

Non-Inversion Agronomy

Guidelines for successful reduced tillage

ISSUE

1



- Starting Points
- Residue Management and Crop Establishment
- Broadcasting Seed
- Soil Health
- Benchmarking Establishment Costings

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Background

Non-inversion agronomy is the husbandry of growing crops without the use of the plough; it covers a number of establishment techniques that go under the “banner” of minimal tillage, no tillage, brodcasting and direct establishment. It is not just a description of establishment techniques, but covers how the subsequent agronomy is influenced by the method of establishment.

This booklet is split into seven sections which address the principal results and key points generated by a jointly funded MAF Sustainable Farming Fund/FAR project on non-inversion agronomy, as well as background data covering responses from the MAF SFF, FAR & Crop & Food Research New Zealand Cropping Sequence Survey conducted in October 2006.

It must be stressed that, due to the diverse nature of equipment on arable farms, this booklet does not conclude that one method of establishment is better than another, but rather seeks to illustrate with the use of project results what measures might be taken in order to improve the reliability of different techniques where cultivation intensity is reduced. In many cases results demonstrate that intensive cultivation only serves to reduce productivity.

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Contents

1. Project Introduction and Objectives	2
• Broadcasting - crop establishment without the use of a seed drill	3
2. Starting Points	4
• Where are we now with cultivation practice? - Results of a MAF Sustainable Farming Fund survey sent out by FAR in October 2006.....	5
• What are the properties of the soil you are dealing with?	6
3. Residue Management and Crop Establishment	8
• Crop establishment following cereal residues.....	9
• Autumn wheat establishment following brassica residues	19
• Crop establishment following grass	21
4. Broadcasting Seed - in which scenarios will it work?	25
• What is broadcasting?	26
• How did broadcasting and direct drilled crops compare to minimal tillage and conventional drilling?	27
5. Soil Health - long term implications of reduced tillage systems	30
• Changes in physical soil properties associated with reduced tillage	31
• Yields and economics associated with longer term trials.....	31
6. Benchmarking Establishment Costings	36
• Benchmarking of New Zealand crops in 2006-2008 (Foundation for Arable Research/Copyright Benchmark Study 2008).....	37
7. Appendix and Acknowledgements	39
• Costing calculations used in the booklet	40

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1. Project Introduction and Objectives

- Broadcasting - crop establishment without the use of a seed drill



Project Introduction and Objectives

Degradation of the quality of New Zealand soils through over cultivation is a serious threat to both the profitability and sustainability of current arable farming systems. Cultivation degrades organic matter content, increases erosion risk and soils become more susceptible to further cultivation damage (compaction, reduced trafficability, soil capping). This project, with funding from the MAF Sustainable Farming Fund (the three year project MAF/SFF 03/150 - 2003-06 and two year extension MAF SFF 06/035 2006-08) and FAR, was set up to demonstrate the most effective and reliable ways to reduce cultivation costs in a range of crop rotation positions using a variety of techniques. The mixture of large block replicated research trials and machinery demonstrations were set up to give growers greater confidence to adopt new techniques, illustrating both the agronomic problems and, where possible, the solutions to achieve the goal of reduced establishment cost.

What is being compared?

In this booklet, Non-Inversion Agronomy - Guidelines for successful reduced tillage techniques, the results of the trials are presented along with the key points that explain the differences created. The booklet does not set out to be a comparison of different establishment equipment, though inevitably there is comparison of different systems, for example tyne versus disc, or a combination of the two. Instead the work sets out different techniques for tackling particular establishment scenarios within the particular crop rotation:

i) Residue management

What were the most successful methods of establishing crops into different crop residues (crop type, quantity and position)? For example what are the issues when establishing crops in chopped cereal straw? Results in section 3 cover crop establishment in the presence of cereal straw, pulse residues and establishing crops following grass.

ii) Minimal tillage and direct establishment

This booklet demonstrates in which scenarios (machinery type and residue) and rotation positions drilling directly into un-cultivated ground was most successful; it also explores different intensities of minimal tillage. Some minimal tillage is better described as non-inversion tillage, since it involves several passes but doesn't incorporate the plough.

iii) Broadcasting or drilling?

A more unusual method of reducing establishment cost is to consider broadcasting seed as opposed to sowing the crop with a drill, this technique was evaluated in several guises in the project and results are presented.

iv) Implications of long term reduced tillage

Data is from two long term trials, the Crop & Food Research/FAR Millennium Trial at Lincoln, where soil changes have been evaluated from a long term pasture phase to a long-term cropping phase, and the long term crop establishment trial at the FAR Arable Site at Chertsey, where soil changes have been examined from a "run down" starting point following a number of years of intensive cropping.

Longer term effects

It is important to point out that the work presented in this booklet is primarily short term, i.e. considers one year harvest results. It is recognised that many growers have evolved reduced tillage systems over many years and have modified their rotations in order to adopt a particular system. In one of the final sections of the booklet results are presented from projects that have been run over a number of years.

Machinery replacement - its role in the adoption of reduced tillage systems

Though most growers have a desire to reduce the level of cultivation in crop establishment, particularly with the recent surge in fuel prices, the ability to change can be constrained by the lack of equipment. As a consequence the rate of adoption may not be as quick as other changes in farming practice, since change will coincide with machinery replacement.

As establishment systems do not change overnight, it is worth suggesting that many farmers approach reduced tillage in an opportunistic way i.e. taking advantage of particular seasons and rotation positions.

Though the overheads and cultivation costs for individual arable enterprises will vary, it is important to have a common means of comparing establishment costs in the trials presented. In order to do this establishment costs presented have been based on calculator tools provided by John Bailey, the mechanisation expert from The Arable Group in the UK, who presented workshops across New Zealand in 2005 and 2006.

New Zealand case studies - benchmarking establishment costs

Lastly the booklet features some benchmarking studies from New Zealand farmers, examining the key statistics surrounding establishment expenditure in wheat and other combinable crops.

Author's definitions for terms used in this booklet

Non-inversion

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

- Top Work

In this booklet the term top work has been reserved for non-inversion establishment with the use of multiple cultivation passes.

- Minimum Tillage

Non-inversion establishment using one to two passes.

No tillage/direct drilling

Crop established in one pass with soil surface disturbance limited to within or from the seed row.

Broadcasting

Crop establishment with the use of a seed drill.

Stubble

Standing straw after the header has combined the paddock.

Straw

The portion of the crop cut during harvesting.

Residue

Residue is the combination of straw and stubble after harvesting.

Chopped straw

Straw chopped during the harvesting process.

2. Starting Points

- Where are we now with cultivation practice?
- What are the properties of the soil you are dealing with?



Where are we now with cultivation practice? - Results from the MAF Sustainable Farming Fund survey (October 2006)

One of the most recent surveys on cultivation practices in New Zealand was carried out in late 2006. The MAF Sustainable Farming Fund, FAR and Crop & Food Research, New Zealand Cropping Rotations Survey was sent out to all New Zealand arable growers. This simple survey revealed that the level of cultivation varies enormously depending on the rotation position that crops are being established in, the equipment growers have available, farmer perceptions and previous experiences.

Crop establishment following cereal residues

The survey revealed that the plough was used less often when establishing a crop following cereals than it was following brassica or pulses. This result is probably linked to the fact that the

survey also revealed that most cereal stubbles are burnt, a practice that removes above ground residue from the system allowing less intensive cultivation to be employed. Whilst it could be argued that this residue is an important source of organic matter, most growers lack the cultivation equipment to deal with this particular residue. In addition, project results have shown that provided burning is used for specific parts of the rotation, particularly crops following wheat, then there are a number of benefits in the following crop where cereal stubbles are burnt (see section 3 - Residue Management and Crop Establishment).

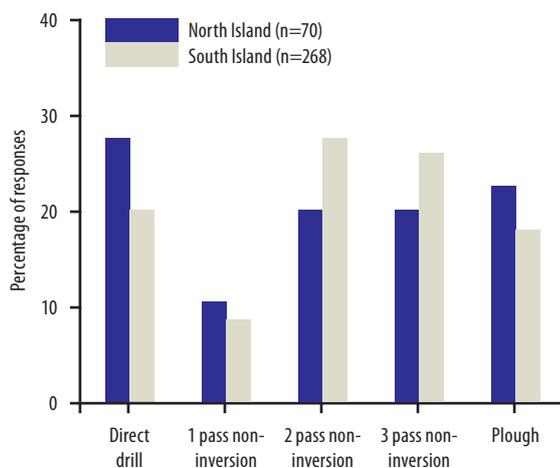
Crop establishment following pulse and brassica residues

Since the carbon to nitrogen ratio is much lower with residues from break crops such as pulses and brassicas, there will be far less nitrogen demand from the soil in order to break them down, unlike cereal residues. In addition pulses will also leave soil residual nitrogen, courtesy of the nitrogen fixing nodules, which can be extremely beneficial for the following crops.

Following pulse and brassica crops it should be easier to adopt more minimal cultivation techniques or direct drilling, since there is less residue, seed soil contact is less likely to be impaired and residue will breakdown far easier. One of the key reasons for greater intensity of cultivation in this rotation position (revealed by the survey) is to improve the evenness of residue distribution from the previous harvest operation and reduce soil compaction from random harvest traffic. In section 3 residue distribution is addressed within this rotation position, however it is worth stating that reliably reducing cultivation starts with the harvest of the previous crop, making sure that residue distribution is even and that harvest traffic is restricted to key areas, so that compaction issues are restricted to specific areas.

Another reasons for the use of the plough following brassica is to even up the soil surface structure if it has been badly damaged with livestock grazing on the residues; this is particularly prevalent in the spring.

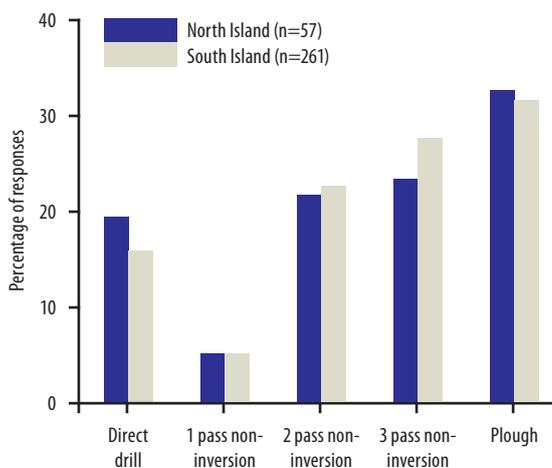
Following cereals



Influence of cereals as a previous crop on subsequent cultivation - % respondents to MAF Sustainable Farming Fund, FAR and Crop & Food Research, New Zealand Cropping Rotations Survey October 2006.

n = no. of responses

Following pulses and brassicas



Influence of pulses and brassicas as a previous crop on subsequent cultivation - % respondents to MAF Sustainable Farming Fund, FAR and Crop & Food Research, New Zealand Cropping Rotations Survey October 2006.



Chopped wheat straw following first wheat

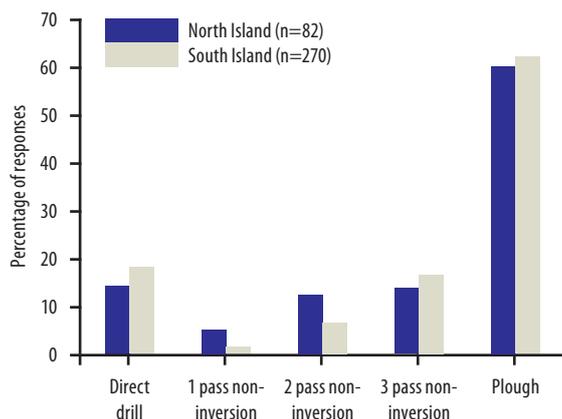


Brassica seed crop residues prior to first wheat

Crop establishment following grass

The plough was most frequently used following grass seed crops and pasture and, whilst this survey did not reveal the age of the grass ley, previous survey information (Land Management Index database - Crop & Food Research) has not revealed a large difference of approach between grass that is less than 18 months old and pasture which is more than 18 months old. Again section 3 looks at the results of four trials set up in this rotation position over the last two seasons.

Following grass/pasture



Influence of grass/pasture as a previous crop on subsequent cultivation - % respondents to MAF Sustainable Farming Fund, FAR and Crop & Food Research, New Zealand Cropping Rotations Survey October 2006.

If you would like to read all of the results in the MAF Sustainable Farming Fund, FAR and Crop & Food Research New Zealand Cropping Rotations Survey then please contact the FAR office for a copy (free to FAR levy payers).

What are the properties of the soil you are dealing with?

The nature of your soil and its characteristics is the essential starting point for any crop establishment programme. Whilst not part of this project it is worth considering some key points concerned with soil type.

How cultivation strategies evolve should first and foremost take account of your soil type, the season and weather conditions at the time of establishment.

Soil Type and weather conditions

Higher clay contents tend to be associated with self structuring properties that mean soils naturally crack and fissure as they get drier, and swell as they get wetter. In general these soils lend themselves to reduced tillage opportunities, particularly in the autumn when summer cropping has helped dry the profile. The naturally weathered tilth on the surface is frequently the best tilth for establishing seeds. Seedbeds produced by deep cultivation may bring wetter clay soil to the surface that dries and is difficult to create a good tilth from.



18 month ryegrass following sheep grazing and glyphosate



** Soil capping - impedes the emergence of germinating seeds*



** Cracking clay soils - self regulate with wet and dry cycles*

** Courtesy of Plant & Food Research Soils Group, Lincoln*

KEY STARTING POINTS:

1. Know your seedbed characteristics, how much clay is in your soil? What is its water holding capacity?
2. Generally autumn seedbeds give a much easier platform from which to reduce cultivation intensity. They are seedbeds, irrespective of soil type, that are moving from a dry phase to a wet phase.
3. In the spring soils are moving from a wet phase to a dry phase, so it is easy to be impatient and damage soil structure by moving on the land too early. In addition

aeration becomes more of a factor on soils with heavy clay contents, a factor that in the autumn may not be an issue due to self regulation - the process by which clays crack and fissure from shrinkage in the summer.

4. Is your soil capping and reducing plant establishment? This could be the result of over working the soil before the drill and impairing plant establishment. Surface residue can be very useful at preventing capping.

Heavier clay soils are more problematic with spring establishment, particularly following heavy rain. In these circumstances there is little air in the soil and greater patience is required if reduced tillage or direct tillage is to be employed. Thus with heavier clay soils there tends to be greater use of intensive cultivation in the spring in order to assist the drying process.

Note that when clay soils are cultivated at depth there is a danger of creating a cultivation pan at either plough or disc depth. Patience and working from the top of the seedbed is important; it is also important that seedbeds are not wet when worked.

It is also important to remember that the roots of crop plants are key components of soil conditioning, particularly in wet seasons at depth. Crop plant roots both aerate and dry soil profiles, which may be less important with silts but can be essential with heavier clays.

KEY POINTS WITH MEDIUM TO HIGH CLAY CONTENT SOILS:

- Where possible use the natural tilth created by weathering (wetting and drying of the top surface) in order to reduce cultivation intensity.
- Make sure that any deeper cultivation on these soils is followed by consolidation in order to avoid clod formation. In some cases this can be considered immediately following cultivation, in other cases some drying is required prior to pressing. Consolidation is a key component for stale seedbed formation (where weeds are encouraged to grow and are controlled prior to the next crop being planted).
- Reduced tillage options should have distinct advantages for autumn sown crops, spring options may be more limited remembering that aeration can be more difficult in the spring if the winter has been very wet.
- If soil is going to be shallowly cultivated in order to encourage a weed strike, consider carrying this out shortly after harvest before the top surface tilth dries out.

Silt based soils are much more easily capped with cultivation, therefore over working can lead to problems with poor establishment and erosion. In these cases surface residue can help bind the top surface of the soil together without creating problems of capping or a hard surface layer.

Where these soils are ploughed, drilling as close behind as possible avoids the need to refresh the seedbed if rain falls in between ploughing and drilling. This can be particularly important in the spring. With these soils it is easy to create too fine a top surface tilth which is both subject to erosion and capping.

KEY POINTS:

- Does your soil naturally cap reducing plant establishment? Is this more prevalent in the spring? Are you cultivating the soil for the seed drill to work or are you doing it for the plant?
- Incorporating residue into the surface or drilling direct can reduce capping and the risk of wind blown erosion.
- Medium quality seedbeds (as opposed to a fine finish) and surface residue can reduce soil capping, improve crop establishment and allow more effective drill operation.

Remember that whether it is a cultivation strategy or crop input strategy, it is imperative to know the characteristics of your soil. Observations on the way soil changes over time through the season dictate opportunities for undertaking less tillage. In some cases weather conditions and paddock operations will dictate a need for cultivation or more intensive cultivation e.g cattle grazing over winter or harvest traffic that has not been controlled under wet conditions. However, the weather can also provide opportunities, for example the natural weathered tilth of a clay soil in the autumn is likely to be better than tilth you achieve through cultivation.



* Onion crop producing cracking in soil with clay content

* Courtesy of Plant & Food Research Soils Group, Lincoln

3. Residue Management and Crop Establishment

- Crop establishment following cereal residues
- Autumn wheat establishment following brassica residues
- Crop establishment following grass



Cultivation for the drill rather than the seed!

Much of the cultivation carried out to the soil is not for the benefit of the crop you are going to grow, but is based on the inability of the seed drill to work in the residues of the previous crop. Over time the introduction of new machinery will reduce the unnecessary cultivation associated with these older seed drills. However, in the meantime many attempts to reduce cultivation have to address the fundamental issue of obtaining uniform seed soil contact in the presence of residues from the previous crop. Whilst there are significant differences in the ability of different seed drills to handle previous crop residues, this project has not centred on numerous drill comparisons; instead it has sought to examine how different residue handling techniques and primary cultivation strategies influence the performance of following crops in different parts of the rotation.

Crop establishment following cereal residues

Cereal residues present the greatest challenge to growers attempting to reduce their cultivation costs. Thus there has been greater emphasis on cultivation with cereal residues within the earlier phases of the project. The following section of the booklet examines:

1. The agronomic effects of burning cereal residues versus chopped cereal straw retention*
2. Different techniques for handling chopped cereal straw residues to minimise difficulties associated with the following crop establishment.

**It should be emphasised that this project has principally focussed on the short term influence of residue retention rather than the long term effects of residue retention. In addition work on burning has only been carried out in one rotation position following wheat. It is not intended that the results presented here are a justification for burning all crop residues, since residue retention holds key benefits in other parts of the rotation.*

Burning versus cereal straw retention

In the following trials chopped cereal straw retention means that all of the residue from the previous wheat crop was chopped and retained. It is not expected that the same results would be generated if only stubbles were retained and straw baled and removed (since there would be far less residue to impede seed soil contact). The effect of retaining chopped wheat straw residue produced different effects on the performance of the following crop depending on which crop was

established. In these experiments, only the short term effect was monitored i.e. the influence on the following crop performance for one year.

Autumn sown wheat on wheat (second wheat establishment)

In three years of the project chopped wheat residues consistently reduced the yield of the

following second wheat crop, compared to burning the residues. Four trials conducted in mid and south Canterbury illustrated that burning wheat residue prior to autumn drilled second wheat increased yield by 1.45 t/ha if the ground was minimally tilled (1-2 passes He-Va Disc Roller) and by 2.0 t/ha if the crop was direct drilled.

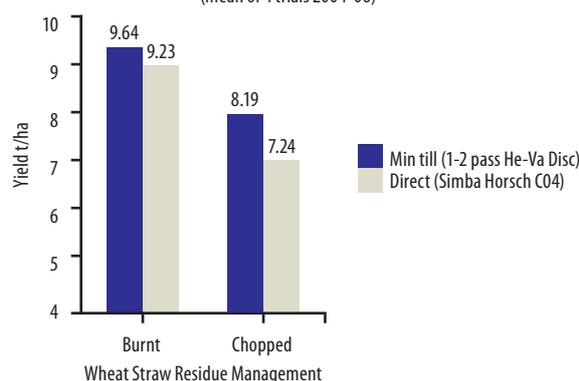


Chopped straw following 1st wheat harvest following direct drilling (Methven 2004)



Burning 1st wheat residues (Methven 2004)

Influence of burning wheat straw residue on the following second wheat yields - (mean of 4 trials 2004-06)



Influence of residue management (burning wheat straw residues compared to chopped and retained) on second wheat yield when comparing minimal tillage (top work - one/two pass) and direct drilling - Methven (Mid Canterbury) 2004 & 2005 & Makikihi (South Canterbury) 2005 & 2006.

Notes: Crops sown with tyne couler (band) drill Simba Horsch 4 m C04 in 2004 and 2005 with KRM triple disc 4 m in 2006. Min till single or double pass carried out with the He-Va disc roller.



Four metre Simba Horsch CO4 band coulters drill sowing direct into chopped wheat straw - autumn sown second wheat



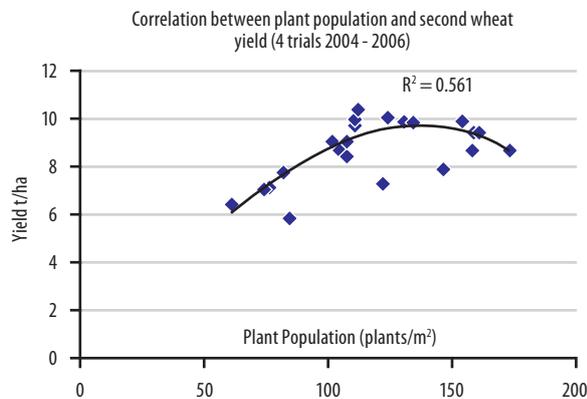
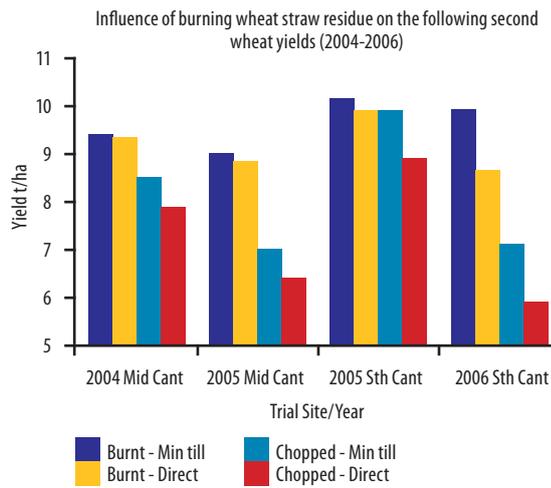
Five metre He-Va disc roller creating a one pass seedbed following chopped wheat stubble Methven 2004

The benefit of burning wheat straw prior to second wheat establishment was very consistent over the four trials in the project, with all trials showing a similar trend.

Why were autumn sown second wheats lower yielding when established into chopped straw?

In some trials plant establishment after chopped straw was lower than where residues had been burnt. In these trials there was a correlation between yield and plant population, indicating that those establishment techniques that resulted in higher plant numbers generally resulted in higher second wheat yields when plant counts were in the range of approximately 70 - 150 plants/m². There appeared to be no yield advantage when the second wheat plant populations were above 120 plants/m² for sowing dates ranging from 20 April to 15 May.

In some cases lower plant establishment in the second wheat was due to "hair pinning" where disc based drills forced the straw into the drill slit preventing seed soil contact. However, in three trials there was an indication that plant population was not the primary reason for reduced crop yields in the presence of chopped straw. In Methven in 2004 and 2005, using a Simba Horsch Tyne based coulters to establish second wheat and a Cross Slot (inverted T - combination of tyne and discs) to establish continuous wheat, similar plant establishment was achieved despite the presence of chopped straw. However, yields were still less than where residues had been burnt. In these cases one factor that did correlate with the lower yield was the root disease take-all *Gaeumannomyces graminis var. tritici*, which was higher in plots that had been established into chopped wheat straw.



Influence of residue management on plant establishment, yield (t/ha) and % whiteheads (take-all) at grain fill - cv Savannah continuous wheat, Methven 2005 blocks direct sown using a Cross Slot drill.

Method of establishment	Plant Establishment (plants/m ²)	Yield t/ha	% Whiteheads during grain fill
Wheat straw chopped and retained	103	9.36	20
Wheat straw burnt	126	10.99	7
LSD		1.13	ns*

*not significant

Influence of residue management on plant establishment, yield (t/ha) and take-all root infection (take-all index) - cv Tanker second wheat, Methven 2004 blocks direct sown using Simba Horsch C04.

Method of establishment	Plant Establishment (plants/m ²)	Yield t/ha	Take-all index rating
Wheat straw chopped - min tilled	158	8.57	24.4 (mean of min till & direct)
Wheat straw chopped - direct sown	146	7.85	---
Wheat straw burnt - min tilled	160	9.38	14.8 (mean of min till & direct)
Wheat straw burnt - direct sown	159	9.36	---
LSD	18	----	P= <0.05%

Pest problems

Another factor associated with poorer yield performance where wheat was sown into chopped first wheat straw was the presence of slugs. The clearest relationship of residue management and establishment system on slug activity came from the work in South Canterbury in 2005. Assessment shortly after sowing revealed much greater slug activity in those blocks that were direct sown with chopped

straw retained. Overall, retaining chopped wheat straw in the trial increased slug damage 5 fold compared to burnt blocks, whilst moving from minimal till to direct sowing doubled the risk. Since broadcasting always involved cultivation to incorporate the seed there was a non significant trend for slug damage to be lower due to the cultivation effects with this form of establishment. These figures were generated just prior to slug pellet application.

Whilst burning is effective against slugs there are other soil pests which are unaffected by this method of residue management. In 2006 slug damage (above ground grazing) was much reduced in severity (4-5% in chopped blocks and no damage in burnt blocks). The damage from a mixed population of grass grub and wireworm was not affected by burning but there were large reductions in damage where land was cultivated.

Influence of residue management and establishment system on % plants showing slug damage at 2 leaf stage (GS 12) - cv Consort Makikihi, South Canterbury 2005.

Establishment Method	Residue Management/ Drill used						Mean (all trts)
	Burnt			Chopped			
	JD 750 A	Simba C04	Broadcast	JD 750 A	Simba C04	Broadcast	
Direct	11	10	3	42	49	36	25
Min till (1 pass)	1	1	3	20	21	23	12
Mean	6	6	3	31	35	30	
LSD	19						

Notes: JD 750 A is a disc based direct drill, the Simba C04 is based on a duet tyne band couler.

Nutrition

The high C:N (carbon:nitrogen) ratio of cereal straw does raise the question of whether the inferior second wheat yields were associated with poor nitrogen status, since in order to breakdown cereal straw residues there is a greater demand for nitrogen from the soil. In this project nutrition was not explored as a reason

for the inferior performance of wheat following chopped straw. However, soil nitrogen tests revealed relatively high soil nitrogen levels (100 kg/ha N or greater - 0-60 cm cores) in the soil in the autumn of planting with grower applied N levels of approximately 200 kg/ha N in most cases, thus N should not have been limiting.

Influence of residue management and establishment system on % plants showing grass grub/wireworm damage at the late tillering stage (GS 26) - cv Consort Makikihi, South Canterbury 2006.

Establishment Method	Residue Management/ Drill used				Mean
	Burnt		Chopped		
	KRM (disc)	Broadcast*	KRM (disc)	Broadcast*	
Direct	24	2.2	29	4.9	15
Min till (1 pass)*	13	1.3	5	5.3	6.2
Mean	19	1.8	17	5.1	

*KRM triple disc drill is a disc based 4 m machine, Broadcasting was carried out with a fertiliser spreader and then cultivated in with the He-Va Disc Roller. Broadcasting seed was carried out following minimum tillage, soil was in effect cultivated twice, once before broadcasting seed and once after.

Know Your Common Slug

***Derocerus reticulatum* (grey field slug)**

Length: Up to 40 mm outstretched

The grey field slug is surface active, but it will move through cracks in the soils. It is a major pest of crops and pastures in many parts of the world. Our data suggests that the grey field slug is the biggest slug pest in cropping systems in the South Island. For the North Island, Milax may be of more concern than *D. reticulatum*, but further data is required to confirm this.



Derocerus reticulatum. Note the reticulated body pattern.

***Derocerus panormitanum* (brown field slug)**

Length: Up to 30 mm outstretched

This slug is generally a brown colour, hence the name brown field slug. It does not have any distinctive markings; however if you disturb (or stroke) this species, it secretes clear mucus. It is also small compared to the grey field slug. It may have a keel, but this is restricted to the tail end of the body, unlike Milax, which has a keel running the full length of the body.



Derocerus panormitanum. Smaller slug, brown in colour with clear mucus.

It is mainly active on the soil surface or under residue, but can burrow to a shallow level. It appears to have a single generation in New Zealand; however it will breed whenever conditions are suitable.

***Milax gagates* (black-keeled slug)**

Length: 40 - 60 mm outstretched

Milax is generally black with a sharp ridge/keel down its back (the whole length of the body). This is more obvious when the slug is disturbed and contracts its body.



Milax gagates. Black in colour. Keel just visible running from mantle (near the head) to end of body.

This species has only been found in maize crops in the North Island from our monitoring. In Australia, it is of particular importance in drier areas, as it has the ability to burrow underground and causes higher levels of damage than the other pest species. Its life cycle is yet to be confirmed in NZ, but is likely to be biennial. Milky coloured eggs are laid in chambers up to 50 mm deep in the soil.

***Arion* sp.**

Length: up to 20 mm outstretched

Arion is identified by the yellow foot and yellow coloured mucus it secretes when disturbed. Its skin will also take on a goose-bump appearance when disturbed. The breathing pore is found at the front of the mantle as opposed to the back for other species.



Arion sp. Note the yellow appearance and breathing pore near front of mantle.

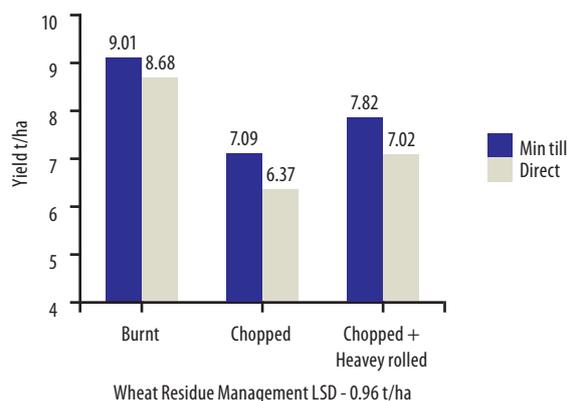
In Australia, *Arion* has an annual life cycle. This also appears to be the case in NZ, even on irrigated sites. Eggs are opaque and are laid in spring. It does not appear to be a serious pest in New Zealand cropping systems and has only been identified on a few monitored properties in the Canterbury region. These sites feature residue retention as a management practice.

Heavy rolling

It has been established that the development of the take-all fungus can be influenced by the consolidation of the seedbed. Cultivating straw into the top soil makes the ground difficult to consolidate so it was postulated that heavy rolling might improve consolidation where straw was chopped and incorporated. Heavy rolling on a Mayfield silt loam immediately post sowing was examined to see if it gave any quantifiable improvements in performance.

The benefits of rolling could not be attributed to one single factor, but heavy rolling after sowing into chopped wheat straw did trend towards increasing yield compared to the unrolled blocks. There was some evidence of slight improvements in establishment and reduced slug damage, none of which were significant. Though take-all was present in the trial there was no evidence that heavy rolling significantly reduced infection.

Influence of wheat residue management on the following second wheat yield (t/ha) - Methven 2005



Notes: The yields were averaged over both drill (Simba Horsch C04) and broadcast treatments and long and short stubble.

KEY POINTS

Autumn sown second and continuous wheat

- In this study burning wheat residues as opposed to chopping and retaining them significantly increased the yield performance of the following second and continuous wheat crops.
- Burning chopped wheat residue increased second wheat yields by 1.45 or 2.0 t/ha (depending on subsequent cultivation) when averaged over four trials conducted from 2004 - 2006.
- Cultivating the seedbed after burning wheat stubble produced 0.41 t/ha advantage over four trials but it was noticeable that this benefit was greatest (1.2 t/ha) in South Canterbury in 2006 when grass grub and wireworm were more problematical in the direct drilled blocks.
- In chopped wheat straw, cultivation (one/two passes with the He-Va Disc Roller) increased yield by 0.95 t/ha averaged over the same four trials.
- Though heavy loadings of chopped wheat straw reduce seed soil contact with disc based establishment systems, low plant populations (below 100 plants/m²) were not the sole explanation of inferior yields associated with chopped wheat straw.
- In 2004 and 2005 chopped straw was associated with greater take-all infections
- Overall tyne based openers and inverted T openers (combination of disc and tyne) were less likely to have plant establishment impaired by chopped straw than disc based coulters where hair pinning of straw was more problematic.
- Burning and cultivating significantly reduced slug damage, though the former had a greater impact.
- Burning had no impact on grass grub and wireworm, though there was some evidence to suggest that chopped straw made cultivation slightly less effective at controlling these pests. In one years data 2007 burning significantly reduced the occurrence of Hessian fly larvae damage.
- Direct sowing into chopped cereal straw generated the greatest problems with all four pest problems.
- When straw is incorporated into the soil obtaining consolidation can be difficult. In one trial, heavy rolling on a Mayfield silt loam increased second wheat yield established in the presence of chopped straw, however the result was not statistically significant.

Autumn sown barley following wheat

In similar trials to those carried out in second wheat, autumn sown barley was evaluated following wheat. The two trials carried out in Lyndhurst, Mid Canterbury in 2004 and 2005, showed that barley yields were not adversely affected by establishment into chopped wheat straw provided the establishment method did not reduce plant populations in comparison to those populations achieved with burning.

These two trials illustrated that establishment of barley into chopped wheat straw was easier

following the milling wheat Aquilla in 2005 than it was following biscuit wheat Claire in 2004 when using the same drill.

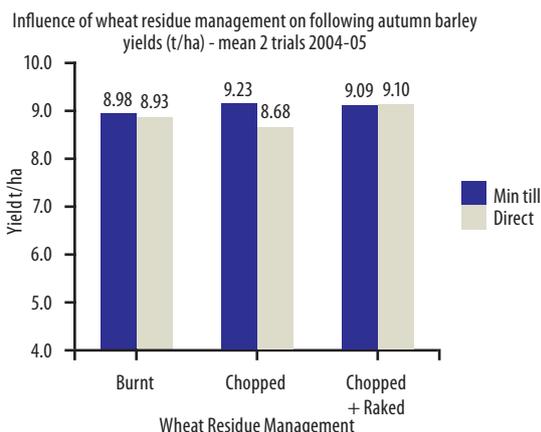
In 2004 sowing into chopped wheat straw with a Great Plains Triple disc drill resulted in significantly lower establishment in comparison to where residues had been burnt. This resulted in lower yields where crops were direct drilled but not where residues were minimally tilled.

In 2005 using the same drill there was no reduction in yield from crops established directly into chopped straw and no difference in plant establishment.

Overall, the results illustrated no inherent disadvantage to establishing autumn sown barley into chopped wheat straw (sown mid May) provided the establishment method ensured good seed to soil contact. This is in contrast to wheat following wheat where, despite ensuring good establishment in chopped straw, yields were still inferior to situations where residues had been burnt. In part this may be connected to the later sowing of barley (relative to second wheat) which allows more time for residue to breakdown prior to sowing or less influence of root diseases such as take-all when barley, as opposed to wheat, follows wheat.

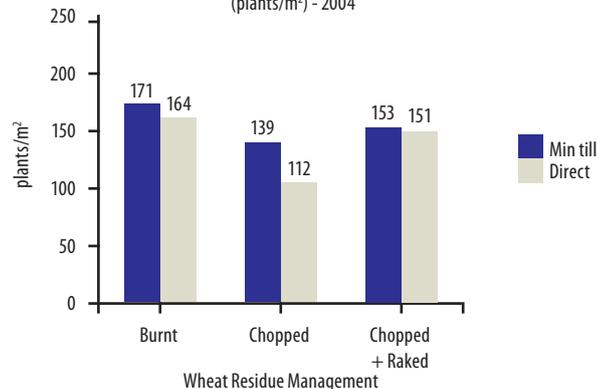


Great Plains Triple disc sowing barley in 2004

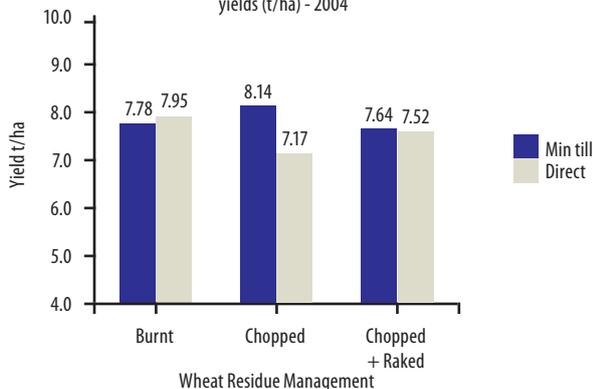


Notes: Crops sown with 3.65 m Great Plains Triple disc in 2004 and 2005. Minimal tillage carried out with the He-Va disc roller (a single pass). In 2004 wheat straw (ex Claire) was raked at right angles to direction of harvest. In 2005 wheat straw (ex Aquilla) raked plots were harrowed post sowing rather than raked prior to cultivation.

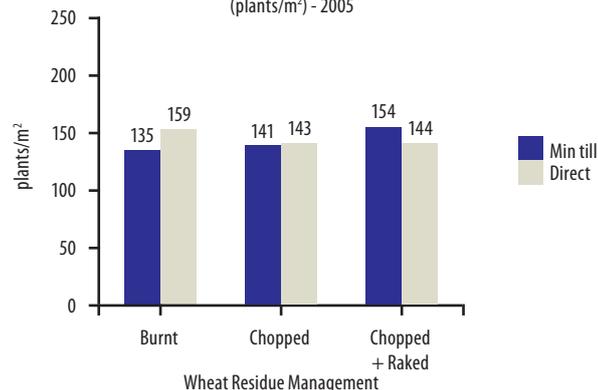
Influence of wheat residue management on following autumn barley establishment (plants/m²) - 2004



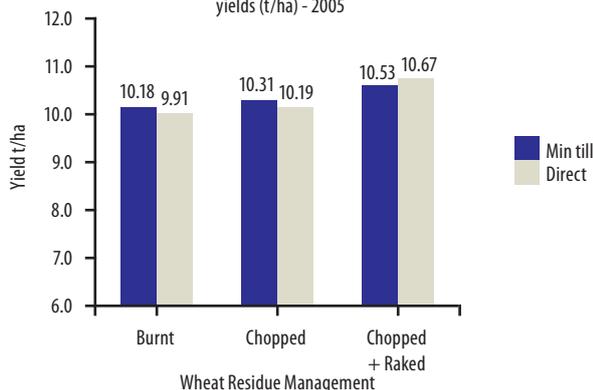
Influence of wheat residue management on following autumn barley yields (t/ha) - 2004



Influence of wheat residue management on following autumn barley establishment (plants/m²) - 2005



Influence of wheat residue management on following autumn barley yields (t/ha) - 2005



How can you ensure better seed soil contact when working direct into chopped straw?

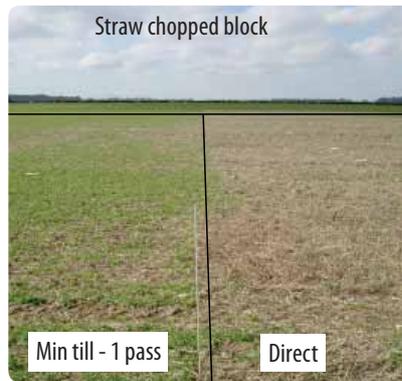
Work with barley emphasised that good seed soil contact is essential in the presence of chopped wheat straw in order to maximise yield. In both trials cultivating chopped straw was a reliable way of improving plant establishment and yields in barley when using a disc based drill.

Short stubble versus long stubble

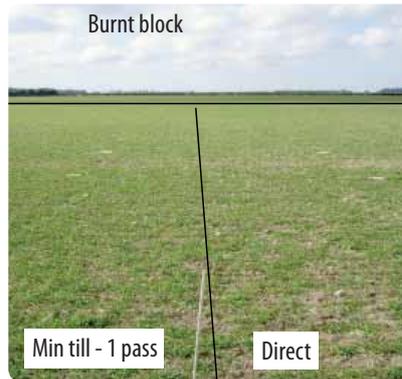
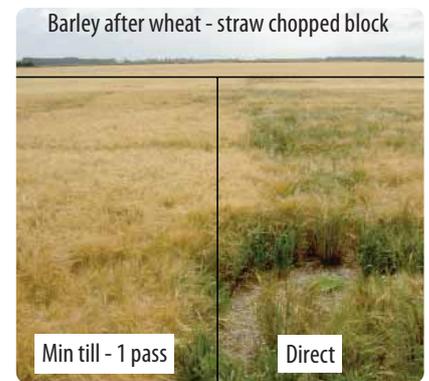
When using a disc based drill direct into chopped straw and stubble there was an indication that stubble length could be an important factor in minimising the extent of hair pinning. Leaving a longer stubble in the previous wheat minimises the reliance on the header to ensure an even spread of residue, since more stubble is left anchored in the paddock in its original position with less in header trails. Longer stubble leaves more uniform residue distribution, but as it is not in contact with soil microbial breakdown rate is slowed. In contrast to short stubble there is a smaller quantity of chopped straw on the soil surface, though the quantity of chaff remains the same irrespective of stubble height.

Where drilling directly into chopped straw there was evidence that spreading header trail residues by racking at right angles prior to sowing in 2004 and harrowing post sowing in 2005 increased the success of direct drilling barley with disc based drills (Great Plains triple disc in this case), but there were no benefits from raking when using a tyne based drill.

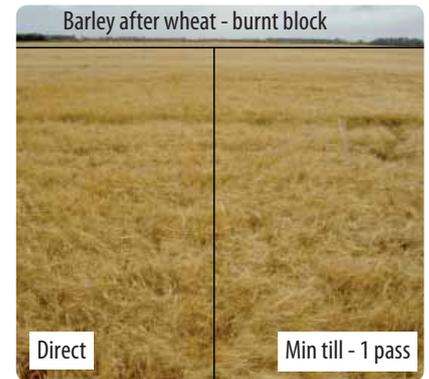
Stubble length created no yield or establishment differences when the soil was cultivated (one pass). However, from a practical standpoint the seedbed was much more uneven where long stubble was retained and then minimally tilled (one pass) as opposed to the same operations following well spread short stubble. In a commercial situation long stubble was more likely to result in the need for a second cultivation to provide a level seedbed.



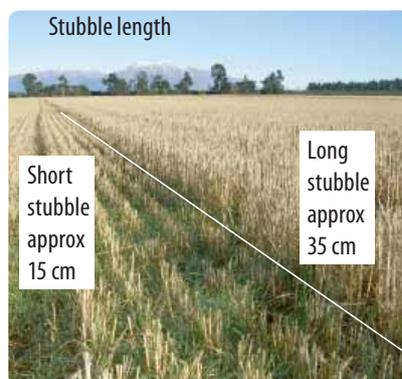
Influence of chopped wheat straw (cv Claire) in 2004 on the establishment of autumn sown barley (cv County) sown 20 May.



Influence of burnt wheat straw (cv Claire) in 2004 on the establishment of autumn sown barley (cv County) sown 20 May.



Long stubble produces less chopped residue on the soil surface which can benefit direct establishment with disc drills but can create uneven seedbeds if cultivated.

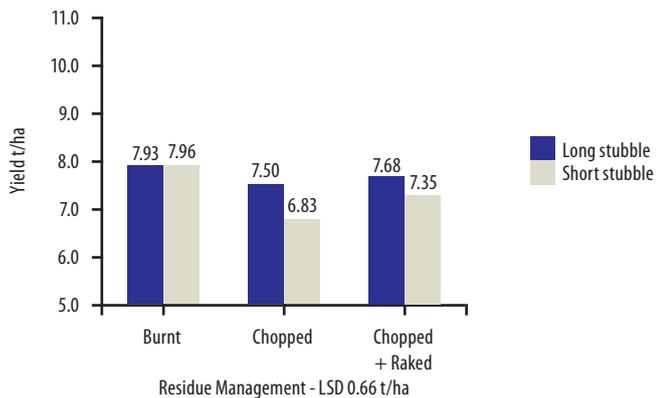


Short stubble



Long stubble

Influence of wheat stubble length and residue management on autumn barley yields (t/ha) when sowing directly into chopped straw using triple disc drill - 2004

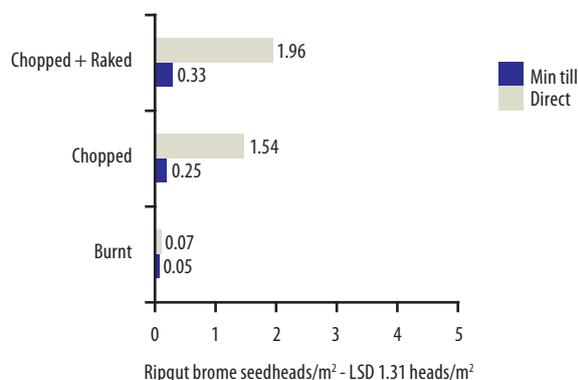


Short stubble 15 cm, long stubble 35 cm. Previous wheat cv Claire yielded 4 t/ha.

Brome control

In 2005 the autumn sown barley trial was subject to a low level of ripgut brome infestation. Despite only low levels of grass weeds the differences due to residue management and establishment system were significant. Where blocks were burnt there was significantly less ripgut brome than where wheat straw had been chopped and retained. In addition, cultivating the soil post burning had no influence on the level of brome infestation. Where chopped straw was retained ripgut brome was noticeable in the crop. A single pass cultivation followed by glyphosate pre-seeding significantly reduced the infestation compared to the direct drilled crop with glyphosate pre-seeding.

Influence of residue management and establishment system on ripgut brome/m² in autumn sown barley - Lyndhurst 2005



KEY POINTS

Autumn sown barley on wheat and autumn sown barley on barley

- Provided good seed soil contact was maintained with the barley following wheat and establishment was not impaired, there were no detrimental effects of the chopped straw on barley yield (as occurred in wheat on wheat).
- It is important to note that establishment into chopped cereal residue was less problematic with tyne and tyne/disc combinations such as the Simba Horsch and the Cross Slot in the project. Similarly it should be noted that where straw is baled, stubble alone would not be expected to cause the same issues for disc based drills.
- If initial establishment was impaired due to the presence of chopped straw then yield effects were similar to those seen with wheat, i.e. chopped straw reduced yield relative to crops following straw burning.
- Unlike wheat a single cultivation pass restored

yields to the level experienced following burning; with wheat on wheat cultivated straw still produced inferior yields to where residues had been burnt.

- Stubble length influenced the success of drilling direct into chopped cereal straw using a disc based drill.
- Leaving longer stubble of wheat minimised the quantity of chopped material on the soil surface and improved yield performance of the following autumn sown barley.
- Raking header residue trails at an angle prior to direct sowing into chopped residues improved resultant yield. The improvement in yield was greater where residues were associated with short stubble.
- A single trial in 2005 showed no disadvantage to chopped straw with autumn sown barley on barley (rather than wheat). However there is a greatly increased risk of stubble borne disease such as net blotch (*Pyrenophora teres f. maculata*) and scald (*Rhynchosporium secalis*) being far more prevalent.

- Where autumn barley follows barley ensure that cultivars are resistant to these two diseases and that pre T1 fungicides are considered if conditions favour these diseases in crop.

Brome control

- Ripgut brome levels were significantly higher where chopped straw had been retained compared to burnt stubbles. Cultivation with chopped straw retained followed by glyphosate significantly reduced infestation relative to direct drilling.
- Overall burning was more effective at providing brome control than top work cultivation.

Note that raking header trails post harvest is a mechanical method of redistributing uneven distribution from the header. With more modern headers fitted with chaff spreaders residues are more evenly distributed.

Autumn sown herbage seed following wheat

This was investigated in 2004 and 2007. In both seasons retained chopped wheat straw had significant impacts on the following perennial ryegrass seed crop establishment and yield compared to burning. Drills used in these trials were the Great Plains triple disc, Simba Horsch C04 and the double disc Sunflower. In both seasons chopped wheat straw reduced plant establishment and the yield of the directly established blocks. In both seasons incorporating the chopped wheat straw shortly after harvest with a disc and press combination, and then glyphosating the stale seedbed prior to drilling, resulted in yields that matched those where residues were burnt. Thus, provided the form of establishment generated good seed soil contact, there was no disadvantage to the presence of chopped wheat straw on subsequent ryegrass seed yields.

Raking

Since header trails rarely result in an even distribution of chopped residues, the trials establishing grass seed also examined whether raking the residues prior to cultivation and establishment resulted in any yield or plant establishment benefits. The results were similar to those with cereals, with some benefits to raking where crops were established with discs, since raking reduced the thickness of residue preventing a proportion of the hair pinning.

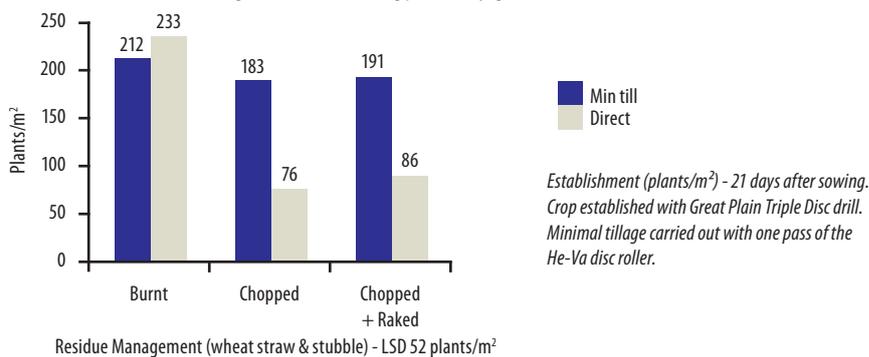
It should be remembered that this raking of residue may not be necessary with all direct drill designs but may be an advantage where disc based systems suffer issues with straw hair pinning. Its greatest benefits were seen when stubbles were cut short and residue distribution from the header had been poor.



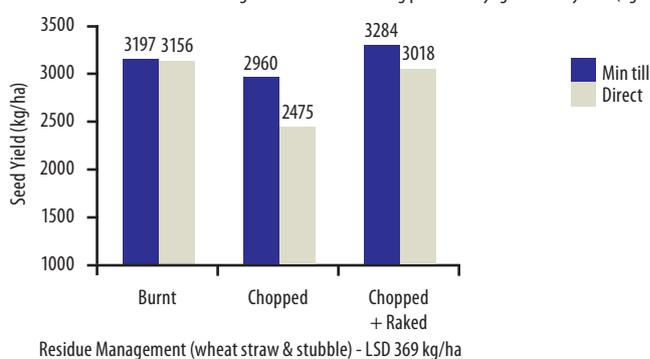
Raking chopped residues as a method of redistribution

The influence of residue management (burning wheat straw residues compared to retaining them) on following herbage seed establishment and yield - (Great Plains triple disc) Ashburton 2004 & (Sunflower double disc & Simba Horsch C04) Methven 2007.

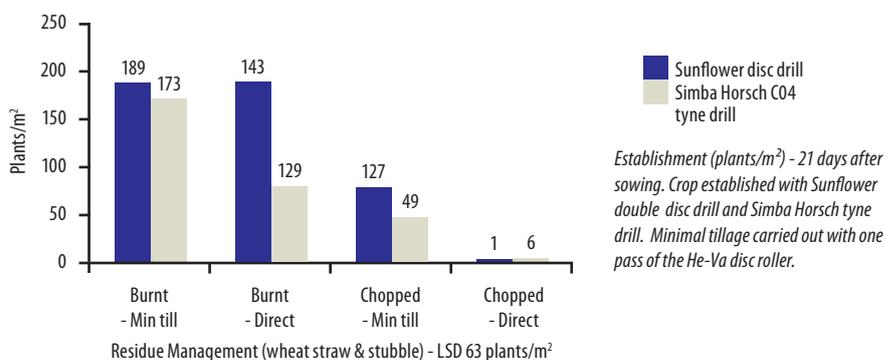
Influence of wheat residue management on the following perennial ryegrass establishment - Ashburton 2004



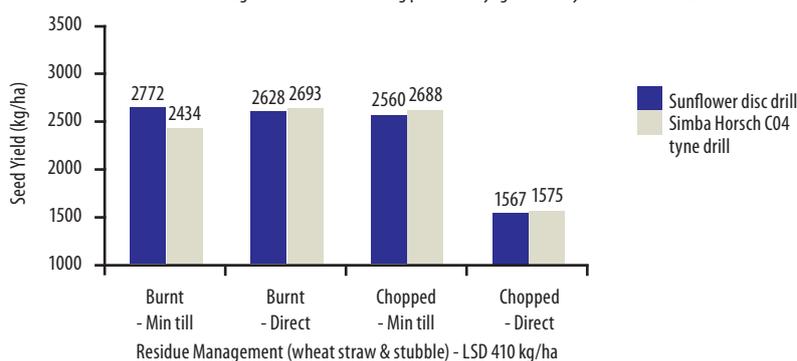
Influence of wheat residue management on the following perennial ryegrass seed yields (kg/ha) - Ashburton 2004



Influence of wheat residue management on the following perennial ryegrass establishment - Methven 2007



Influence of wheat residue management on the following perennial ryegrass seed yields - Methven 2007



Work with cereal stubbles revealed few benefits from raking when using a tyne based drill, but there were small positive effects when working with disc based drills. In brassica residues using a cross slot drill a combination of both tyne and disc there were also small benefits - see next section.

Weed problems with chopped straw

A benefit of burning cereal residues in terms of weed control was volunteer cereal control in ryegrass and grassweed control in cereals. Burning wheat straw residues was observed to significantly reduce the number of wheat volunteers present in the following ryegrass seed crops. As the agrichemicals for wheat control in ryegrass become more restricted this will become a significant issue. Although wheat can be easily separated from harvested ryegrass, there is less opportunity to remove volunteer wheat with glyphosate prior to planting due to earlier sowing and a shorter stale seedbed window.

KEY POINTS

Autumn sown ryegrass following wheat

- Chopped straw prevented seed soil contact with double and triple disc drill, leading to significantly reduced establishment, poorer yields and higher machine dressing losses. The same eradications were also seen with a tyne drill in 2007.
- In these trials the problems with seed soil contact were largely overcome by a single or double pass cultivation (soil type dependent) and yields matched those following burning stubble.
- When residues were burnt there was no advantage to cultivating the seedbed prior to sowing ryegrass in these trials.
- Burning significantly reduced the number of wheat volunteers and grassweeds compared to where wheat residues were chopped and retained.
- Where residues from wheat were chopped and retained, minimal tillage of the seedbed combined with glyphosate prior to sowing reduced wheat volunteer levels.
- The ryegrass population did not provide competition to wheat volunteers when establishing ryegrass into chopped straw.

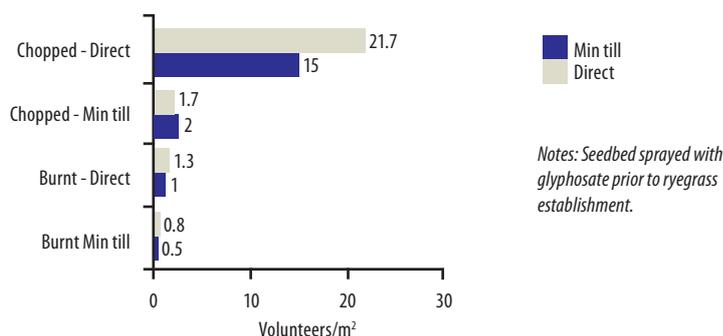


Volunteer wheat in ryegrass following minimal tillage of chopped straw



Burnt wheat stubble resulting in lower wheat volunteer competition

Influence of wheat residue management on wheat volunteers/m² in following ryegrass establishment - Methven 2007



Amount of macronutrients found in wheat straw.

	Approximate nutrient content (kg/t straw)	Nutrient content per 250 kg bale (kg/bale)
Nitrogen	6.9	1.73
Phosphorus	0.8	0.20
Potassium	13.5	3.38
Sulphur	1.3	0.33
Magnesium	0.8	0.20

Nutrient loss when burning straw

This section has outlined a number of agronomic benefits to burning wheat straw residues in comparison to chopped and retained residues. However, it is important to outline the nutrient loss associated with burning.

What do I lose when I burn?

The majority of the nitrogen and sulphur in residue will be lost to the atmosphere when it is burnt. N losses will vary from 30-90% depending on the extent of the combustion i.e. a good burn will lose up to 90%. Other nutrients in the residue at burning e.g. phosphorus, potassium, magnesium will largely return to the soil as ash.

Crop residue makes up approximately 50% of total plant (above ground) yield in cereals. Therefore a 10 t/ha grain yield will provide approximately 10 t/ha of straw. In dryland crops the percentage harvested grain may fall from 50% down to 30-40%, thus residue bulk may not be reduced to the same extent.

OVERALL SUMMARY

Value of burning cereal residues for autumn sowing

- Burning cereal stubbles reduced the overall need for cultivation in the following crops of autumn sown wheat, barley and ryegrass and increased the yield of the second wheat crops relative to the same crops established in the presence of chopped straw.
- Burning reduced slug damage and grassweed infestation in the following crops and the need for agrichemical use was reduced.
- Ryegrass seed yields and barley yields following wheat were frequently lower following chopped straw, since plant establishment was reduced. In trials where poor establishment was due to lack of seed soil contact a single cultivation pass increased yields to the level achieved following burning.
- Second wheat or continuous wheat was the only scenario where chopped straw reduced yield irrespective of establishment and cultivation method.

- The increase in crop yields following burning, which was observed in wheat, was not seen with barley on barley provided there was good seed soil contact. However, the saving in establishment costs by removing the residues was apparent in all trials and was calculated to be a minimum of \$40-50/ha, on the basis that it removed the need for at least one cultivation pass post burning.

- When sowing direct, with a disc based drill (Great Plains triple disc), the reduced chopped wheat associated with long stubbles resulted in improved plant establishment and yield compared to short stubble.

- Stubble length created no yield or establishment differences when the soil was cultivated (one pass), but from a practical standpoint the seedbed was much more uneven where long stubble was retained and then minimally tilled disc cultivator, as compared to the same operations following short stubble.

- Raking header residue trails at an angle prior to direct drilling into chopped residues

improved yield compared to direct drilling without raking (note that the advantage of this technique is very dependent on the volume and evenness of residue deposited by the header), though the improvement in yield was greater where residues were associated with short stubble (thicker trail behind header).

- When using a tyne based drill (Horsch CO4) direct into chopped straw residue stubble length did not affect establishment, but travelling at right angles to previous drill rows caused problems with blockage.

Note: These trials studied the one year effects of establishing crops in chopped cereal straw.

The project did not study the long term effects of retaining chopped straw. It is also acknowledged that there is nutrient loss associated with burning cereal straw.

Autumn wheat establishment following brassica residues

Following brassica and pulse crops the small bulk and nature of the residue (i.e. lower C:N ratio) means in theory there is little need to consider burning or cultivating the residue, provided it is evenly chopped or baled or grazed to achieve good plant establishment.

Thus with break crop residues the factors that frequently prevent direct drilling are:

- Chopped residue unevenly spread off the header.
- Compaction and wheel ruts from harvest of the previous break crop and or the baling operations (this is particularly important during wet or late harvests).

Controlled traffic

Some form of controlled traffic policy during harvest can restrict damage to particular areas so that remedial cultivations are only carried out on part of the paddock. Alternatively harvest traffic can be fully controlled with the use of precision farming techniques based on GPS (global positioning systems).

Redistribution of residues prior to sowing

Not cultivating but raking residue to redistribute unevenly spread harvest residue has been tried in both cereals and brassica residues

(see results below). Obviously livestock could also be used to eat the residues prior to direct sowing. In these circumstances it is important to examine whether livestock have created surface compaction. If they have, then some lifting of the soil may be necessary before sowing.

The project examined different establishment methods following seed brassica residues in soils (Lismore silt loam) that had been direct drilled for more than one season. Wheat was sown using a Cross slot drill (an inverted T shaped opener - combination of both tyne and disc) into chopped and chopped and raked residues direct or following a one or two pass top work cultivation (He-Va disc roller). Burning was not included in these trials and residues were not

grazed. In these circumstances the project also addressed whether the nitrogen strategy for direct drilled autumn sown wheat should be the same as for minimally cultivated crops.

Results over two seasons indicated there were small yield benefits from raking brassica residues (+ 0.11 t/ha in 2004 and + 0.48 t/ha in 2005) when crops were direct drilled, but that these benefits disappeared when the same situation was cultivated with a disc based cultivator prior to drilling. In both seasons the yield of crops established with minimal tillage was significantly better than the direct drilled crops, but over two seasons there was no benefit in exceeding a single cultivation pass.

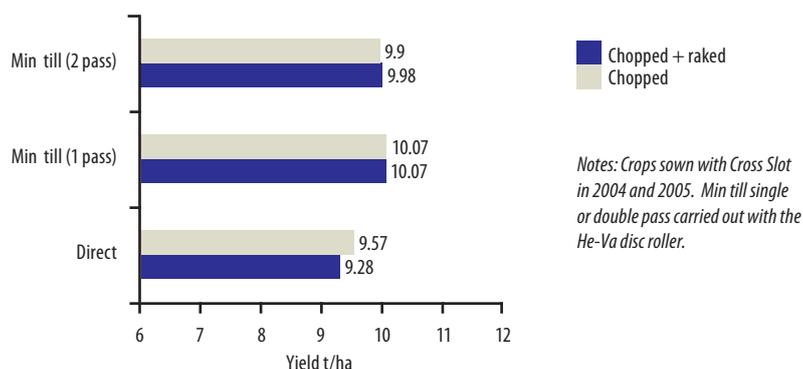


Residue handling following a brassica seed crop



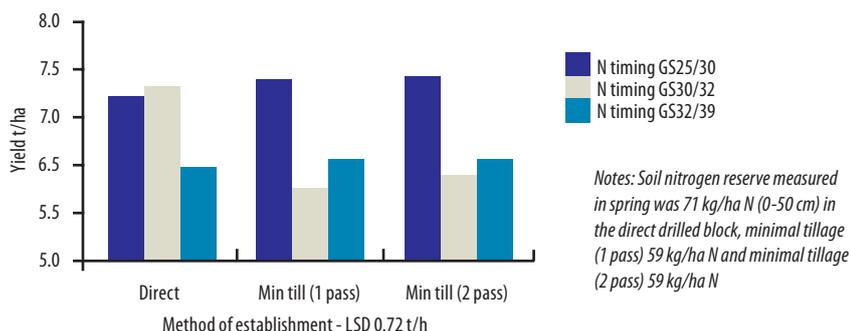
Cross Slot drill being used to establish wheat directly into brassica residues

Influence of residue management and establishment system on wheat yields following brassica - Ashburton mean 2004 & 2005



Notes: Crops sown with Cross Slot in 2004 and 2005. Min till single or double pass carried out with the He-Va disc roller.

Interaction of establishment method with nitrogen timing strategy - Ashburton 2004 - 1st wheat after brassica



Notes: Soil nitrogen reserve measured in spring was 71 kg/ha N (0-50 cm) in the direct drilled block, minimal tillage (1 pass) 59 kg/ha N and minimal tillage (2 pass) 59 kg/ha N

Influence of brassica residue management and cultivation on slug damage in the following wheat crop - Ashburton 2005. All plots drilled with a Cross Slot.

Cultivation	Drilling (Cross Slot)	% Plants showing leaf damage at GS12	
		Raked Residues	Unraked Residues
Min till (2 Pass - He-Va Disc roller)	Yes	3	4
Min till (1 Pass - He-Va Disc roller)	Yes	3	5
Direct Drilled	Yes (direct drill)	14	19
Sig		***	
Cv%		63	
LSD		8	

* Note trial was treated with slug pellets at sowing in both cases

Nitrogen regime for direct sown autumn wheat

Project trials in 2004 indicated that direct drilled wheat crops following brassica were more responsive to early spring nitrogen timings (GS30) than minimally tilled crops. However in 2005 this was not the case. One possible explanation for this was that soil nitrogen reserve in the spring of 2004 was low following a wet winter (50 - 70 kg N/ha (0-50 cm)) compared to over 200 kg N/ha (0-60 cm) in spring 2005. Thus following a wet winter, the direct drilled wheat after brassica may be more responsive to earlier nitrogen timing (GS30 - GS32 doses), instead of the of GS32/39 timing split observed in 2005.

Slug damage in wheat following brassica

As observed in the cereal trials, there was greater damage from slugs (surface grazing) where direct drilling was used following brassica residues compared to minimal tillage. Raking residues gave a non significant reduction in slug damage.

KEY POINTS

Autumn sown wheat following brassica

- Brassica provide opportunities for reducing cultivation since residue has a more favourable carbon to nitrogen ratio (lower) and is less bulky or is baled and removed.
- Frequently harvest traffic damage and unevenness of residues can lead to the need for cultivation.
- In two trials on Lismore silt loam (using a Cross Slot drill) where wheat followed brassica there was a yield advantage to a single pass cultivation over the direct drilled crop, but no advantage to a double pass.
- Raking residues in order to redistribute the unevenness of header trails gave small non-significant benefits in both establishment and yield of direct drilled blocks.
- Raking also saw slightly reduced slug damage (not significant) but cultivation significantly reduced slug damage (slug pellets applied at sowing on the surface).

Crop establishment following grass

The project has only investigated crop establishment following grass since 2006 and only for spring sown crops. In two seasons combining peas were evaluated following 18 month ryegrass seed crops. In 2007/08 a wider range of crops were evaluated in the same rotation position (following 18 months ryegrass), these included linseed, peas and spring wheat.

Peas

Trials direct sowing broad leaved crops, peas and linseed, have been encouraging. Despite slightly lower crop establishment, direct sowing of these crops after 18 months of ryegrass (12 months ryegrass seed crop and then 6 months winter grazing, silaging or topping) has been equal or more profitable than cultivating or ploughing the grass prior to establishment.

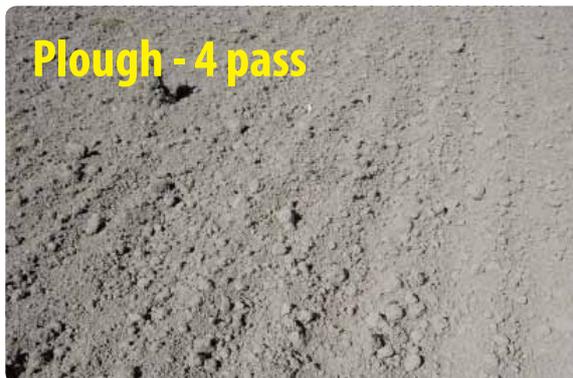
Trials with peas on a Wakanui Clay showed no yield benefit to cultivating the soil (plough or top working the soil) over direct drilling or applying starter fertiliser when direct sowing.

Using John Bailey (TAG UK) costings, based on new machinery and farmer costs (not contractor costs), the differences in cost and time were calculated to be substantial.

In 2007 direct drilling in a Tai Tapu silt loam was not as successful as the other treatments. There was some evidence of poorer establishment due to lighter ground and lack of soil resistance to turn the drill discs. In this trial ground was grazed with sheep prior to glyphosate application and establishment.

In both years it was clear that ryegrass volunteers were at significantly higher numbers in the top worked blocks.

Finished soil conditions after sowing Peas following 18 month ryegrass - Wakanui 2006



Plough plus cultivation (4 pass) following 18 months of ryegrass on a Wakanui Clay

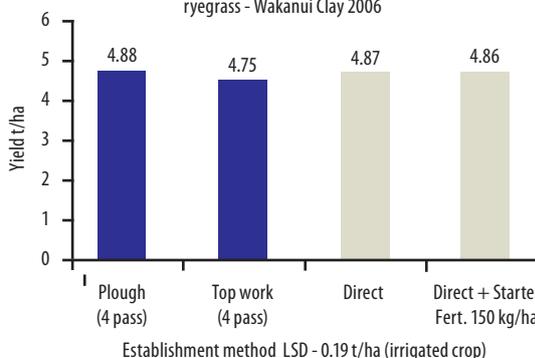


Top work (4 pass) following 18 months of ryegrass on a Wakanui Clay



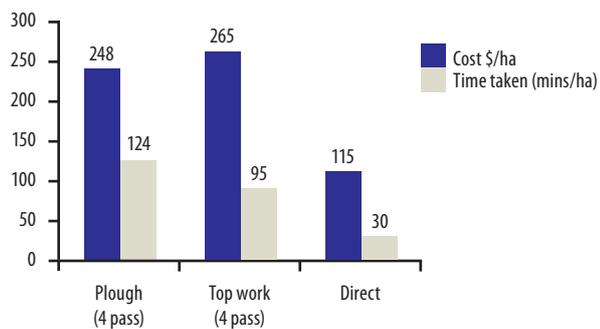
Direct drilled Peas following 18 months of ryegrass on a Wakanui Clay (Cross Slot)

Influence of establishment method on pea yields (t/ha) following 18 months of ryegrass - Wakanui Clay 2006

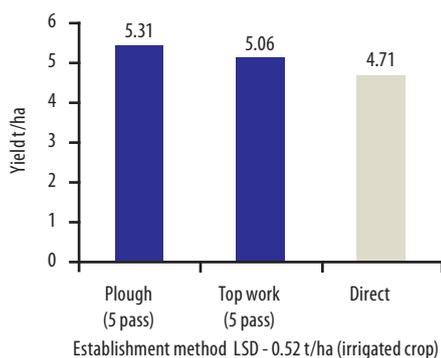


Notes: Plough 4 pass - (Plough f.b. press (separate pass), powerharrow (4 m), Simba Pronto drill) Top work 4 pass - (Top work twice He-Va disc roller with ripper, powerharrow (4 m), Simba Pronto drill). Direct drill using Cross Slot with and without 150 kg/ha DAP.

Influence of Pea establishment method on cost and time/ha following 18 month ryegrass - Wakanui Clay 2006

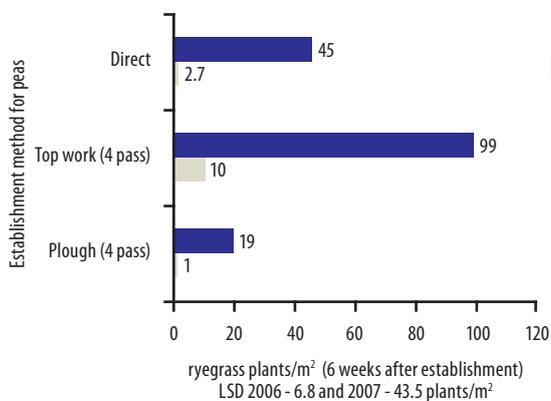


Influence of establishment method on pea yields following 18 month ryegrass - Tai Tapu Silt loam 2007

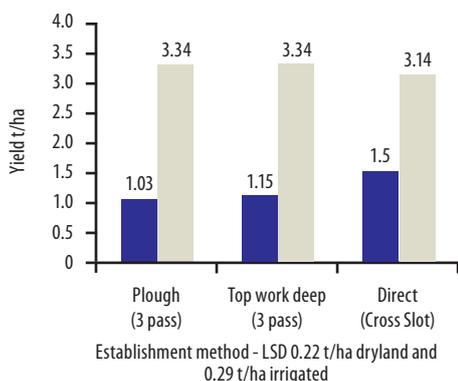


Notes: Approximate time taken to establish different treatments (minutes/ha) and approximate farmer cost (\$/ha) - Plough, powerharrow, roll, cultivate twice and drill 156 mins/ha and \$243/ha, Top work, cultivate twice, powerharrow, cultivate and drill 118 mins/ha and \$206/ha and Direct drilling (Cross Slot) 30 mins/ha and \$115/ha - Tai Tapu 2007.

Influence of establishment method on grassweed volunteers following ryegrass - 2006 and 2007



Linseed establishment method following ryegrass - FAR Arable Site 2007 cv Juliet



Plough and top work blocks sown with Great Plains triple disc 26 October. Deep ripped was carried out with two passes of He-Va disc roller fitted with ripper tynes. Cross Slot plots had 20 kg/ha N applied at seeding down with the seed whilst other treatments received the same 20 kg/ha N with the first top dressing.

Linseed

In Linseed, following 18 months of ryegrass on a Chertsey Silt loam, there was slightly lower crop establishment (significant $p < 5\%$) with the direct drill treatments and cultivated treatments but generally superior yields in a dryland scenario. In irrigated crops the advantage of direct sowing was not apparent. Ploughing treatments produced the highest broad leaved weed numbers following establishment and the lowest grass weed counts.

Peas and Linseed

KEY POINTS

Spring crop establishment following grass
Cultivating and sowing

- The fibrous nature of the grass turf can be seen as both a benefit and an impediment.

- On the plus side following grass gives some protection against excess compaction since the fibrous nature of the top 30 cm acts as a better "shock absorber" for the weight of cultivation equipment compared to other cropped land. This can be an advantage in spring when cultivating on cropping land carries a danger of going before the soil is fully dried in the top surface.

- On the downside the fibrous nature of the top soil and top surface thatch particularly associated with long term pasture requires greater cultivation in order to establish a seedbed. Some direct drills also have difficulty penetrating surface thatch, while others are able to use it as an effective cover. For this reason the plough is frequently employed in these scenarios (60% of growers).

- One factor that can be employed to help overcome fibrous nature of the material, is to destroy the sward with glyphosate earlier in order to give time for the grass to die back. Whilst reducing forage dry matter for livestock, this will help make the soil more friable. That said in the project trials direct drilling and minimal tillage was more comparable to ploughing in the 2006 trials when grass was still green when first cultivation was implemented.

Weed control

- Top working (non-inversion) the soil following 18 months of ryegrass increases grass weed pressure, relative to direct drilling and ploughing. In broad leaved crops such as pulses and brassica grass weeds are more easily and cheaply controlled, however in cereals it can result in extra expenditure, since grassweed herbicides can be relatively more expensive.
- Ploughing produced the lowest levels of grassweeds post grass. However, where broad leaved weed seed banks are high, ploughing will increase broad leaved weed germination. In break crops, such as pulses and brassicas, this can result in more expensive herbicide strategies, whereas in cereals the same weeds are easier and cheaper to control.

Therefore purely from a herbicide strategy perspective:

- Ploughing: less problem with grass weeds, but more broad leaved weeds, this is more suited to cereals after grass.
- Direct sowing: less broad leaved weeds but more grassweed pressure, more suited to break crops after grass. In addition the dead ryegrass still acts as competition to germinating broad leaved weeds.

Pest control when establishing cereals after grass

Only one trial has been carried out as part of the project where spring cereals were sown following grass. This work revealed a number of key points that need to be addressed if one is to be successful with direct drilling cereals following grass. As commented upon in the previous section it is generally easier agronomically to follow the grass phase with a break crop and then go into cereals rather than going directly into cereals. However, with the economics of grass seed and wheat being superior to that of many break crops there is interest in going directly from grass to wheat.

In 2007 a single trial illustrated that to be successful with direct drilling spring wheat following ryegrass significant emphasis has to be placed on positioning first fertiliser doses with the seed and ensuring that Barley Yellow Dwarf Virus BYDV is controlled. In the trial there was a significant yield depression from direct drilling compared to top work and plough which was primarily associated with BYDV infection. Although there was slightly lower establishment with the direct drilled blocks (Direct with fertiliser down the spout at sowing 134 plants/m², Top work 146 plants/m² and plough

158 plants/m²), the principal factor implicated in yield differences was higher BYDV infection. In this trial an insecticide seed treatment (Poncho) was applied to all blocks, but insecticide was not mixed with glyphosate and neither was an insecticide spray applied at early tillering.

From the results obtained it is clear that a seed treatment in this situation was not sufficient, since despite Poncho seed treatment for BYDV, virus expression was far more prominent where crop was established directly, compared to the cultivated scenarios.

KEY POINTS - CEREALS

There are four major pests to watch for when going from grass to cereals by direct drilling.

- BYDV transmitted by aphids
- Argentine stem weevil (ASW)
- Spring tails
- Slugs

The only pest encountered in the single project trial was BYDV (aphids), but particular attention needs to be drawn to all four.

Spraying off the grass with Chlorpyrifos, tank mixed with the glyphosate, gives control of aphids (that transmit BYDV – Barley Yellow Dwarf Virus), Argentine Stem Weevil (both the eggs and adults) and springtails. The rate of Chlorpyrifos required to kill ASW is greater than that required to control aphids and springtails and is far more effective when combined with a fallow period between spraying and drilling. Where an integrated pest management approach (IPM) is required the fallow period becomes even more important, since chlorpyrifos will be detrimental to predators as well as ASW. For aphid control growers could consider primicarb in order to provide greater protection for predators.

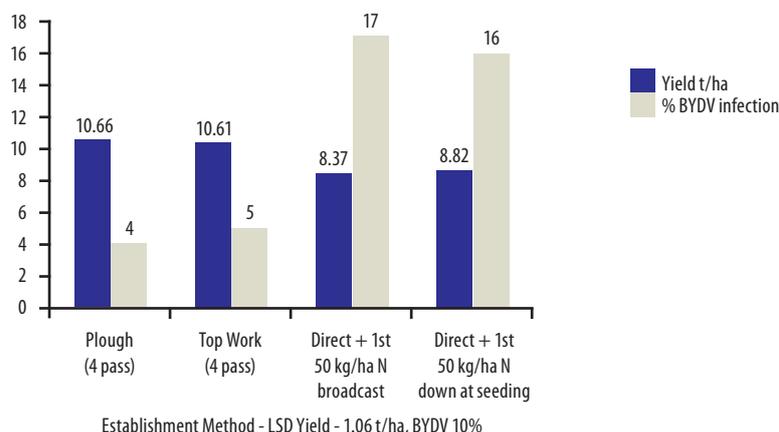
In order to prevent BYDV infection when direct drilling cereal crops following grass, the grower can carryout a number of measures to ensure early protection.

- Use of a seed treatment - another defence against BYDV infection in direct drilled cereals following grass is to treat cereal seed with an insecticide such as Imidacloprid (Gaucho) or Clothianidin (Poncho). This will protect the cereal plant until the start of tillering.

- Foliar insecticide use in spring sown cereals. It is difficult to provide a cereal crop with complete cover against aphids, since winged aphids are flying into the crop on a daily basis in the spring and new growth is diluting the effectiveness of products such as the pyrethroids. However it is worth remembering that the yield effect of virus infection is more severe in smaller plants so growers are better to try and protect the early phases of growth (seedling leaves and early tillering) if foliar pyrethroids are going to be used. Again these products are difficult to reconcile with an IPM approach.

Slugs can be difficult to control with direct drilled crops following grass, with one of the most difficult decisions being where to place the slug baits (down the spout or broadcast on the surface). There has been a suggestion that sowing slug baits with the seed is more effective if the seed is more shallowly sown but that deeper sown crops such as cereals might benefit from broadcast applications. In many cases it is likely to be affected by weather conditions and the size of the slugs being controlled; small grain hollowing slugs would still benefit from applications with the seed.

Influence of establishment method on % BYDV infection and wheat yield (t/ha) - Wakanui 2007 cv Morph



Influence of insecticide strategy for grass grub control in autumn wheat following ploughed and cultivated grass. FAR Arable Site cv Phoenix 2008.

Seed treatment	TO (drilling)	Dryland			Irrigated		
		6 June pl/m ²	% damaged	29 Jan Yield t/ha	6 June pl/m ²	% damaged	29 Jan Yield t/ha
Raxil	nil	105	11	2.90	87	20	4.80
Raxil	Suscon Green	103	2	5.23	104	8	8.86
Raxil	Suscon Green + Diazinon	108	3	5.22	118	4	9.27
Raxil combi	nil	93	3	4.74	90	6	7.75
Raxil combi	Suscon Green	108	3	4.95	88	4	8.60
Raxil combi	Suscon Green + Diazinon	90	3	5.06	93	6	8.66
	Mean			4.68			7.99
	sig			**			***
	CV%			16.4			11.0
	LSD			1.16			1.32

Note: Trial in ploughed and cultivated scenario.

Other pests

Grass Grub

Grass grub have not been encountered in the spring crops following grass in project trials. However, when crop follows grass in the autumn there have been huge issues with grass grub, irrespective of cultivation, although the less intensive the cultivation techniques the more prone crops are to damage. Remember that more than one approach should be adopted if the crop following grass is high risk. In recent work at the FAR Arable Site, the above results were obtained with autumn wheat following grass.

Though not observed in these trials, it has been noted that direct sown crops on dryland suffer relatively less grass grub damage than equivalent irrigated crops.

Slugs can also be a headache in the absence of cultivation but in this project have been less problematic in crops following grass in the spring than in crops following chopped cereal straw in the autumn.

Nutrition

Soil nitrogen and carbon movements following grass have not been evaluated in detail in this project, though it will be the focus of a new initiative "Grass 2 Crop" which commenced in July 2008.

Limited studies in the Non-inversion agronomy project have examined the role of fertiliser applied down the coulters at seeding. In two trials following grass, no benefit of fertiliser at seeding was recorded with direct sown peas in three of four trials conducted in 2006 and 2008, but a

yield increase of 0.45 t/ha was recorded in direct sown cereals following grass. The work on peas is backed by previous studies showing little or no benefit of starter fertiliser in tilled seedbeds.

Irrigation

At the FAR Arable Site, where the same cultivations have been employed for a number of years, there was a yield benefit of direct sown crops over cultivated crops in a dryland scenario; this was particularly the case with late sown linseed following grass in 2007/08.

4. Broadcasting Seed

- in which scenarios will it work?

- What is broadcasting?
- How did broadcasting and direct drilled crops compare to minimal tillage and conventional drilling?



Broadcasting seed - in which scenarios will it work?

What is broadcasting?

Over the last three years of the project there have been a number of comparisons of broadcasting with drilling the seed. The objective of this work was to look at the reliability of broadcasting versus sowing the seed with the drill.

Potential advantages of broadcasting would be that establishing the crop could be far quicker than sowing, saving both time and money.

Commercial Scenario

Where broadcasting has been used commercially, growers have commented on the speed of operation being the primary benefit, particularly when establishing crops on difficult soils.

Benefits put forward for broadcasting as a technique for reduced establishment include:

Reduced Costs

- Less tractor hours
- Less man hours

Capital

- Less machinery costs and depreciation

Less compaction

- cultivation and rolling/harrowing completed after seed broadcast (less wheeling associated with drilling operation)

Cheaper bulk seed handling

Simple system yet accuracy maintained

- tramlines maintained
- outside headland drilled to ensure even distribution to field boundary.

Most broadcasting is carried out for green feed crops not grain crops. So how successful is it and in what conditions does it work?

But when is this technique most successful?

In project trials we have examined different techniques for broadcasting seed, these approaches differ principally in the number of passes carried out. Where seed is broadcast from a fertiliser spreader, the seed has to be cultivated in separately with a second pass. Where the seed is broadcast from the cultivator, it is cultivated in using the same pass. Obviously using the fertiliser spreader does not involve the purchase



Broadcasting seed from a fertiliser spreader and the barley crop established (courtesy Rodger & Guy Slater)

Example establishment times - Broadcasting

Broadcasting with fertiliser spreader - 15-20 ha/hr (including filling)	= 4 mins/ha
Incorporation pass - 6 m cultivator 6ha/hr (h.p. dependent)	= 10 mins/ha
Harrowing and rolling - 8 m combination 8 ha/hr	= 7.5 mins/ha

(FAR Conference 2007 courtesy of Rodger & Guy Slater)



Using a pneumatic fertiliser spreader to broadcast seed



Broadcasting seed on the discs of a He-Va disc roller

of specialist engineering adaptations for the cultivator so has less capital outlay.

Broadcasting methods employed

1. Broadcasting from the fertiliser spreader and cultivating in (2 pass operation).
2. Broadcasting onto deflector plates mounted on the front of the He-Va disc roller (1 pass operation).
3. Broadcasting on to the cultivating discs of the cultivator (1 pass operation).

Two machines were trialled in this category the Vaderstad Biodrill and the He-Va disc roller.

In the six project trials, broadcasting techniques were undertaken directly into an uncultivated seedbed and after a stale seedbed (non inversion top worked) had already been created. This technique was tried in first wheat situations following break crops and in second wheat after both chopped and burnt wheat straw.

How did broadcasting and direct drilled crops compare to crops established following minimal tillage?

Lower establishment

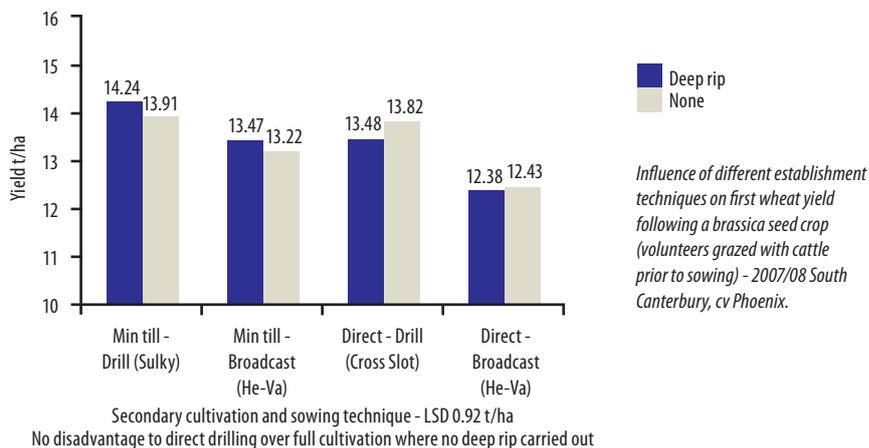
In project trials, broadcasting yields were inferior to drilling wherever the established plant populations were inferior (due to greater field losses with this technique) to those achieved with drilling the seed. In the majority of trials (4 out of 6) broadcasting seed produced lower levels of plant establishment than drilling, in some cases by as much 50% lower, the yield effect of this reduction being particularly evident with establishment in the spring.

Importance of stale seedbed

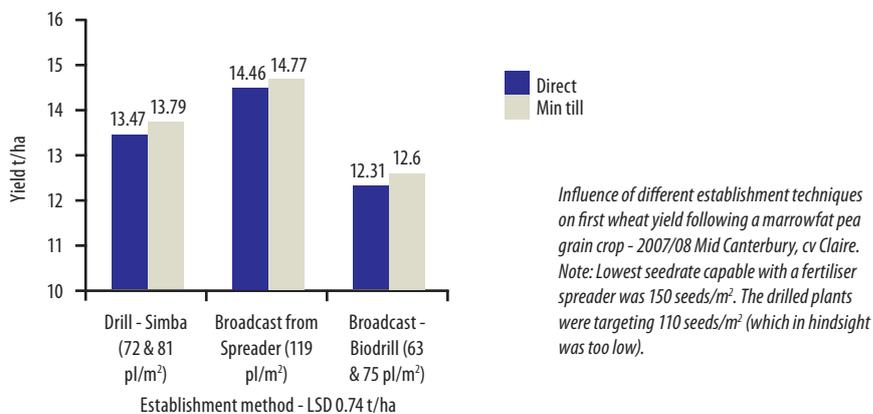
Broadcasting was more successful when a stale seedbed had already been created. If the ground had already been minimally tilled prior to broadcasting there was frequently no statistical differences in yield between techniques. Where establishment was being attempted directly into previous crop residues, work in South Canterbury, following autumn grazed brassica volunteers revealed that direct drilling of the crop with a Cross Slot drill was equal in yield to the minimally tilled crop (2 passes of primary cultivation followed with a Sulky cultivation drill) and significantly superior to broadcasting.

The most influential factor on yield in these two trials appeared to be the plant population established as a result of the establishment system. Broadcasting was more successful where plant populations exceeded those achieved with drilling. It is likely that plant population plays such an important role on yield in these trial results because the plant population range is very sensitive below 100 plants/m². It is known that populations in the 50-90 plants/m² are sub optimal for high yielding irrigated scenarios sown in late April.

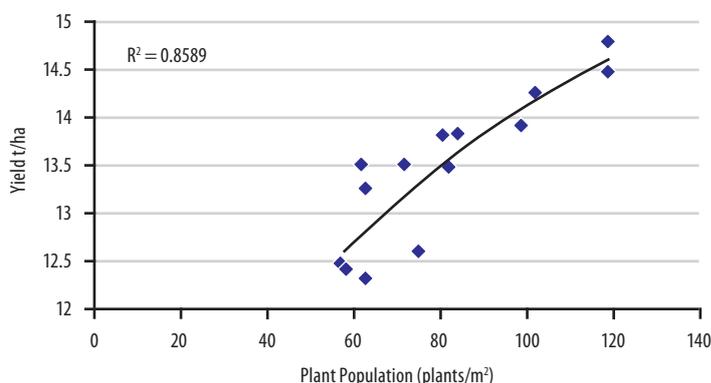
Drilling versus broadcasting - wheat following brassica - Temuka, South Canterbury 2007 cv Phoenix



Drilling versus broadcasting - wheat following peas - Wakanui, Mid Canterbury 2007 cv Claire



Influence of plant population on first wheat yields following broadcasting & drilling - 2007 (mean of two trials)



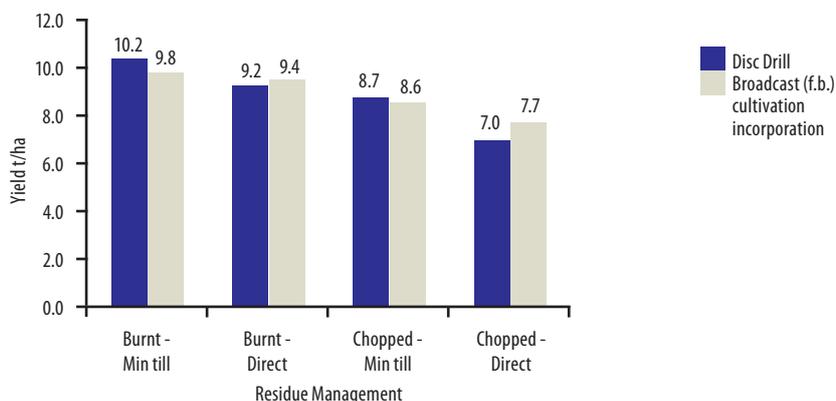
Broadcasting seed from the cultivator (in the project Vaderstad Carrier Biodrill or He Va disc roller) can be carried out in one pass but requires the correct working depth for the cultivator, otherwise seed placement in the shadow of the operating discs can be too deep. This may explain the poorer performance of the biodrill treatment in the Mid Canterbury trial; however it should be remembered that the target population was 90 plants/m² the same as the drilled plots. Where seed was placed on the surface and cultivated in, the problem did not seem as pronounced, but it should be emphasised that the target population was nearer 150 plants/m² not 90 plants/m².

Overall seed depth and variation in seed depth can be an issue when employing broadcasting techniques and may be responsible for the plant losses recorded, but if this is compensated for in seed rate, it should not be a problem. In general, the simpler form of broadcasting from a fertiliser spreader followed by a light cultivation was equally successful to cultivator based broadcasting.

Broadcasting second wheat

Broadcasting has also been evaluated in second wheat. Here it has been shown to be advantageous in those situations where the cultivation is necessary to obtain seed soil contact (remembering that after seed is broadcast it has to be cultivated into the soil). As was illustrated earlier chopped wheat straw is a serious impediment to obtaining good seed soil contact with disc based drill systems when establishing second wheat directly into the chopped residues of the first wheat. It is in these scenarios that broadcasting offered small advantages over drilling. Where residues were burnt or residues were cultivated there was little difference in performance between drilling and broadcasting.

Influence of drilling compared to broadcasting on 2nd wheat yields - 2005 & 2006 South Canterbury



Notes: Where seed was broadcast direct it meant that there was a single cultivation pass carried out with the He-Va Disc roller cultivator after seeding. Where broadcasting was trialled on a minimally tilled seedbed, two cultivation passes were employed, one pass after harvest and a second after seeding. Disc drill - 4 m KRM triple disc.

KEY POINTS

- Broadcasting advantages over drilling principally revolve around speed of operation.
- In project trials seed losses were greater with broadcasting than drilling resulting in lower plant establishment. In a number of trials plant establishment was 60-70% of that achieved with drilling.
- In many trials lower plant establishment was strongly correlated to the differences in yield between the two systems, particularly when plant establishment fell below 100 plants/m².
- In contrast where plant establishment with broadcasting was targeted at higher plant numbers than drilling (Wakanui 2007) it was illustrated that broadcasting was higher yielding than drilling.
- When broadcasting wheat it is essential to allow for larger seed losses to achieve the same plant population and yields as for drilling, particularly if plant establishment is below 100 plants/m² for autumn sown wheat and 150 plants/m² for spring sown wheat.
- When broadcasting in the autumn consider increasing seeding rates by 15-25% and fine tuning up or downwards depending on success. In the spring target a 25% increase as losses in project trials have been greater when the seedbed is moving from wet to dry, rather than dry to wet in the autumn.
- Broadcasting was more successful when a stale seedbed had already been created, therefore if the ground had already been minimally tilled prior to broadcasting there was frequently no statistical disadvantage to the technique.
- In contrast where no stale seedbed had been prepared prior to establishment, direct drilling was a more successful approach than broadcasting at reducing costs with cereal establishment. This was particularly true after break crops.
- The only exception was where disc based drill systems were being used to direct drill second wheat into chopped wheat straw. In this scenario the cultivation associated with incorporating the broadcast direct seed provided better seed soil contact than the direct drill.

Second wheat establishment using broadcasting or drilling either direct or following minimal tillage.



101 plants/m²

Broadcast



90 plants/m²

Disc Drill



107 plants/m²

Tyne Drill

Second wheat establishment into straw chopped blocks 41 days after sowing, Makikihi, South Canterbury



127 plants/m²

Broadcast



131 plants/m²

Disc Drill



124 plants/m²

Tyne Drill

Second wheat establishment in burnt blocks - 41 days after sowing, Makikihi, South Canterbury

5. Soil Health

- long term implications of reduced tillage systems

- Changes in physical soil properties associated with reduced tillage
- Yields and economics associated with longer term trials



Soil Health - long term implications of reduced tillage systems

Changes in physical soil properties associated with reduced tillage

On-going trial work at the FAR Arable Site at Chertsey in Mid Canterbury has been examining the influence of different intensities of cultivation on soil health as measured by physical, chemical and biological indicators. Soil quality measurements (SQMS), conducted by Crop & Food Research, revealed that over time there have been trends in soil quality measurements, though treatment effects on soil quality have not been consistent in each year. Where trends in effect were clearly observed it was with regard to structural stability (MWD - Mean weight diameter and % aggregates >1 mm). It was found that structural stability was higher under direct drilling. These measures have in previous work (Beare et al. 2001) been associated with relative yield performance in grain, forage and vegetable crops. Lower aggregate stability scores have tended to be associated with the plough treatments with minimal tillage treatment intermediate in effect.

Overall structural condition scores (SCS - is a semi-quantitative assessment of soil structure) for different treatments in the trial have shown a slight decline over time but there have not been consistent differences between treatments. Likewise Profile Density Scores have not shown consistent trends for establishment methods.

Earthworm numbers have declined from initial numbers (840 worms/m²) recorded in 2003 down to 200 - 400 worms/m² in 2006 -2008 period, a result that is consistent with continuous cropping irrespective of treatment.

Following 18 months of ryegrass in 2006 - 2007 there was evidence of a lift in total soil N. It declined from the start point of 0.23% in 2003 down to 0.18% in 2006, but has come back to a site average of 0.21% in autumn 2008. There has been little evidence that establishment treatment has affected total soil N. In terms of total soil carbon there has been evidence in some seasons (2006) over the last five years that it has been significantly higher in direct drilled blocks. Overall there has been a slight decline in % soil carbon with the trial site mean, being 2.62% in 2003 down to an average of 2.59% soil C on dry land and 2.56% soil C on irrigated land in autumn 2008.

Many of the soil indicators for autumn 2008 have represented an average regional yield output according to the SQMS scores. Have there been

Influence of establishment technique on final yield of linseed (kg/ha) following 18 months of ryegrass (seed crop). - FAR Arable Site, Chertsey 2008 cv Juliet.

Establishment Treatment	Dryland	Irrigated	Mean
Plough & press - drill with Great Plains triple disc	1031	3340	2186
Plough & press - He-Va disc roller (1 pass) drill with Great Plains triple disc	1183	3206	2195
Min till - He-Va disc roller (2 passes shallow) - drill with Great Plains triple disc	1128	2728	1928
Min till - He-Va disc roller (2 passes deep) - drill with Great Plains triple disc	1154	3340	2247
Direct Drill - Great Plains triple disc	1239	2475	1857
Direct Drill - Cross Slot	1497	3142	2320
Mean	1205	3038	2122
Significance	**	***	NS
Cv %	11.9	6.3	13.6
LSD	220	290	436

NB. Though nitrogen levels were identical (80kg/ha N) for all treatments, the Cross Slot treatments received 20kg/ha N down the coulter at seeding.

any yield differences in crops established for the 2007/08 season? (see table above)

Under the dryland scenario there was evidence that the direct drilled establishment techniques were providing higher productivity, whilst on the irrigated columns higher yields were associated with more intensive tillage, with the exception of the Cross Slot direct drilled block. The application of nitrogen at seeding with this late sown linseed crop may have given an advantage to the Cross Slot blocks over the other shallow establishment systems under irrigated conditions, but note that there was no difference in overall nitrogen applied.

Soil Carbon

Due to the complexity and expense of monitoring soil carbon there are few examples in New Zealand arable research of soil carbon status being more thoroughly monitored than it has been in the Lincoln Millennium Tillage Trial run by Crop & Food Research (see next section). In this trial soil carbon levels have been monitored over seven years following the return of the paddock (Wakanui silt loam) from long term pasture back to cropping. Over that time soil carbon has been assessed on replicated blocks that have been subject to ploughing, minimal tillage and direct drilling.

The results have revealed that soil organic matter declines under cropping after being in pasture. The rate of soil carbon loss in the top 30 cm differed according to the tillage practice employed post pasture. After one year of cropping there was a dramatic loss of soil carbon from the top 30 cm of soil in the more intensively

tilled crops compared to those that were no-till/direct drilled crops; however after seven years the total soil carbon losses were approximately the same under the different tillage treatments. In addition the work illustrated the importance of maintaining plant cover in order to retain soil carbon, since fallowed ground with no return of plant material over the same time period had the lowest levels of soil carbon.

Interestingly in the early years post pasture where soil carbon levels were highest in the direct drill no-till plots, yields with these tillage techniques did not out yield the more intensive tillage systems (see next section). However after seven years whilst soil carbon content of the top 30 cm was similar, no till yields improved in relation to the other tillage treatments; a result that may be linked to top soil structure, nitrogen availability and water holding capacity, though this has not yet been confirmed.

Yields and Economics associated with longer term trials

One of the most comprehensive tillage trials carried out over recent years is the Lincoln Millennium Tillage Trial run by Plant & Food Research, funded by FRST. FAR became involved with temporary funding for this project in 2008 when its future looked in doubt.



(Where PP = permanent pasture; PF = permanent fallow; N = no spring tillage; M = minimum spring tillage; I = intensive spring tillage; n = no autumn tillage; m = minimum autumn tillage; i = intensive autumn tillage).

The following section was compiled by Plant & Food Research staff, Mike Beare and Trish Fraser for FAR and first featured as a FAR Arable Update in 2008.

Trial Background

In October 2000, at a long term pasture site near Lincoln (Wakanui silt loam soil in grass pasture for >14 years), Crop & Food Research soil scientists established a new trial to investigate the effects of different tillage practices (and winter cover crop management practices) on crop performance and a wide range of soil properties (including soil organic matter, soil nutrients, soil biota and soil structure). The aim of the trial was to determine if the use of less intensive tillage practices could help to sustain soil quality and arable crop performance following improvements under grass pasture. The trial was scheduled to finish in 2007, but FAR has provided funding to maintain the trial in 2007/08, allowing the researchers time to evaluate its long-term future.

Methods

The trial has six tillage treatments (based on different combinations of spring & autumn tillage) plus a 'control' of uncultivated permanent pasture alongside a permanent fallow treatment (each 28 m x 9 m plot). Each of the six tillage treatment plots cover an area of 28 m x 18 m. Each of the main plots are split into two (28 m x 9 m) so that cover crops can be grown over the winter on one half whilst the other half remains in winter fallow. Each treatment is replicated three times, so there are 42 treatment plots altogether (see trial site layout above). The cultivation treatments consist

Tillage treatments

Spring Tillage	Autumn Tillage		
	Intensive (i)	Minimum (m)	None (n)
Intensive (I)	li	Im	In
Minimum (M)		Mm	Mn
None (N)			Nn

of various combinations of spring and autumn cultivation events, varying in intensity from no-tillage to more intensive cultivation with multiple passes.

The three main tillage methods used were:

1. No-tillage: No cultivation, seeds direct drilled.
2. Minimum tillage: Discd (0-10 cm), harrowed and rolled twice (at right angles) prior to sowing.
3. Intensive tillage: Mouldboard ploughed (0-20 cm), maxi-till (0-10 cm), then harrowed and rolled twice prior to sowing.

The treatments only include tillage combinations where autumn tillage is of equal or lesser intensity than the spring tillage event, giving a total of six tillage treatments. The first (spring) tillage event each year is represented by an upper case letter and the second (autumn) tillage is represented by a lower case letter. Hence, continuous no-tillage is denoted as "N" (spring) and "n" (autumn); and similarly continuous Intensive tillage as "I" and "i" and Minimum tillage as "M" and "m".

Each spring, a main crop (either barley, wheat or peas; see Table overleaf) was sown over all of the cultivated plots and then harvested at maturity in mid to late summer. Winter cover crops (Greenfeed oats in 2001, forage rape thereafter) were sown on one half of each of the main tillage treatment plots and the other half remained in fallow for the winter period.

For consistency all crops were sown with a Great Plains Direct Drill (with appropriate adjustments made to achieve similar seed placement and plant population sizes in each treatment). For the control treatments, half of each main plot has been maintained in permanent grazed pasture (as in the original condition) and the other half in a permanent chemically induced fallow. The permanent fallow treatment was introduced to balance the statistical design, but has also proven to be very scientifically interesting.

Crop management

Irrigation was applied using a Southern Cross Irrigator such that soil moisture was never yield limiting (typically based on a sum P.E.T. of 40 mm which was the trigger point for irrigation). Although it is not necessarily ideal, irrigation has had to be applied to all plots in response to the

Trial management information - Lincoln Millennium Tillage Trial 2000 - 2008, Plant & Food Research.

Year	Crop sown (cultivar)	Date sown	Starter fertiliser (kg/ha)	Side dressing fertiliser (kg/ha)	Rainfall over growing season (mm) (sowing to harvest)	No. of irrigations (total mm applied)	Date harvested
2000/01	Barley (Cask)	6 Nov 00	Crop 20 (100)	CAN (300)	161	6 (239 mm)	12 Mar
2001/02	Wheat (Commando)	21 Sep 01	Crop 20 (130)	CAN (300)	349	3 (67 mm)	12 Feb
2002/03	Peas (Rex)	26 Oct 02	Crop 15 (100)	Nil	179	4 (118 mm)	5-26 Feb
2003/04	Barley (Cask)	18 Sep 03	Crop 20 (100)	CAN (370)	128	4 (140 mm)	19-20 Jan
2004/05	Peas (Rex)	21 Sep 04	Crop 15 (100)	Nil	261	3 (110 mm)	26 Jan-3 Feb
2005/06	Barley (Cask)	20 Oct 05	Crop 20 (130)	CAN (370)	147	9 (254 mm)	13-21 Feb
2006/07	Barley (Cask)	12 Oct 06	Crop 20 (120)	Urea (217)	225	4 (149 mm)	20-28 Feb
2007/08	Barley (Doyen)	26 Oct 07	Crop 20 (385)	Urea (217)	226	6 (204 mm)	19-27 Feb

Main crop plant populations at establishment (plant per m²) - Lincoln Millennium Tillage Trial 2000 - 2008, Plant & Food Research.

Tillage Treatment	Winter cover	Barley (00-01)	Wheat (01-02)	Peas (02-03)	Barley (03-04)	Peas (04-05)	Barley (05-06)	Barley (06-07)	Barley (07-08)
Intensive Tillage (Ii)	Cover crop#	386	342	75	272	92	187	161	213
	Winter Fallow	-	268	84	262	92	227	149	229
Minimum Tillage (Mm)	Cover crop#	395	266	78	241	87	213	132	216
	Winter Fallow	-	239	90	218	83	216	141	214
No-Tillage (Nn)	Cover crop#	384	201	62	171	87	157	152	221
	Winter Fallow	-	186	54	173	58	140	146	180

= Greenfeed oats in 2001, forage rape thereafter

needs of the driest plots. Although occasionally applied at sowing, irrigation was not usually required for the cover crops. Fertiliser has been applied at standard recommended rates for each crop based on soil test results. All post-harvest cereal crop residues were chopped and returned to the soil (except 2006 when the large volume of barley straw was baled and removed). All pea straw residues were baled and removed from the site. Cover crops were grazed using sheep prior to spring cultivation.

Pasture and fallow plot management

All of the permanent pasture (PP) and the permanent fallow (PF) plots were irrigated in summer (consistent with the cropping plots). The PP plots were periodically grazed by sheep (typically 10 times per year and 20 animals per plot), with all animal manure and urine returned to the plots. Herbicide (roundup) was applied

as required to maintain the PF plots plant free. No fertiliser was applied and no animals grazed the PF plots, so there has been no disturbance to the soil surface (e.g. livestock treading) and no nutrient additions to this treatment.

Trial site monitoring

Soil moisture (0-20 cm depth) has been measured on a weekly to fortnightly basis depending on the season. Soil temperature has been continuously monitored in selected plots using data loggers. Disease monitoring has been undertaken by regular visual inspection (scouting) by a disease expert. Slug populations have been monitored periodically (usually for several weeks prior to and after cultivation and sowing) and slug bait ("Slugout") was applied at recommended rates when deemed necessary based on the monitoring results.

Plant measurements

Plant establishment counts have been made in each plot following the emergence of each crop (main crops and cover crops). At harvest, samples of plant material were removed from representative areas of each plot by hand harvesting to determine plant yields. A small plot harvester was also used to assess yields. Measurements of dry matter production have also been made on the permanent pasture plots prior to each grazing event.

Tillage Treatment	Winter cover	Barley (00-01)	Wheat (01-02)	Peas (02-03)	Barley (03-04)	Peas (04-05)	Barley (05-06)	Barley (06-07)	Barley (07-08)
Intensive Tillage (Ii)	Cover crop#	10.8	8.1	6.0	9.3	7.0	8.6	9.3	9.8
	Winter Fallow	-	7.8	6.2	9.7	6.0	7.6	8.7	8.7
Minimum Tillage (Mm)	Cover crop#	10.3	7.9	6.3	9.2	6.8	9.2	9.7	10.6
	Winter Fallow	-	8.2	6.6	10.2	5.9	7.8	9.3	9.8
No-Tillage (Nn)	Cover crop#	10.4	7.4	6.0	9.3	6.7	11.0	11.8	11.3
	Winter Fallow	-	7.5	6.1	9.4	4.9	9.7	10.9	10.4

= Greenfeed oats in 2001, forage rape thereafter

Results

Crop Performance Results

For simplicity, the results presented here are for the Ii, Mm and Nn treatments only (see Treatment Table); as the effects of the intermediate treatments have been much less pronounced. This section focuses on the crop establishment and yield results for the main crops only.

Establishment of main crops

Effects of the tillage treatments on crop establishment differed between years. In the first year of the trial, the population (plants per m²) of barley plants at crop emergence was very similar for all three tillage treatments. This was achieved despite very different soil structural conditions in the top 10 cm of soil surface. In contrast to year one, the plant populations established for the crops sown in years 2-6 (2001-2005) were markedly affected by the tillage treatments.

For these crops, the plant populations established in intensive tillage treatments tended to be slightly higher than those on minimum tillage treatments and much higher than those established on no-tillage treatments. The plant populations established at emergence of the two most recent barley crops (2006-2008) were similar across all three tillage treatments.

Effects of tillage treatments on spring crop yields

Despite differences in the plant populations at emergence, there were no clear and consistent differences in yield between the three tillage treatments of spring-sown crops (barley, wheat, peas, and barley) grown during the first four years (2000-2004) of the trial. During this period, there were also no consistent differences in the yield of crops grown on the winter cover crop and winter fallow treatments. However thereafter some differences started to appear. In 2004/05

the no-tillage treatment (Nn) produced a markedly lower yield of peas than the cultivated treatments (Mm and Ii). This resulted from poor plant establishment, caused by a combination of slug and bird damage to the emerging pea plants in the Nn treatment that year. The population of pea plants established in 2002/03 was also lower in the no-tillage treatment, however in this case crop yields were similar across all tillage treatments. In each of the next three years (2005-2008), however, the no-tillage treatment produced barley crops with markedly higher yields (1 to 2.4 t/ha greater) than those recorded for the cultivated treatments. Over this same period, the barley crops that followed winter cover crops yielded 1 t/ha more grain than those following winter fallow management. Although an explanation for these yield differences is yet to be confirmed it is suspected that they may be attributed to greater water storage, improved crop water use efficiency and more plant available (mineralisable) N in the top soil layers of no-tillage treatments compared to the cultivated treatments. Investigations are currently underway to confirm this explanation.

The appearance of a yield advantage after several years under 'no tillage' management is consistent with the findings of a number of overseas studies. Researchers have reported that differences between cultivation treatments are not significant in the early stages of management change, but that beneficial effects from reduced tillage appeared after several years of continuous management.

Effects of tillage treatments on winter cover crop yields

The dry matter produced from the first cover crop (forage oats) was very poor due to late establishment and, therefore was chopped and returned as green manure. In all subsequent years forage rape has been sown as the cover crop and overall its production has varied greatly between years. The dry matter produced from

these forage rape crops has been affected by sowing date and the presence of slugs (especially the Mm and Nn plots).

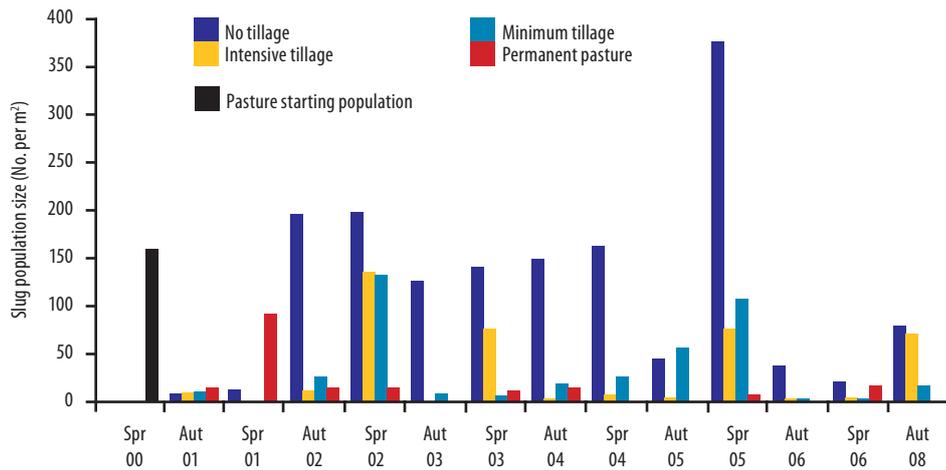
Influence of slug populations

The monitoring of slug populations showed that their numbers fluctuated greatly from year to year, but tended to be much higher overall in the no-tillage plots than in the cultivated treatments. The effect of slugs on crop performance was most evident for peas and for forage rape crops. The impact of slugs on the establishment and yield of pea crops was particularly evident in the winter fallow plots of the no-tillage treatments. The better crop establishment and higher yields recorded for peas sown after winter grazing of forage rape may have resulted from sheep treading reducing slug populations in spring.

Although baiting with "Slugout" usually reduced slug numbers substantially during crop emergence, in some cases (e.g. when baits were applied prior to heavy rain) the bait was not highly effective and slug populations quickly recovered, particularly in the no-tillage treatments. Despite the elevated slug pressure, crop yields in the no-tillage (Nn) treatments remained equal to or better than the cultivated treatments throughout the trial. In general, we have found that slug population monitoring and targeted use of slug baits is one of the most effective ways to manage the impacts of slugs in minimum and no-tillage cropping systems.

KEY POINTS

- The Lincoln Millennium Tillage Trial was established to determine if the use of less intensive tillage practices could help to sustain soil quality and arable crop performance following improvements under grass pasture.
- In the short term (first 4 years) tillage intensity had no significant effect on main crop yields.
- In the longer term (>5 years) no-tillage and, to a lesser extent, minimum tillage practices produced higher yielding crops that may be attributed to higher water use efficiency and greater top soil nitrogen availability.
- Effective slug control is important for crop establishment under no tillage, particularly for autumn sown cover crops and also spring crops known to be susceptible to slug damage - such as peas.



Size of slug populations prior to any tillage and/or slug bait application in spring (Spr) or autumn (Aut) of each given year.
- Lincoln Millennium Tillage Trial 2006-2008, Plant & Food Research.

6. Benchmarking Establishment Costings

- Benchmarking of New Zealand crops in 2006-2008



Benchmarking of New Zealand Crops in 2006-2008

Benchmarking of New Zealand wheat crops in 2006-2008

(FAR/CropRight Benchmark Study 2008)

As part of a MAF Sustainable Farming Fund project on arable business sustainability CropRight has been conducting a benchmarking study on establishment expenditure. The following section of the booklet examines how the establishment costs of crops from paddocks across New Zealand compare. The adjacent graph illustrates the range in establishment expenditure for winter wheat and the tables below illustrate the key statistics regarding typical establishment costs in milling wheat, feed wheat, autumn barley, spring barley, perennial ryegrass and annual ryegrass.

Breaking wheat data down further, the following tables examine the minimum cost, lower quartile, mean, upper quartile and maximum cost/ha for milling and feed wheat establishment. (It must be noted that uncertainty still remains from this study as to whether lower cost represented lower cost of production since it cannot be verified that reduced establishment cost did not reduce yield).

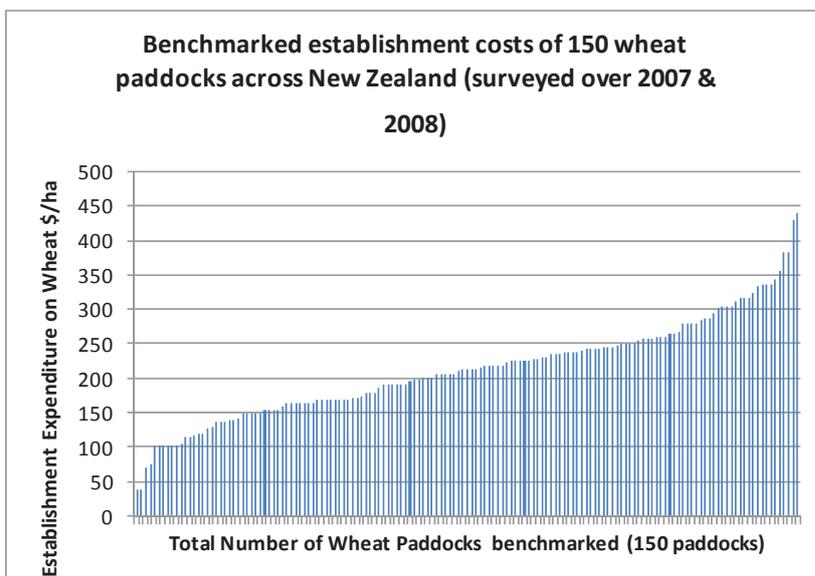
With both milling and feed wheat establishment costs were generally tracking upwards between the 2006/07 and 2007/08 seasons. This is thought to be mostly driven by diesel price increases, but is not solely the reason as the default machinery costings did not change significantly between the two seasons, therefore there must have been more passes and/or more expensive passes (whether increased diesel or more expensive equipment combined).

Data on barley indicated that establishment costs were reasonably similar whether autumn or spring, dryland or irrigated. The tables show a range of expenditure being \$75 to \$395 representing direct drilled ex peas through to a conventional scenario including ploughing & discing but also including several 'leveling' passes prior to drilling.

Benchmarking of New Zealand ryegrass crops in 2007-08

(FAR/CropRight Benchmark Study 2008)

Establishment expenditure was consistent across seasons and for both dryland or irrigated crops whether annual or perennial. The highest establishment expenditures involved ploughing and power harrowing. Zero establishment cost occurred when 2nd year crops were analysed.



Mean establishment expenditure over 150 paddocks of wheat = \$213/ha

Notes: Source from FAR/CropRight Benchmark Study. Establishment expenditure includes all crop establishment passes including spraying off, cultivation, drilling and rolling passes, but not fertiliser passes.

Key statistics re milling wheat establishment expenditure /ha.

	Dryland		Irrigated	
	2006/07	2007/08	2006/07	2007/08
Min	\$103	\$170	\$70	\$131
Lower quartile	\$153	\$191	\$158	\$180
Mean	\$197	\$243	\$187	\$208
Upper quartile	\$233	\$258	\$240	\$232
Max	\$315	\$429	\$265	\$312

Key statistics re feed wheat establishment expenditure /ha.

	Dryland		Irrigated	
	2006/07	2007/08	2006/07	2007/08
Min	\$40	\$103	\$119	\$115
Lower quartile	\$139	\$161	\$155	\$180
Mean	\$215	\$214	\$206	\$235
Upper quartile	\$289	\$244	\$259	\$259
Max	\$383	\$337	\$295	\$438

Key statistics re autumn barley establishment expenditure /ha.

	Dryland		Irrigated	
	2006/07	2007/08	2006/07	2007/08
Min	\$190	\$155	\$154	\$150
Lower quartile	\$193	\$175	\$173	\$154
Mean	\$212	\$217	\$189	\$187
Upper quartile	\$223	\$246	\$207	\$210
Max	\$251	\$302	\$221	\$246

Key statistics re spring barley establishment expenditure /ha.

	Dryland		Irrigated	
	2006/07	2007/08	2006/07	2007/08
Min	\$149	\$75	\$84	\$82
Lower quartile	\$200	\$205	\$124	\$126
Mean	\$255	\$233	\$176	\$201
Upper quartile	\$303	\$268	\$239	\$249
Max	\$395	\$313	\$265	\$367

Key statistics re annual ryegrass establishment expenditure /ha.

	Dryland		Irrigated	
	2006/07	2007/08	2006/07	2007/08
Min	\$104	\$115	\$91	\$105
Lower quartile	\$129	\$130	\$129	\$121
Mean	\$151	\$146	\$148	\$152
Upper quartile	\$165	\$163	\$171	\$172
Max	\$194	\$180	\$194	\$233

Key statistics re perennial ryegrass establishment expenditure /ha.

	Dryland		Irrigated	
	2006/07	2007/08	2006/07	2007/08
Min	\$0	\$0	\$0	\$0
Lower quartile	\$144	\$135	\$157	\$131
Mean	\$149	\$155	\$174	\$189
Upper quartile	\$194	\$186	\$213	\$255
Max	\$214	\$230	\$264	\$325

7. Appendix and Acknowledgements

- Costing calculations used in the booklet



Appendix and acknowledgements

Costing calculations used in the booklet

When costings have been used in this guide the general principles from which they were derived were based on the John Bailey Workshops (leading UK mechanisation expert from the UK) that FAR ran in 2005 & 2006. In these workshops John illustrated a method whereby all cultivation costs could be worked out using the same principles. The following illustrates such an example. It does not relate to a specific cultivation drill but has been included to show the different costs involved.

Step 1.

Firstly work from the value of cultivator or drill (in the example a new drill is assumed), then the typical (not fastest) work rate, the number of hectares covered per annum with the machine and lastly a figure for depreciation (John Bailey in the main used 12-15% in his examples).

Step 2.

Calculate the second hand value after a working life of so many years (as appropriate for the machine type). This is derived by reducing the value by the depreciation % for each year of working life. Thus in the example devaluing the new drill by 15% per annum for 5 years left a second hand value of \$47,920 compared to a new value of \$108,000. The difference between new - secondhand value gives the total depreciation which when divided by the number of years gives annual depreciation, therefore $\$108,000 - \$47,920 = \$60,080$. $\$60,080$ divided by 5 = \$12,016 per annum. The interest that the money would have earned in the bank rather than on the machine is worked out using the current interest rate based on the mean value of the machine over the 5 years. The mean value is calculated from adding the new value + second hand value and dividing by two. Thus in the example, $\$108,000 + \$47,920 = \$155,920$ divided by two = \$77,960. 7% interest on this sum of money would be \$5457.

Step 3.

Set repairs and maintenance as a % of the new value, this will obviously depend on the age of the machine and the length of time it is operated. A typical figure range that John Bailey presented was 3-5%. Insurance is calculated on the mean value in this example, the mean value has been broken down into \$5000 segments. The tractor and driver calculation is derived from a separate calculation based on labour cost, operating hours and tractor running costs

(not shown in this example). In this example it is calculated at \$22,000 per annum (200 hours at \$110/hr).

Step 4.

Add the depreciation, interest, repairs & maintenance, insurance and running cost and divide by the number of hectares covered per annum.

Please note: This is an example calculation to show how these figures can be derived. Growers are encouraged to work out their own calculations using these general principles.

4 m Cultivation drill

New price	\$108,000 with discount
Rate of work	3 hectares/hour
Hectares/annum	600 hectares
Depreciation per annum	15%

Working Life	5 years	8 years
Second-hand value	\$47,920	\$29,429

Depreciation	\$12,016	\$9,821
Interest rate %	7.0	7.0
Interest on mean value	\$5,457	\$4,810
Repairs as % of new price	3.0%	3.5%
Repairs and Maintenance	\$3,240	\$3,780
Insurance	\$1,123	\$989
Tractor and driver at \$110/hr	\$22,000	\$22,000
Total	\$43,836	\$42,048
Cost per hectare	\$73	\$70

Note: Insurance at \$72 per \$5,000 mean value (total mean value \$77,960)

Acknowledgements

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Note: Since this work was carried out Crop & Food Research have become Plant & Food Research.



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