 March¹ 2005</th>
<th>29 April¹ 2005</th>
<th>5 January² 2006</th>
<th>15 March¹ 2005</th>
<th>29 April¹ 2005</th>
<th>5 January² 2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burning</td>
<td>4.5</td>
<td>12.0</td>
<td>0.1</td>
<td>6.0</td>
<td>45.7</td>
<td>0.1</td>
</tr>
<tr>
<td>Early till</td>
<td>44.8</td>
<td>40.2</td>
<td>0.5</td>
<td>29.8</td>
<td>35.0</td>
<td>0.1</td>
</tr>
<tr>
<td>Late till</td>
<td>36.5</td>
<td>0.0</td>
<td>0.5</td>
<td>148.9</td>
<td>1.7</td>
<td>0.1</td>
</tr>
<tr>
<td>No till</td>
<td>40.4</td>
<td>15.5</td>
<td>9.0</td>
<td>209.5</td>
<td>42.2</td>
<td>7.8</td>
</tr>
<tr>
<td>LSD 0.05</td>
<td>28.96</td>
<td>21.50</td>
<td>3.7</td>
<td>93.56</td>
<td>ns</td>
<td>3.2</td>
</tr>
</tbody>
</table>

¹ Average of eight 0.1 m² quadrats per plot  ² Average of six readings of 1 m² quadrats per plots

Notes: Late till treatment cultivated 11 April 2005.
Notes: All treatments were glyphosate treated after March assessment and April assessment.
All treatments received uniform application of in-crop herbicides following treatments outlined, crop sown 7 June 2005.

Growing whole crop silage/hay is an important method of grass weed control in Australia. The oat hay crop is an excellent means of harvesting ryegrass weeds before they have chance to set seed, the weeds are baled and removed with the forage and there is little, if any weed seed return. For those growers with livestock customers, this important non-chemical weed control measure should not be overlooked. Both burning and whole crop hay and silage would result in grass weed control of over 70% when conducted under optimum conditions.

In conclusion, for the profitability of reduced tillage systems to be maintained, greater emphasis on non-chemical weed control is needed if grass weeds are to be kept in check. Where possible we need to combine this with proven anti-resistance strategies, better spray application and new sensing technologies, which will allow better targeting of herbicides. Targeting could mean using expensive modes of action not usually considered economic for broad acre. This will not only help reduce resistance risk with our existing herbicides but will help combat the inherently higher grass weed numbers encountered in no-till and shallow till systems compared to ploughing.
**Key point guidelines**

- Moving away from the plough to non-inversion establishment techniques increases grass volunteer and grass weed populations following the grass phase in the rotation.

- In contrast, previous grass crop residues sprayed off with glyphosate offer a very effective platform for direct drilling broad leaf crops since the mulch provides good broad leaf weed control.

- Whilst new agrichemical herbicide active ingredients will enable us to keep one step ahead of grass weeds, it is likely that non-chemical weed control options will become increasingly important if we are to effectively manage grass weeds in our farming systems.

- Rotation, in particular spring cropping, is an extremely important method of controlling grass weeds. Other approaches that are likely to be successful are:
  - Strategic stubble burning following cereals
  - Growing forage crops and harvesting before seed set
  - Fallowing (likely to be uneconomic)
  - Rotational ploughing
  - Increased seeding rates
  - More vigorous competitive cultivars
  - Delayed sowing date giving greater chances of grass weed control pre-sowing

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**Broad leaf weed populations**

In FAR trials direct drilling into grass residues (destroyed with glyphosate) provides an excellent platform for broad leaf weed control. As a consequence it is an ideal rotation position for specialist broad leaf seed crops that have few safe herbicide options to use on the crop. The only exceptions tend to be perennial broad leaf weeds, such as thistles or docks, where the grass sward residue offers less protection.

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**Ploughing gives excellent control of grass weeds, including volunteer ryegrass, a result observed in the Methven trial in 2008 when radish was established following 30 months ryegrass**

**a) Plough**

Radish - 33 plants/m²
Ryegrass - 3.4 plants/m²

**b) Top work**

Radish - 41 plants/m²
Ryegrass - 19 plants/m²

**c) Direct**

Radish - 36 plants/m²
Ryegrass - 58 plants/m²
Enterprise: Rosevilla Ltd, 240ha arable and 40ha hill country

Property size: 280ha

Livestock: Breeding flock, winter lamb finishing and beef

Irrigation: Fully irrigated

Soil type: Tai Tapu clay loams (medium - heavy) Motukarara silt and clay loams (medium - heavy)

Grass phase length: 18 months or permanent pasture

Establishment method: Non-inversion (top working) and conventional tillage based on the plough

Double Cropping on a “Tidal Farm”!
The location of Rosevilla, Jim and Jenny Macartney, and their son Tom’s farm, provides plenty of challenges in the winter, mainly because the farm is only 8 metres above sea level. Lake Ellesmere is situated roughly 7kms away and is opened mechanically approximately three times a year to stop the surrounding farmland being flooded. Working with these saturated soils is a constant challenge for Jim and his son Tom.

Enterprise and rotation
Jim and Jenny Macartney and their son Tom run a mixed farming enterprise (seed production, milling wheat with sheep and beef livestock enterprise) just south of Tai Tapu in North Canterbury. The farm comprises of 240ha of flat irrigated land and 40ha of hill country in permanent pasture for grazing breeding stock. The soil is medium to heavy Tai Tapu clay loams or Motukarara silt and clay loams. Currently, Jim and Tom are concentrating on maximising their cropping options with their double cropping system and the number of lambs they can eventually turn over with the current good lamb prices.

Jim grows one year hybrid or annual ryegrass crops prior to returning to the cropping phase in the spring with crops such as peas. Wheat will then be sown in the autumn and followed with either white clover or be sown back into ryegrass. The ryegrass crops are broken in the spring to take advantage of the forage for stock over the winter.

Moving from grass to crop
In the spring, Jim breaks the grass by grazing the stubble hard with sheep followed by a period of time to allow for re-growth. He will then spray one application of glyphosate and after three days the sheep are put back in to graze the re-growth. Jim will then plough with a five furrow Overum reversible plough and follows with one pass of the 3.5 m Maschio powerharrow and press. Treflan is incorporated with the maxi till. Jim then uses a five meter Aquire drill to sow his spring crop which he follows with a roller.

Sowing crops in the spring can be an issue due to the saturated nature of the soils. Each paddock has variable soil types so soil saturation is very inconsistent within the paddock, therefore Jim doesn’t see direct drilling as an option. Working up the paddocks with the plough exposes the wet soils and speeds up drying for sowing. Ploughing also levels out the pugging created by stock and vehicles over the winter. Jim finds that this method of establishment also allows for more flexibility at planting time and good opportunities for pre-emergence weed control.

The grass to crop phase is a key element of the rotation at Rosevilla and integrates very well with operations. Following ryegrass with peas offers many advantages before going into wheat. Maximising the use of the grass forage for livestock fits well with the short duration of the pea crop which is only in the ground for five months; sown in October and harvested in February. The pea crop stubble post-harvest also offers the advantage of a quick turnover (two days using conventional top work cultivation using a Sunflower six meter tine cultivator). The spring crop establishment route is a safer option than drilling autumn wheat straight after ryegrass due to the increased risk of take-all and trouble controlling grass weeds. Jim has also found that he always gets a better crop of peas following ryegrass than in other rotation positions.

Changes in cultivation practice over the last 10 years
Six years ago, Jim used discs to cultivate their ground but found they were doing a number of cultivation passes to achieve the optimal seed bed. Quicker turnaround times were sought and an investment was made in a power harrow which is used to give faster establishment. With their current setup, it takes less time and effort to get good seedbeds in the variable soils of Rosevilla. Jim would consider making a shift towards more direct drilling if he could get the right equipment for his variable soil types at the right price; however he maintains that with the short timeframes enforced with double cropping, and the variable wet soils, cultivation improves turnaround times by enabling a degree of drying.
a) 5 m Aquire drill

b) 6 m Sunflower tine based cultivator
3.8 Soil carbon (C)

Influence on total soil carbon
Carbon (C) content of the soil tends to decline under continuous cropping due to lower inputs from arable crops compared with pasture and the breakdown of soil organic matter (SOM).

The Millennium Tillage Trial (initiated in 2000) managed by Plant & Food Research (PFR) at Lincoln in Canterbury clearly illustrates this decline in soil carbon when moving from the long term pasture to the cropping phase. Whilst the decline in soil carbon was more pronounced in the early years following ploughing (Intensive Tillage) and top working (Minimum Tillage) as opposed to direct drilling (No-Tillage), after seven years the level of soil carbon under all establishment practices had declined to similar levels. The loss of soil carbon over the seven years was greatest in those blocks which had been kept permanently fallow (chemical) for the seven years. Soil carbon levels under permanent pasture remained relatively constant over the seven years.

Individual soil carbon pools
The level of soil carbon in the soil ultimately determines the level of nitrogen that will mineralise from the soil. In 2010 Plant & Food Research and Commonwealth Scientific and Industrial Research Organisation (CSIRO) (funded by FAR & MAF SFR) carried out preliminary studies on a new technique that allows more rapid identification of the four different fractions of soil organic matter: plant residues on and in the soil; particulate organic carbon (small fragments of partially decomposed plant residues); humus (decomposed materials stuck to soil minerals); recalcitrant organic carbon (e.g. pieces of charcoal). Being able to define the quantities of carbon in these different soil carbon pools should allow better modelling of N mineralisation, which at present is one of the more difficult soil processes to model. The technique illustrates that whilst two soils may have the same total carbon content, the ability to mineralise nitrogen could be very different depending on how much carbon is in the humus fraction as opposed to recalcitrant carbon or partially decomposed plant residue.

Influence of tillage practice on carbon content of the soil at the Millennium Tillage Trial in year one and year seven following permanent pasture. Data provided courtesy of Dr. M. Beare, Plant & Food Research, Lincoln.

<table>
<thead>
<tr>
<th>Tillage treatment</th>
<th>Baseline 2001 (1 year cropping)</th>
<th>2007 (7 years cropping)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Content Mg C/ha</td>
<td>Content Mg C/ha</td>
</tr>
<tr>
<td>Intensive till</td>
<td>79.2</td>
<td>74.6</td>
</tr>
<tr>
<td>Minimum till</td>
<td>80.6</td>
<td>77.5</td>
</tr>
<tr>
<td>No till</td>
<td>78.2</td>
<td>77.4</td>
</tr>
<tr>
<td>Permanent Fallow</td>
<td>82.3</td>
<td>77.2</td>
</tr>
<tr>
<td>Permanent Pasture</td>
<td>82.3</td>
<td>81.8</td>
</tr>
<tr>
<td>LSD (5%)</td>
<td>2.8</td>
<td></td>
</tr>
</tbody>
</table>

Importance of defining composition of soil carbon pools on N mineralisation

<table>
<thead>
<tr>
<th>Fraction (C/N ratio)</th>
<th>Amount of N present (kg N/ha)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Residues / articulate (50)</td>
<td></td>
</tr>
<tr>
<td>Soil 1</td>
<td>300</td>
<td>2600</td>
</tr>
<tr>
<td>Soil 2</td>
<td>500</td>
<td>2600</td>
</tr>
<tr>
<td></td>
<td>Humus (10)</td>
<td></td>
</tr>
<tr>
<td>Portion that decomposes</td>
<td>0.3</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Inert/char (50)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Amount of N mineralised (kg N/ha)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Residues /Particulate</td>
<td></td>
</tr>
<tr>
<td>Soil 1</td>
<td>-45</td>
<td>147</td>
</tr>
<tr>
<td>Soil 2</td>
<td>-75</td>
<td>91</td>
</tr>
<tr>
<td></td>
<td>Humus</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inert/char</td>
<td></td>
</tr>
<tr>
<td>Soil 1</td>
<td>0</td>
<td>102</td>
</tr>
<tr>
<td>Soil 2</td>
<td>0</td>
<td>16</td>
</tr>
</tbody>
</table>

Source: Theoretical example courtesy of Dr J. Baldock CSIRO Land & Water (Adelaide)
Though three years is a relatively short period for evaluating total soil carbon, the three long term trials (Waikato, Rangitikei and Methven) that examined soil carbon stocks found no difference in the total soil carbon content due to tillage method when measured following harvest in each year of the trial. The total carbon stocks in the top 35 cm at the three sites were:

<table>
<thead>
<tr>
<th>Site</th>
<th>Soil Carbon (t/ha)</th>
<th>Grass Phase</th>
<th>Soil Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 1. Waikato</td>
<td>74</td>
<td>30 years</td>
<td>Otorohanga silt loam</td>
</tr>
<tr>
<td>Site 2. Rangitikei</td>
<td>120</td>
<td>54 months</td>
<td>Marton clay loam</td>
</tr>
<tr>
<td>Site 3. Methven</td>
<td>116</td>
<td>30 months</td>
<td>Mayfield/Hororata silt loam</td>
</tr>
</tbody>
</table>

a) Site 1. Waikato

b) Site 2. Rangitikei

c) Site 3. Methven

Soil carbon content (t/ha) by depth for the Grass 2 Crop trials following the third main crop established (after 3 years) post the grass phase (measured in autumn 2011) for a) Waikato b) Rangitikei and c) Methven. Bars represent 5% LSD. ST = Strip tillage and CT = Conventional tillage.
Distribution of soil carbon with tillage

There was no difference in overall carbon levels at the end of the project (3 years), however tillage did significantly influence the distribution of the total carbon in the soil. Ploughing had lower concentrations in the soil surface profile, but higher concentrations at 0.15 - 0.25 cm depth, reflecting the inversion effect of ploughing. By comparison direct drilling tended to concentrate soil carbon in the top part of the soil.

a) Site 1. Waikato

b) Site 2. Rangitikei

c) Site 3. Methven

Soil carbon content (%) by depth for the Grass 2 Crop trials following the third main crop established post the grass phase (measured in autumn 2011) for a) Waikato, b) Rangitikei and c) Methven. Bars represent 5% LSD.

N.B. points on the above graphs have been placed at the deepest depth of the soil profile tested. For example, the graph points at 0.075 m depth represent the soil carbon content of the 0 - 0.075 m (0 - 7.5 cm) profile.
Key point guidelines

- Carbon content of the soil tends to decline with continuous cropping due to lower returns of organic matter to the soil under cultivation compared to pasture, and the breakdown of soil organic matter under cultivation.

- In this project, tillage method did not influence overall soil carbon levels when assessed three years into the cropping phase. Tillage did however influence the distribution of soil carbon in the soil profile.

- Where soils are ploughed soil carbon is distributed more evenly through the soil profile (0 - 35 cm), however with direct drilling the soil carbon tends to concentrate nearer the soil surface.

- Current studies are examining whether the effect of tillage on carbon distribution affects other factors such as water holding capacity.

- Research, focussed on rapid methods of identifying and modelling the behaviour of the different soil carbon pools in the soil, may help understand the ability of soil organic matter to mineralise nitrogen from different soil carbon fractions.

- The amount of N mineralised is influenced by the quantity of carbon in each soil carbon pool, soil moisture and temperature. Simple crop calculators work on approximately 3 - 5% of soil organic N mineralised in the course of the season. For example, if the total N in the soil is 1400 kg N/ha then 42 - 70 kg N/ha could be mineralised.

Establishment in wheat following two year grass a) direct drilled with a Cross Slot b) top worked and drilled with a Simba Pronto c) ploughed, top worked and drilled with a Simba Pronto - St Andrews, South Canterbury 2011
Enterprise and rotation

Essendon consists of 200ha of irrigated medium soils and 140ha of light to medium soils. Grazing the pasture and stubbles are 800 breeding ewes and 500 replacement hoggets. Paul and Ann also graze 2000 finishing lambs for fattening. The sheep along with burning and baling offer an ideal way to handle previous crop residues prior to establishing the next crop in their no-till system.

Currently, on the better soils under irrigation, Essendon’s rotation generally goes from: 12 month ryegrass seed crop grazed over winter > peas > carrot seed > autumn wheat > winter green feed oats and then into a spring vegetable seed crop such as radish, before going back into autumn wheat and then to ryegrass. Alternatively, the rotation will insert white clover, in place of green feed, and spring barley prior to going back to ryegrass. The rotation Paul and Ann manage is very flexible to the changing markets.

On the light dryland soils, which get priority for early sowing, the Jarmans grow oats and ryecorn. Paul has found that he can achieve better oat yields on lighter soils compared to wheat. The rotation begins with two years of pasture for grazing which is then broken in the autumn for either two years of milling oats or two years of milling ryecorn.

The change to direct drilling on most of the farm has given Paul many benefits in terms of increased organic matter content in the top 15 cm of the soil, labour savings (one less labour unit for nine months) and reduced tractor hours (60%) which is also reflected in fuel, repairs and maintenance.

Cultivation in the farming system is now restricted to the establishment of higher risk specialist seed crops such as radish or carrot seed where two passes with a tined cultivator is used to create a good seedbed for the precision drill.

Moving from grass to crop

All crops are direct drilled after the grass phase in the rotation. Prior to direct drilling peas, the paddock will receive two applications of glyphosate. The first glyphosate application is made at the higher rates followed by lower doses pre and post sowing (prior to the emergence of the peas). Paddocks are grazed pre and post establishment (any thatch being brought up by the direct drill post drilling being eaten down by the sheep). Slug control from the ewes’ hooves is an additional benefit of this technique. Grass grub infestation is combated with imidacloprid treated seed and insecticide applications when populations are high.

Changes in cultivation practice over the last 10 years

Traditionally (prior to 1999) the rotation consisted of 12 months of ryegrass followed by white clover (which was undersown with the ryegrass), then into winter wheat, winter green feed oats, spring sown barley and then put back into winter green feed oats, to peas and back to ryegrass. With this rotation, the green feed oats offered an opportunity to control wild oats after grazing. However the rotation also had limitations, particularly with regard to the management of the undersown white clover.

With this rotation all cultivation was based on conventional tillage, either top working the soil with a maxi till tined cultivator or ploughing and then adopting secondary cultivation. Time taken to carry out field operations has reduced dramatically since converting to direct drilling.

No-till farming in a traditional mixed farming system combined with the best scientific research

Paul and Ann Jarman own a 340ha mixed cropping, sheep and beef farm ‘Essendon’ at Greendale in Central Canterbury. The fluctuating climate has been a key catalyst in the development of the Jarmans’ current farm management system. In 1999 they began to adopt a no tillage system to try to improve soil properties and to save time and establishment cost. The decision was made to not pull out existing hedge-rows to expand the irrigation system, but to reduce the risk of wind damage by leaving the trees in. Paul also sees this as a way to reduce evapotranspiration in the crops. By 2003, 90% of the farm was fully operated under the no tillage system.
But the change did not come without problems. Due to the slightly higher establishment losses, Paul has increased his sowing rates by 5%. Paul has also had to increase his chemical use, particularly for weed control. Residue problems arose when using Glean so this particular chemical has been dropped from the irrigated sector. Broad leaf weed problems have generally been no different to earlier times under conventional cultivation, furthermore they are often less troublesome due to the minimal soil disturbance between the glyphosate spray and crop emergence. Previous concerns with grass weeds are now well under control since the introduction of the ‘Firebird’ product. For the Jarmans, the benefits of direct drilling outweigh the grass weed problems they more regularly have to deal with.

### Establishment of wheat following pasture at Essendon

<table>
<thead>
<tr>
<th></th>
<th>Conventional cultivation until 1999</th>
<th>Direct Drilling after 2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action</td>
<td>Tractor (hours/ha)</td>
<td>Fuel (litres/ha)</td>
</tr>
<tr>
<td>Grubber x 2 passes</td>
<td>0.3</td>
<td>5.0</td>
</tr>
<tr>
<td>Plough</td>
<td>0.5</td>
<td>7.5</td>
</tr>
<tr>
<td>Maxi till</td>
<td>0.3</td>
<td>5.0</td>
</tr>
<tr>
<td>Drill (3ha/hr)</td>
<td>0.3</td>
<td>5.0</td>
</tr>
</tbody>
</table>

a.) Teague drill that Paul was using to direct drill his cropping programme up to 2010. It has now been replaced with an updated model of the same make. This lower cost drill option has worked well in Paul’s farming system since livestock, burning and baling result in generally lower residue levels.

b) Knifepoint openers on the same drill.
3.9 Economics

An economic analysis was done on the three long term trials (3 years) conducted at Methven, Rangitikei and in the Waikato. The margins for the different establishment systems were calculated using both the farmer and contractor approximate costs. The establishment costs give an approximate guide to establishment costs but growers are urged to work out their own farmer figures where possible.

Cultivation and crop establishment costs ($/ha)

In the following tables, costs ($/ha) are estimated using farmer costs that are set at 70% of the typical contractor costs. Please note that contractor costs vary from region to region and that the following costs are put forward so that growers and advisors can see how margins were derived.

Approximate cost for establishment (farmer costs based on 70% of contractor cost in the analysis) cost $/ha

<table>
<thead>
<tr>
<th>Establishment costing</th>
<th>Contractor ($/ha)</th>
<th>Farmer ($/ha)</th>
<th>Work rate (ha/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ploughing</td>
<td>130</td>
<td>91</td>
<td>1.7</td>
</tr>
<tr>
<td>Top working (4 m)</td>
<td>60</td>
<td>42</td>
<td>3.5</td>
</tr>
<tr>
<td>Drilling (triple disc)</td>
<td>90 - 100</td>
<td>63 - 70</td>
<td>2.7</td>
</tr>
<tr>
<td>Drilling (Cross Slot)</td>
<td>165</td>
<td>116</td>
<td>2.0</td>
</tr>
<tr>
<td>Powerharrow (4 m)</td>
<td>80</td>
<td>56</td>
<td>2.5</td>
</tr>
<tr>
<td>Aeration (subsoil)</td>
<td>80</td>
<td>56</td>
<td>2.5</td>
</tr>
<tr>
<td>Rolling (6 m)</td>
<td>40</td>
<td>28</td>
<td>5.0</td>
</tr>
<tr>
<td>Strip tillage (1 pass)</td>
<td>100</td>
<td>70</td>
<td>2.0 - 3.0</td>
</tr>
</tbody>
</table>

Margins after establishment costs

i) Methven, Canterbury 2009 - 2011 harvest

At Methven a radish seed crop was established after 30 months of ryegrass (seed and over winter forage). The radish was followed by autumn sown wheat and then autumn sown cocksfoot. There were no significant differences in the yield of any of these crops due to establishment method over the three years of the trial. As a consequence it was the cheapest establishment method of direct drilling that created the greatest margins. However, the mean differences in margins between establishment treatments for the three years was small ($66/ha) covering the average difference between the three establishment techniques. In individual years the advantage of direct drilling over the plough varied from $14 - 214/ha.

Margin after establishment cost (year 1 - 3) based on farmer costs ($/ha) - Methven, Canterbury

<table>
<thead>
<tr>
<th>Establishment method</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plough</td>
<td>5233</td>
<td>3167</td>
<td>467</td>
<td>2956</td>
</tr>
<tr>
<td>Top work</td>
<td>5033</td>
<td>3255</td>
<td>531</td>
<td>2940</td>
</tr>
<tr>
<td>Direct</td>
<td>5247</td>
<td>3185</td>
<td>587</td>
<td>3006</td>
</tr>
</tbody>
</table>

ii) Rangitikei 2009 - 2011 harvest

At Rangitikei spring barley was established following 54 months of grass pasture used for a livestock enterprise. Spring sown barley was grown for the next three years with a six month annual ryegrass phase each winter, used for livestock grazing. The four methods of establishment conducted on the same plots over the three years produced identical mean yields of spring barley. In individual years there were some differences in yields, though none of these differences were significant.

a) Yield (t/ha) and b) Margin ($/ha) after establishment costs (year 1 - 3) based on farmer costs ($/ha) - Rangitikei

a) Yield t/ha

<table>
<thead>
<tr>
<th>Establishment method</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plough</td>
<td>6.8</td>
<td>8.3</td>
<td>6.7</td>
<td>7.3</td>
</tr>
<tr>
<td>Top work</td>
<td>7.2</td>
<td>7.9</td>
<td>6.9</td>
<td>7.3</td>
</tr>
<tr>
<td>Direct</td>
<td>7.1</td>
<td>7.9</td>
<td>7.0</td>
<td>7.3</td>
</tr>
<tr>
<td>Aerate + Direct</td>
<td>7.0</td>
<td>8.2</td>
<td>6.8</td>
<td>7.3</td>
</tr>
</tbody>
</table>

b) Margins $/ha

<table>
<thead>
<tr>
<th>Establishment method</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plough</td>
<td>2177</td>
<td>2692</td>
<td>2135</td>
<td>2335</td>
</tr>
<tr>
<td>Top work</td>
<td>2345</td>
<td>2608</td>
<td>2254</td>
<td>2405</td>
</tr>
<tr>
<td>Direct</td>
<td>2377</td>
<td>2653</td>
<td>2334</td>
<td>2455</td>
</tr>
<tr>
<td>Aerate + Direct</td>
<td>2268</td>
<td>2674</td>
<td>2208</td>
<td>2383</td>
</tr>
</tbody>
</table>

The margins after establishment cost (N.B. no other crop costs included) indicated an average advantage to direct drilling over the plough of $120/ha, however in individual years the rank order of treatments were different. In years one and three the margin advantage to direct drilling over ploughing was $200/ha. It differed for year two and it should be emphasised that the yields on which the margins were based were not statistically different. Top working gave margins intermediate to plough and direct drilling, principally because the costs were intermediate between plough and direct.

iii) Waikato 2009 - 2011 harvest

At this site forage maize was established after 30 years of pasture using either conventional tillage based on ploughing, or a strip tillage system based on two passes. Because of the fertility of this site, yields of the forage maize were compared with no fertiliser applied. In all three years there was no significant difference in yield between the conventional and strip tillage approach, however in all three years there was a small advantage to conventional tillage based on the plough. There was a financial benefit from intensive tillage if the yield data (non-significant) from this trial and contractor costs were used.
Influence of tillage method (conventional ploughing versus strip tillage - no fertiliser applied) on forage maize yields (t/ha) and gross value ($/ha) at $0.23/kg dry matter - Waikato 2008 - 2010

<table>
<thead>
<tr>
<th>Method</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Mean</th>
<th>Value $/ha @ $0.23/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intensive tillage</td>
<td>28.1</td>
<td>17.9</td>
<td>19.2</td>
<td>21.7</td>
<td>(4991)</td>
</tr>
<tr>
<td>($340/ha)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strip tillage</td>
<td>26.9</td>
<td>16.4</td>
<td>17.2</td>
<td>20.2</td>
<td>(4646)</td>
</tr>
<tr>
<td>($330/ha)</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

N.B. Strip tillage costs based on two passes of the Soil Warrior prior to precision sowing charged at contractor rates

Key point guidelines

- Taking the two long term (3 year) trials at Methven and Rangitikei there were no significant differences in yield due to establishment technique following grass phases of 30 and 54 months. As a consequence the cheapest forms of establishment (direct drilling) following grass produced the highest $ margins.

- The $ margin advantage of direct drilling over the plough averaged $120/ha over the three years of the trial at Rangitikei, though this average ranged from + $200/ha to - $40/ha. Top working gave margins that lay between ploughing and direct drilling, principally since the costs were intermediate.

- At Methven the $ margin advantage to direct drilling over plough was $66/ha, with plough and top working giving very similar $ margins.

- The Methven and Rangitikei results should give confidence to growers to evaluate direct drilling/no-tillage establishment following grass phase in the rotation.

- Continuing with ploughing on a rotational basis may still help off-set increased grass weed herbicide or insecticide/slug bait costs where the combination of reduced cultivation and rotation results lead to an increase in pest and weed problems.

- Ploughing and top working can lead to greater biomass accumulation in the early stages of growth than direct drilling. This may well be an advantage in forage crops but in grain crops it might not always be the case.

- Soil quality was shown to deteriorate over the three years under ploughing, as compared to direct drilling when measured in terms of soil aggregate size (soil crumb size). This aspect of soil quality, along with others, has been linked directly to productivity in research work carried out by Plant & Food Research.

- Forage maize margins, based on actual yields (no statistical difference), indicated an advantage to conventional plough based tillage over strip tillage, principally because yields of strip tillage were inferior (not significantly). In this example there was only a small reduction ($10/ha) in tillage costs using strip tillage (since two passes of the strip till machine were performed prior to precision sowing).

Starting points: Direct (a) versus plough (b) prior to peas being sown in spring 2010. % yields were direct 98, top work 107 and plough 105 (no significant yield difference).
4. Cropping Sequence Survey results 2011

MAF SFF/FAR/Plant & Food Research
As part of the Grass 2 Crop project it was agreed that FAR would conduct a cropping sequence survey that was almost identical to that conducted in 2006. The survey, which went to all FAR levy payers, was returned by 400 growers from across New Zealand. The survey has been analysed by Plant & Food Research (PFR and the full report (Plant & Food Research Report No. 6057 by PM Fraser and EJ Lawrence-Smith, September 2011) is available from the FAR office at Templeton if any levy payer would like to receive a copy.

The survey gives an opportunity to look at current practices amongst cropping farmers and to determine trends since 2006.

The 2006 survey was a strong signal for starting the Grass 2 Crop project, the 2011 survey will show if there has been any change in establishment practices following the grass/pasture phase in the rotation. There has been an increase of approximately 10% in the number of growers direct drilling following grass/pasture over the last five years and a drop of approximately 10% in the number ploughing following the grass phase. In 2011 52% of those growers surveyed used the plough to break their grass/pasture phase in order to return to cropping, compared to 61% in 2006. Over the last five years the proportion of growers with grass phases longer than three years fell from 16% to 8% whilst those with pasture phases longer than three years fell from 35 to 32%. Shorter grass/pasture phases in the rotation tend to increase the opportunity of using reduced tillage techniques.
There were numerous key points to emerge from the report, however the following summary was taken from Plant & Food Research Report No. 6057

**Key Points**

**Most profitable crop in rotations**
The key economic crop affecting the composition of crop rotations in the North Island was identified as maize, whereas the key economic crop affecting the composition of crop rotations in the South Island was wheat. The exceptions to this were that grass replaced wheat as the key economic crop in the Marlborough/Nelson/Tasman area and barley was reported as of equal importance to wheat in the Otago/Southland region.

Key crops driving the economics of cropping sequences in the North Island of New Zealand.

Key crops driving the economics of cropping sequences in the South Island of New Zealand.
Most frequently grown crops in rotations
The five crops most often grown within rotations across New Zealand were green-feed crops, autumn wheat, spring barley, grass and pasture. The most commonly grown green-feed crop in the North Island was green-feed grass, but in the South Island green-feed brassicas were the most common.

Role of dairy support crops
Around 50% of survey respondents reported that they grew dairy support crops. Across New Zealand the main dairy support crops were grass, kale/brassicas, oats/green-feed oats and maize. In the North Island, maize (40% of responses) and grass (17% of responses) were reported as the most common dairy support crops. In contrast, on the South Island kale/brassicas (26% of responses), grass (24% of responses) and oats/green-feed oats (16% of responses) were the most common of the dairy support crops.

Management problems and problem crops
The most commonly reported management problem in crop rotations was weeds (34% of problem points reported in the grower survey), followed by establishment (17%) and pests (17%). These problems were most often (33% of responses) reported as generic to a wide range of crops. However, some respondents also clearly identified problems with specific crops, particularly wheat (22%), grass (13%) and barley (9%).

Residue management practices
The majority of South Island respondents from the Marlborough/Nelson/Tasman and Otago/Southland regions do not burn wheat straw residues. However, 46% of those in North and Mid Canterbury as well as 59% of those in South Canterbury reported that they burn their wheat straw residues. Overall 31% of North Island survey respondents reported that they burned 10 - 100% of their barley residues, with 25% burning 90 - 100% of the barley residues. Relatively similar trends were reported by South Island survey respondents, with 45% of respondents burning 10 - 100% and 17% burning 90 - 100% of barley straw residues.

Tillage practices
Whereas direct drilling and non-inversion tillage (2 passes) are commonly used to establish arable crops following break crops or cereals, ploughing is still by far the most common form of tillage used to establish arable crops following pasture. Following break crops, the dominant form of tillage varied considerably between North and South Island survey respondents. Direct drilling was by far the preferred form of tillage used in the North Island (44%), but non-inversion (2 passes) tillage was preferred (30%) in the South Island. The main form of tillage used by North Island respondents to establish arable crops (other than maize) following cereals was identified as direct drilling (36%). By contrast, South Island growers most commonly used either non-inversion (2 passes; 22%) tillage or direct drilling (20%). Overall, North Island growers tended to use less intensive forms of tillage than did those in the South Island.
5. Appendices
A number of sections (text, graphs and tables) of this report were taken directly from Plant & Food Research Report No. 5857 by EJ Lawrence-Smith et al (August 2011). In section 4.0 of the booklet some key points have been extracted directly from the 2011 Cropping Sequence Survey report (Plant & Food Research Report No. 6057) by PM Fraser and EJ Lawrence-Smith from Plant & Food Research. If you would like to receive a copy of one or both of these reports please contact the FAR office at Templeton.
6. Acknowledgements
This booklet has been published as the fifth booklet in the FAR Focus series. It is aimed at providing a compilation of trials data taken from the Grass 2 Crop trials run over the last three years. These trials have studied the performance of grain, seed and forage crops (maize) established after the grass phase in the rotation, examining in particular the influence of establishment methods following grass. This FAR Focus edition links with FAR Focus Issue 1 Non-Inversion Agronomy - Guidelines for successful reduced tillage.

Funding
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Plant & Food Research
I would like to acknowledge the huge input to the Grass 2 Crop project by Erin Lawrence-Smith and Paul Johnstone and their respective teams at The New Zealand Institute for Plant & Food Research Limited (Plant & Food Research). Plant & Food Research Report No. 5857 by EJ Lawrence-Smith et al, August 2011, has provided many of the sections for this FAR Focus. In addition I would like to thank Trish Fraser from Plant & Food Research who compiled the results of the MAF SFF/FAR/Plant & Food Research Cropping Sequence Survey sent out in 2011 (Plant & Food Research Report No. 6057 by PM Fraser & EJ Lawrence-Smith, September 2011). The data on changes in soil C stocks at the Millennium Tillage Trial (Lincoln) were provided courtesy of Dr Mike Beare at Plant & Food Research.

I would also like to thank my colleagues Julie-Anne Sime, Diana Mathers and Mike Parker (and my former colleague Andrea Pearson) for all of their hard work on the field trials and on conducting the farmer case studies.

Steering Group Farmers
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Machinery Provision
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Steering Group Chairman
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Author: Nick Poole, Research Co-ordinator, FAR

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• Plant & Food Research Report No. 5857 by EJ Lawrence-Smith et al (August 2011)

• Plant & Food Research Report No. 6057 by PM Fraser and EJ Lawrence Smith (September 2011)

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