WA STUBBLE RETENTION

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WESTERN REGION

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COVER: Zero-till disc seeding into high stubble load
PHOTO: WANTFA

Contents

Chapter 1: Introduction

Conservation agriculture is a system of sustainable land management aimed at protecting soil from erosion and degradation, improving soil quality and biodiversity and preserving natural resources, while simultaneously maximising crop yields (Climate-ADAPT, 2020). Its four main principles are:

1. minimising soil disturbance from cultural or mechanical operations;
2. maintaining permanent or semi-permanent soil cover with crop residues;
3. implementing diverse crop rotations; and
4. reducing compaction by practicing controlled-traffic farming.

One of the core practices of conservation agriculture, stubble retention, confers multiple benefits to growers, including increased soil moisture retention, reduced wind erosion and run-off, lower evaporation and higher infiltration rates. However, stubble-retained systems can also present challenges. High stubble loads can increase the risk of blockages occurring at sowing, reduce the efficacy of pre-emergent weed control, and affect crop emergence and establishment. Stubble retention can also lead to disease and weed issues if not managed properly.

In recent years, the adoption of no-tillage farming in line with new guidance and using refined herbicide technology has enabled greater residue retention in Australian cropping systems. The Western Australian cropping region alone produces about seven million tonnes of crop stubble biomass each year and retention of these residues offers significant benefits to growers.

This booklet brings together international and local research on optimal ways of managing stubble to achieve the benefits of residue retention while avoiding the potential threats. Combining contemporary research with grower case studies, it covers topics such as wind and water erosion, balancing soil nutrients, the effects of stubble retention on soil temperature, mitigating risks associated with weeds, diseases and pests, and exploring machinery solutions for stubble management.

There is still much to learn about the complex dynamics of stubble retention as part of an integrated cropping system, however its clear advantages with respect to soil and environmental health, as well as the direct benefits it provides to growers, make it a worthwhile topic to investigate. Key knowledge gaps are identified, offering fruitful opportunities for future studies and practice-based research.

Seedlings emerging between rows of standing stubble. Source: Ashworth et al. (2010)

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An Argentinian paddock at harvest time showing extreme wind erosion caused by a storm front. Source: Unknown

Chapter 2: Effect of crop residues on wind erosion, soil water dynamics and stored carbon

Key messages

- Maintaining 50 per cent surface cover or 30 per cent standing stubble can reduce the effects of wind erosion, however these figures may vary with soil type and topography.
- More than 8t/ha of stubble is needed to conserve moisture throughout the entire summer, but stubble loads of 2 to 5t/ha can slow evaporation, extending the opportunity to seed and establish crops following late summer and autumn rainfall.
- Stubble is about 45 per cent carbon by weight and represents a significant input of carbon to soil, however it can take decades for retained stubble to increase the amount of soil organic carbon.

Recognising the need to learn, to change

Bill Crabtree farms near Mullewa in the northern wheatbelt. He has been a champion of conservation agriculture since the inception of the Western Australian No Tillage Farmers Association in 1992.

The initial motivation for Bill to get into no-till farming was seeing the wind erosion on the south coast of WA. The soil was blowing away and fences were being buried by soil. Growers said, "We've just got to learn how to stop this erosion". They also wanted to grow more crops because prices for crops were good, whereas the sheep price was poor in the late eighties. The solution came from keeping the crop residue, which protected the soil while also adding nutrients to it.

The accelerated removal of topsoil by wind erosion impacts on productivity both directly and indirectly. Directly, it reduces crop yields by 'sand blasting' and burying crops; stripping nutrients from topsoil; contributing to a loss of rooting depth; degrading the soil structure and reducing plant-available water reserves. Indirectly, it reduces soil fertility by removing the top layer of soil containing nutrient-rich organic matter that is required for ecosystem services. From a social perspective, sandstorms can cause significant damage, affecting homes and townships in rural areas.

Retaining stubble offers advantages across the short and long term (Table 1). The short-term advantages relate to the way stubble physically protects the soil surface from wind and rain, therefore mitigating against erosion. The presence of stubble can also increase soil moisture retention, particularly in surface soil pre-sowing and in early crop development (Poole, 1987). Long-term advantages are due to retained stubble improving conditions for plant growth, soil health and beneficial macro-organisms, which help to maintain or sequester soil organic carbon.

Table 1: Short-term and long-term advantages of retaining stubble.

Short-term advantages	Long-term advantages
Reduced wind and water erosion	Increased or maintained soil organic carbon
Improved water infiltration, reduced evaporation and increased water storage	Increased soil biological activity and earthworm numbers

Source: Poole (1987)

Severe wind erosion events can occur after droughts and are exacerbated by overgrazing and extensive tillage. Source: David Minkey

Stubble and soil erosion

Clint Della Bosca, Southern Cross, WA

"We place a very high price on our residue in our stubble management, even to the point where we're looking at strategies on where we can lengthen the stubble or cut the crops higher, particularly in the low-yielding crops, to allow more soil cover."

Retained ground cover can minimise soil erosion (Figure 1) by keeping cropping soil in place, reducing surface water run-off and slowing wind speed. The percentage of ground cover needed to protect against erosion depends on soil type, stubble type and topography.

The May 2020 storm

In the autumn of 2020, growers east of Geraldton were hit by what can only be described as a super windstorm that lasted for eight hours and shifted countless tonnes of sandy soil.

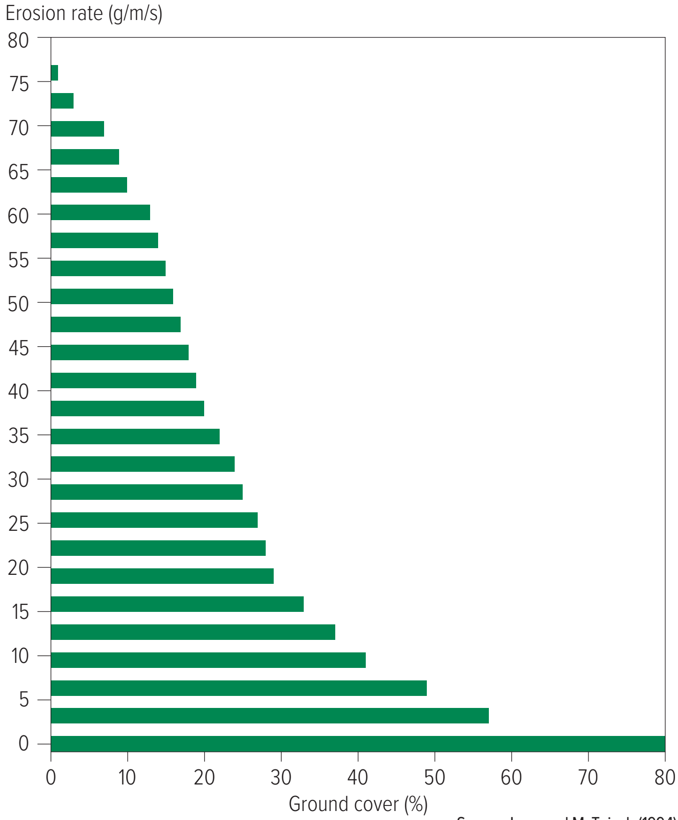
"It was a serious blow that really focused the minds of growers," said Craig Topham from Agrarian Management. "It was just the length of time of that sustained wind that made it so damaging."

The wind event occurred after a large portion of the cropping program had been seeded dry, leaving the soil exposed after the disturbance from the sowing operations. Seeding systems that left greater amounts of standing and anchored stubble had far less erosion and seemingly minor things – such as stubble height, the orientation of the working and the amount of disturbance produced by seeding machinery – all had a significant effect on reducing the amount of soil displaced.

Actions taken to ameliorate soil have significant effects on the productivity of crops in the lighter soils around Geraldton, however on this occasion, some growers were unfortunately caught out by the storm. Soil amelioration is always risky, even more so on lighter, sandplain soil.

"There are a lot of small things growers can do to reduce the erosion risks, such as how you leave the soil after the amelioration process, and managing stubble load before the soil amelioration process," noted Craig.

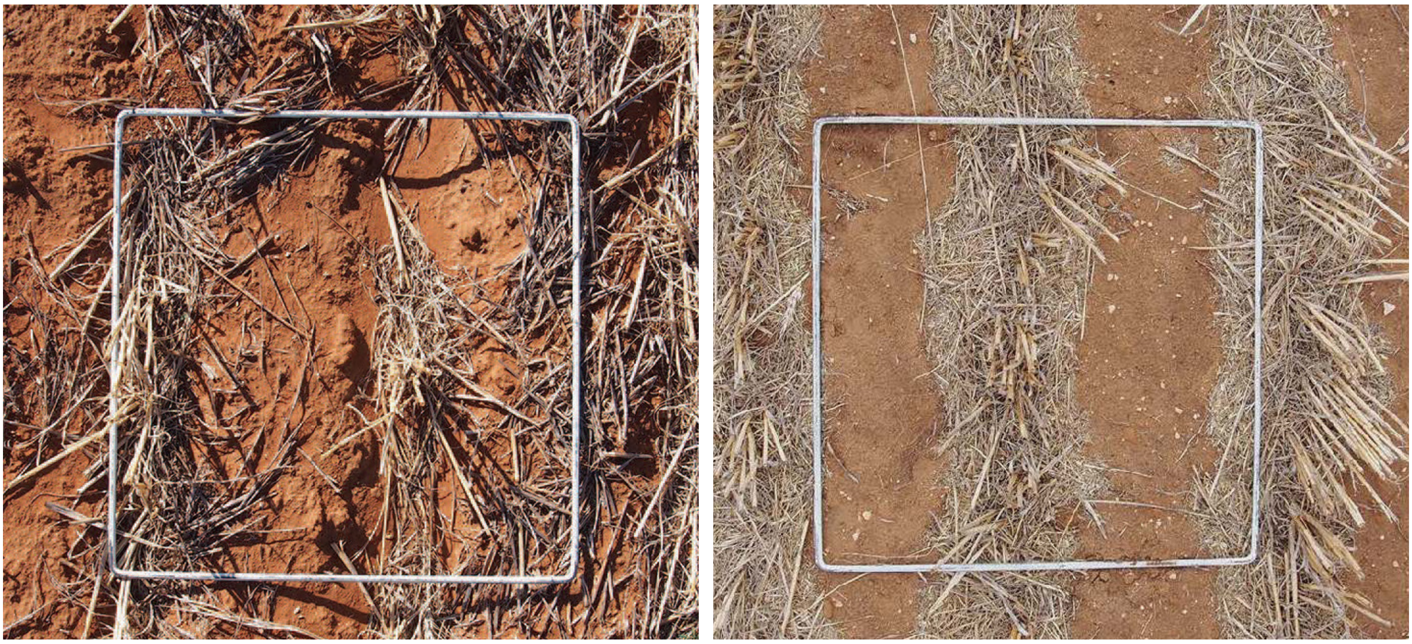
Figure 1: Effect of ground cover on the rate of soil loss.



Source: Leys and McTainsh (1994)

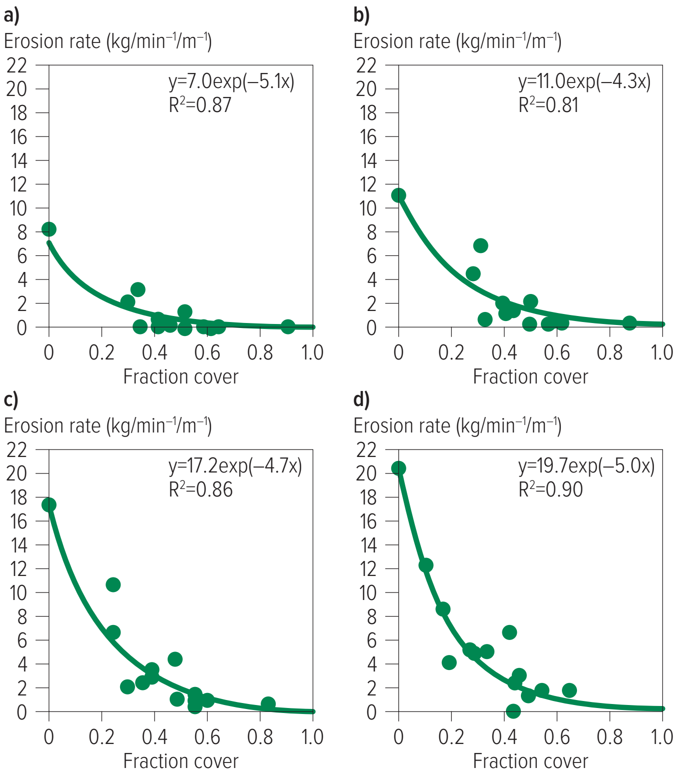
An overgrazed paddock in Merredin, WA, being eroded by the wind over summer. Source: Jade Bagley

Research conducted in Australia has demonstrated that standing wheat stubble can reduce wind speed at the ground surface by up to 80 per cent compared with the speed measured at 2.4m above the ground (Aiken et al., 2003). To significantly reduce wind erosion, about 50 per cent ground cover is required and adequate stubble needs to be maintained for six to eight weeks following seeding (Leonard, 1993). It is generally considered that 50 per cent ground cover is achieved when there is 1t/ha of cereal stubble (typically 0.5t/ha grain yield), 2t/ha of lupin stubble (typically 1t/ha grain yield) or 3t/ha of canola stubble (typically 1t/ha grain yield; Leonard, 1993). However, any previous years' residue will also contribute to stubble loads, as demonstrated in the images below.



Examples of stubble retention showing 70 per cent stubble cover on the left and 50 per cent on the right. Source: MSF (2013)

Figure 2: The influence of ground cover from prostrate lupin stubble on erosion rate from sandy soil at various wind speeds.*



*wind speeds were recorded 65cm above ground of (a) 13.4m/s, (b) 15.4m/s, (c) 16.9m/s and (d) 18.6m/s in a wind tunnel experiment conducted in the paddock.

Source: Findlater et al. (1990)

Findlater et al. (1990) used a wind tunnel to investigate the erosion protection offered by prostrate lupin stubble laying on the surface of sandy soils, modelling the results. The lupin stubbles ranged from 1 to 10t/ha, which equated to 20 to 95 per cent ground cover. Bare soil was included as a control. About 50 per cent ground cover was required to minimise erosion soil loss (Figure 2).

In later research, Findlater and Riethmuller (2000) found that ground cover at 50 per cent with prostrate stubbles and at 20 to 30 per cent with standing stubbles at 15cm height, minimised wind erosion risk. However, if the prostrate residues were easily detached, as with pea stubble, then stubble loads of 80 per cent were required to protect the soil surface.

Stubble and soil moisture

In Western Australia, studies suggest that wheat stubble amounts up to 2.5t/ha are enough to reduce soil moisture evaporation, but when they are greater than 4 to 6t/ha, they can reduce 80 per cent of evaporation when compared to bare soil (Perry, 1987). Surface residues in WA are less effective in suppressing evaporative losses across the whole summer season, due to its length and extreme temperatures, however stubble does effectively conserve soil water in the short term during the growing season, and stop rainfall from evaporating when it is received close to seeding time (Ward and Siddique, 2015). Early sowing into stubbles allows the crop to mitigate moisture and temperature stresses later in the season.

In addition to mitigating evaporative losses, retaining cropping residue can also increase soil water content by decreasing run-off and increasing infiltration. However, as can be seen in Figures 3 and 4, stubble has minimal impact on longer-term soil water evaporation unless significant amounts of stubble are present (Felton et al., 1987).

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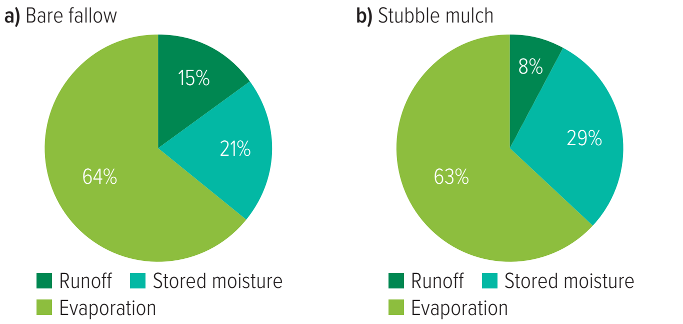
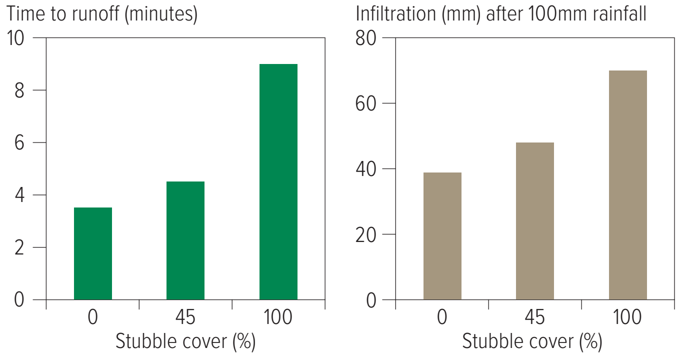
Figure 3: Graphs comparing runoff, stored moisture and evaporation in bare fallow soils and those with stubble mulch.



Source: Adapted from Felton et al. (1987)

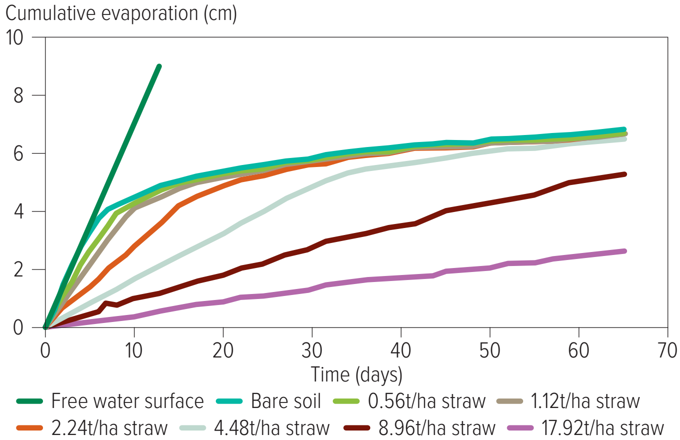
As Figure 3 shows, retained stubble is able to store more water in the soil, mostly due to a reduction in run-off. The production benefits of any conserved moisture will depend on the timing and intensity of rainfall. As can be seen in Figure 4, the level of stubble cover has a direct impact on the run-off timing of rainfall events. Increasing the time taken for rain to run off the soil surface, in other words, slowing the water down, increases its chance of infiltration. Late summer/early autumn rains falling onto high stubble levels will retain soil water for a longer period than low stubble levels, therefore, maintaining high stubble levels into autumn will improve the germination and establishment of the following crop.

Figure 4: The influence of different proportions of ground cover from retained wheat stubble on time to runoff (green) and water infiltration (brown).



Source: Thomas et al. (2008)

Figure 5: Impact of retained wheat stubble compared to bare soil on the cumulative evaporation of soil moisture over 65 days during summer.



Source: Bond and Willis (1970)

Bond and Willis (1970) showed that more than 8t/ha of stubble was needed to reduce evaporation and conserve moisture during summer in southern Australia (Figure 5). However, while stubble loads of 8t/ha are unlikely to be reached in the Western Australian wheatbelt due to limited rainfall, research shows that stubble loads of 2 to 5t/ha still have a significant impact on slowing evaporation, which could enable earlier seeding and better establishment in autumn (Roper et al., 2013). Early crop establishment is particularly important in dry seasons or those with late breaks.

Stubble and soil organic matter

Farming practices that return organic matter to the soil improve carbon turnover, increasing the health and productivity of the soil. These practices can include retaining stubble, increasing crop biomass, incorporating clay and green manure, and including pasture crops in the rotation.

As soil organic matter (SOM) decomposes it releases nitrogen, phosphorus, sulfur and other nutrients, which become available for uptake by plants, supporting their growth. SOM also improves soil structure because it holds soil particles together, improving water-holding capacity and encouraging root growth.

The most effective way to build stable levels of SOM is to include a well-managed pasture phase into the farming system rotation or to invert residue to depth. While crop residues are generally high in carbon, they are low in nitrogen (N), phosphorus (P) and sulfur (S). To build SOM in a continuous cropping system in which crop residues are the only source of carbon, additional nutrients (N, P and S) need to be added to maintain and/or build nutrient-rich humus.

Stubble is about 45 per cent carbon by weight, and while this represents a significant input of carbon to the soil, it can take decades for retained stubble to increase the amount of soil organic carbon due to the high rates of decomposition and the lack of buffering capacity in sandy soils that occur across WA.

This can be seen in trials conducted in Wagga Wagga, NSW, where there are also sandy soils. After 10 years, stubble retention generated 2t/ha more soil organic carbon than stubble-burnt plots to a depth of 10cm in a red chromosol soil during cropping trials with ley pasture rotations (Scott et al., 2010). However, after 25 years in which a clover pasture was included in the rotation, soil organic carbon was more significantly increased than when stubble retention alone was trialled (Chan and Conyers, 2011).

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Chapter 3: Effect of crop residues on soil nutrition

Key messages

- Retained stubble, particularly of cereal crops, can tie up nitrogen as microbes extract mineral nitrogen from the soil to break down the stubble.
- In a paddock with a cereal stubble load of 5t/ha, about 25kg/ha of nitrogen will be tied up.
- Nitrogen tie-up from decomposing stubble can leave crops short on available nitrogen during their early growth stages.
- Over time, immobilised nitrogen can become available through mineralisation.

The effects of crop residues, and different ways of managing them, on the nutrient 'supplying power' of soils over the short term (next growing season) and long term (next several years) are complex and not well understood, especially with regard to nitrogen. Various factors, including the amount of rainfall, soil type, temperature and method of agronomic management, affect residue decomposition and nutrient availability through processes of immobilisation and mineralisation (Figure 1).

Noel Keding, Kojonup, WA

Noel Keding, a Kojonup grower using a strip and disc system thinks that "with the increased amount of stubble, the nitrogen tie-up will probably be an issue, with the nitrogen being used by the soil microbiology to break the stubble down, making it unavailable for crop growth early in the season".

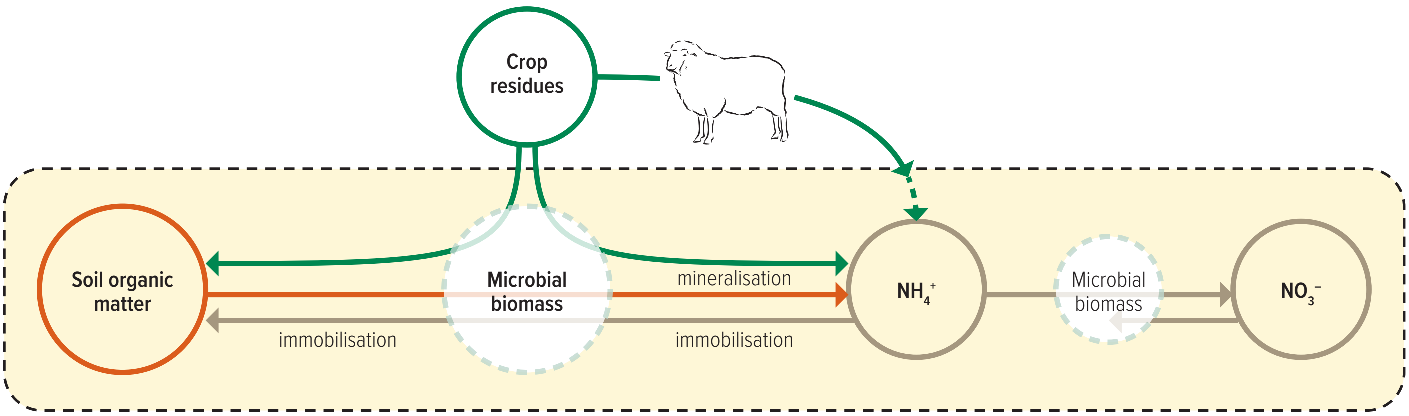
Effects of crop residue management on nutrient availability

The organic matter of retained crop residue is broken down by a diverse community of decomposing macro-organisms (including ants, earthworms and termites) and soil microorganisms (including various fungi, bacteria, microalgae and nematodes; Gupta et al., 2011). This much is known, however little is understood about the extent and activity of beneficial microorganisms on surface-exposed residues (Schoenau and Campbell, 1996). While macro-organisms are generally responsible for breaking down crop residue into smaller fragments (Evans et al., 2011), the large and diverse microbial biomass drives the process of mineralisation (Fenchel et al., 2012).

In Australia, the size of the microbial biomass has been shown to increase with the quantity of crop residue (Gupta et al., 1994), while the quality of crop residues determines the make-up and functioning of the microbial community (Murphy et al., 2011). For example, retaining low-quality stubble (that is, >C:N ratio) can lead to a shift in the microbial composition, increasing fungal communities more adapted to drier conditions at the soil–residue surface (Murphy et al., 2011).

The microbial biomass consists mostly of bacteria and fungi, which decompose organic matter, including crop residues in soil. This process releases nutrients, such as nitrogen, into the soil where they are available for plant uptake. About half the microbial biomass is located in the top 10cm of the soil profile and most of the nutrient release (mineralisation) also occurs here (as shown in Figure 1). This is a two-stage process where generally, up to 5 per cent of the total organic carbon and nitrogen in soil is in the microbial biomass unavailable to plants. When microorganisms die, these nutrients are also released in forms that can be taken up by plants. The microbial biomass is a significant source of nitrogen, and in Western Australia can hold 20 to 60kg N/ha.

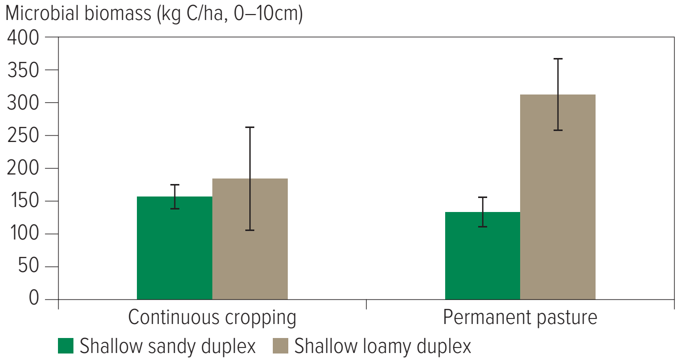
Figure 1: Nitrogen pathways showing *immobilisation* of mineral nitrogen (NH^4 and NO^3) by soil microbes breaking down stubble residues and *mineralisation* as microbes die and the nitrogen is released into the soil.



Source: Unkovich et al. (2016)

The different crops/pastures in rotation and the soil type can affect the microbial biomass. The residues of legume crops can increase the microbial biomass due to the larger amounts of nitrogen they contain. Rotations that have longer pasture phases increase microbial biomass due to minimal soil disturbance (Figure 2), though this is not the case in sandy soils where the lack of clay means organic matter is broken down rapidly, effectively 'starving' the microbial biomass.

Figure 2: Microbial biomass in soils with different clay content and under different management.



Source: Murphy et al. (1998)

Nitrogen immobilisation

In retained stubble systems, soil microbes breaking down the stubble compete with the living crop for nitrogen, if there is inadequate nitrogen in the residues. As a result, it is important to budget for any immobilised nitrogen when calculating the crop nutrient demand for the year. A rough rule of thumb is that for every tonne of cereal or canola stubble, 5kg/ha of nitrogen will be immobilised (tied up) in microbes during the stubble breakdown process. This nitrogen is then released (mineralised) to the soil when the microbes die and themselves decompose. This means that in a paddock with a cereal stubble load of 5t/ha, about 25kg/ha of nitrogen will be tied up.

Accounting for nitrogen immobilisation is reasonably straightforward: supply 5kg of nitrogen early in the season for each tonne per hectare of cereal residue. If there is insufficient fertiliser nitrogen applied, nitrogen tie-up from stubble break-down can leave crops short of nitrogen during their early growth phase.

Nitrogen tied up in microbes will be released later in the season (after four to eight weeks) via mineralisation (Figure 1). Therefore, when the stubble present has a high carbon to nitrogen ratio, adding nitrogen at sowing provides the microbial biomass with sufficient nutrition to break down existing stubble, ensuring the germinating crop has sufficient nitrogen to establish. This ultimately helps maintain yield potential.

Stubble management and nitrogen availability

Growers can influence their nitrogen availability through various stubble management practices such as crop rotation, incorporation of cereal stubble, burning of heavy stubble loads and no-tillage practices which all affect the cycling of nitrogen through the system in different ways.

Budgeting for nitrogen tie-up

Taken from Unkovich et al. (2016)

Establishing a nitrogen budget can help growers estimate crop nitrogen requirements in stubble-retained systems.

The amount of nitrogen a cereal crop requires is directly related to yield. In total, a cereal crop needs 40kg of nitrogen per tonne of yield, which can be supplied from the soil, in-crop mineralisation from residue breakdown and, where necessary, from fertiliser.

Step 1: Quantify available soil nitrogen at sowing (as measured with a deep-nitrogen soil test).

- Segregate the sample plots into a minimum of two depths (0-10cm and 10-60cm). (When using Yield Prophet® sampling depths need to be 0-10, 10-40, 40-70 and 70-100cm.)

Step 2: Establish net mineralisation in-crop (by calculating mineralisation less immobilisation).

- If incorporating cereal or canola stubble, some extra nitrogen may be needed to ensure soil levels are above 60kg N/ha to reduce nitrogen tie-up early in the crop.
- Mineralisation will provide additional nitrogen to the crop later in the season, particularly in spring when soil temperatures warm up. The amount will depend on soil type and crop rotation history (that is, pulses in the rotation will generally result in greater nitrogen mineralisation than a canola/wheat rotation).
- There is no set method for measuring in-crop mineralisation on-farm but a rule of thumb that can be used is: Growing season rainfall (mm) x organic carbon % x 0.15 = kg N/ha.

Step 3: Establish the amount of nitrogen that will need to be applied in order to achieve target yields.

- Wheat (11 per cent protein) will need 40kg/ha nitrogen per tonne of grain.
- Canola will need 80kg/ha nitrogen per tonne of grain.
- Barley will need 35kg/ha nitrogen per tonne of grain.

Step 4: Determine the timing of nitrogen application (pre-sowing and sowing).

- When soil tests show mineral nitrogen to be below 40kg/ha in the top 60cm of soil, then 20kg N/ha should be applied to wheat crops at sowing to ensure the crop gets through to the start of stem elongation.
- If there is more than 40kg N/ha, wheat and barley will make it to Zadoks Growth Stage Z30 (start of stem elongation) and canola will reach the six-leaf growth stage without the application of additional nitrogen, and not lose any yield potential.

1. Crop rotation

The carbon to nitrogen ratio (C:N) of crop residue governs the rate of decomposition. Pulse residues (C:N = 20:1 to 41:1) decompose more quickly than wheat residues (C:N = 45:1 to 178:1). Faster decomposition may improve nutrient availability for the following crop, however long-term effects of different residue qualities on soil carbon levels, especially in a rotation mix, are yet to be determined.

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Crop residues with a carbon to nitrogen ratio of more than about 20:1 to 25:1 result in nitrogen immobilisation, while lower carbon to nitrogen ratios result in nitrogen mineralisation (release) (Figure 3). Wheat stubbles tend to have C:N ratios of about 90:1, whereas ratios of legume stubbles tend to be about 35:1 and therefore tie-up less nitrogen (Table 1).

As Figure 1 indicates, as the relative amount of nitrogen in residues lessens, microbial demand for soil nitrogen increases, resulting in nitrogen immobilisation, and less bio-available nitrogen in the soil. The amount of nitrogen rendered unavailable through microbial immobilisation increases with stubble load.

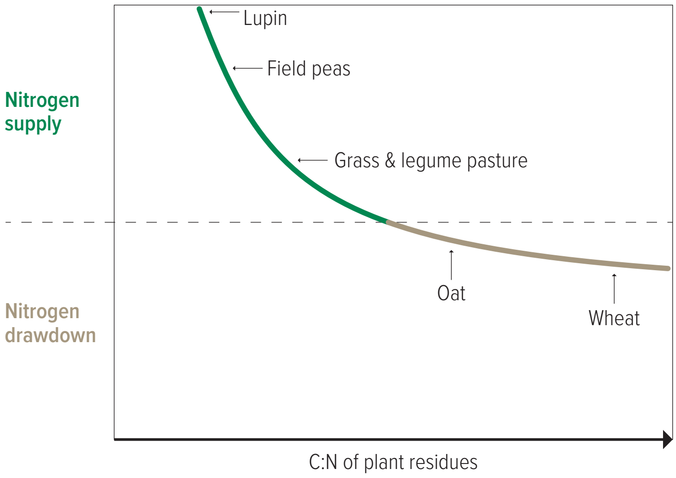
2. Incorporating cereal stubble

Cultivation to incorporate cereal stubble increases nitrogen mobilisation, with the rate dependent on soil type, mineral nitrogen status of the soil and amount of rainfall. Conversely, leaving cereal stubble on the surface can increase immobilisation (nitrogen tie-up; Figure 4). However, cultivation can also lead to faster losses of carbon from the soil and microbial biomass over the long term, along with increased risks of wind and water erosion (Hoyle et al., 2006).

3. Burning heavy stubble loads

Burning of stubble loads can reduce nitrogen tie-up in the system (less carbon), but increases the risk of wind erosion, lowers soil fertility and exacerbates soil moisture loss through increased evaporation. Burning cereal residues reduces immobilisation, but effectively 'releases' little nitrogen for the crop. Up to 80 per cent of the total nitrogen and a significant amount of the sulfur (S), phosphorus (P) and potassium (K) contained in the stubble are lost as a result of the burn (Table 2).

Figure 3: High stubble loads with a high ratio of C:N in the stubble significantly reduce available nitrogen in the soil.



Source: Hoyle and Murphy (2018). Soil Quality: 3 Soil Organic carbon. In: Soil Quality Series (D Murphy, F Hoyle, G Boggs, C Gazey; Eds.), SoilsWest. 42p. ISBN: 978-0-6482227-2-9. Figure redrawn from Hoyle FC, Baldock JA and Murphy DV (2011) 'Soil organic carbon - role in rainfed farming systems: with particular reference to Australian conditions'. In: P Tow, I Cooper, I Partridge, C Birch (Eds) *Rainfed Farming Systems*. Springer, Netherlands, pp.339-361

Table 1: Carbon to nitrogen ratios of crop residues remaining after grain harvest.*

Crop species	Reported C:N ratio (average)	Range of C:N ratios (lowest to highest)
Barley	66	39–129
Wheat	79	35–143
Canola	79	23–179
Chickpea	32	19–44
Faba bean	28	23–34
Field peas	32	14–83
Lentil	25	17–37
Narrow-leaf lupin	42	15–67

* Crop residues with a C:N ratio greater than 22:1 will result in nitrogen immobilisation.
Source: Unkovich et al. (2016)

Figure 4: Nitrogen deficiency (yellow bands of crop) along old stubble rows (harvester windrows) caused by nitrogen tie-up.

Source: Ken Flower

Source: David Minkey

Narrow windrow burning after the harvester has followed the same path each year can lead to significant nutrient losses. Moving the windrows one metre annually can reduce losses.

Source: GRDC

Table 2: Proportion of stubble nutrients lost during a hot burn.

Nutrient	Amount in one tonne of cereal stubble (kg/ha)	Proportion of stubble nutrients lost during a hot burn (%)
Nitrogen (N)	5.0	82
Phosphorus (P)	0.5	44
Sulfur (S)	0.5	80
Potassium (K)	10.0	40

Source: Department of Agriculture WA, Farmnote, 2001

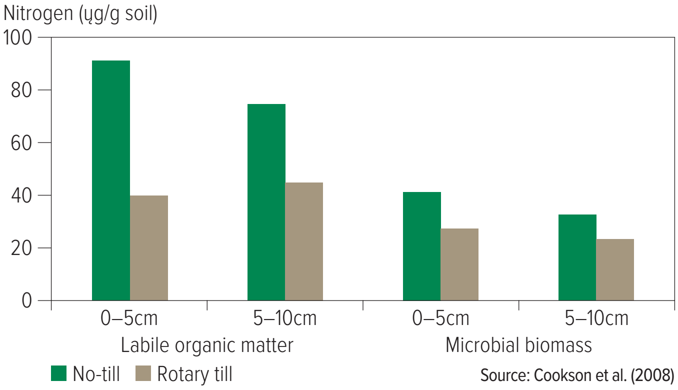
Heavy cereal stubble loads can lead to nitrogen tie-up.

Source: Ashworth et al. (2010)

4. No-till practices

No-tillage seeding practices are minimally disruptive to soil and can increase the microbial biomass by increasing labile carbon in the soil (Figure 5). Such management practices also protect soil aggregates and keep fungal networks intact, which are an important habitat for microbes in the soil. These factors can overcome nitrogen immobilisation from high stubble loads in the short term, but they take time, so nitrogen rates applied at seeding need to be adjusted according to conditions.

Figure 5: Comparison of nitrogen content in labile organic matter and microbial biomass for no-till versus rotary-till operations in a nine-year field trial at Wongan Hills, WA.



Source: Cookson et al. (2008)

Conclusion

The dynamics that govern nutrient availability with respect to stubble retention and stubble management are complex but can be managed. Short-term tie-up of nitrogen can be offset in systems with long-term residue retention in various ways, such as by implementing no-till operations or adding extra nitrogen at the appropriate stage of the growing cycle.

The amount of nitrogen applied at sowing may need to be increased when:

- the crop is following a non-legume (for example, a cereal or canola crop);
- levels of soil organic carbon are low (<0.8 per cent);
- stored soil moisture is above average;
- stubble loads are high (>3t/ha); or
- the target yield is high.

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Chapter 4: Effect of crop residues on soil and air temperature

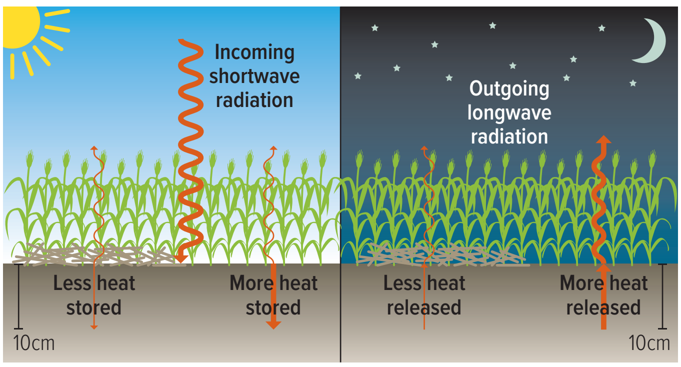
Key messages

- High stubble loads can increase the impact and duration of frost events, resulting in greater frost damage, reduced yield and lower quality of grain in moderate to severe frost seasons.
- Research found that at sites prone to severe and moderate frost damage, increasing stubble loads reduced gross income.
- Stubble removal is unlikely to be of value in areas of lower yield potential (<2t/ha) and/or in regions with less risk of frost and greater risk of soil erosion.
- The effect of stubble load and row orientation on heat stress in crops is unknown.

Crop residues generally have a moderating effect on soil temperature, leading to cooler day-time temperatures and warmer night-time temperatures. This can positively affect seedling growth in Australian farming systems, where crops are often seeded into warm/hot soil (Bristow and Abrecht, 1989), especially when they have been seeded early.

Retaining crop residues affects air temperature and soil temperature differently. Swella (2014) recorded higher day-time air temperatures and lower night-time temperatures 0.05m above soil level, when crop residues were retained. This is due to the fact that residues effectively 'blanket' the soil, reducing soil heat loss at night, which contributes to lower air temperature above the mulched soil, as it is the soil losing heat during the night that raises the air temperature just above ground level (Figure 1).

Figure 1: Effect of crop residues on daytime and night-time temperatures in the top 10cm of soil and the air immediately above ground level.



Source: Swella (2014)

Residue height and orientation (that is, whether it is standing or lying flat on the ground) also affects soil temperature, with Swella (2014) showing that taller standing residue had a greater moderating effect than shorter standing residue, and that residue lying flat on the ground had a greater effect than standing residue.

Stubble height, shading and soil temperature

Noel Keding, a strip-and-disc grower from Kojonup, WA, on the effects of stubble height on soil temperature, due to shading – a factor that can affect germination:
"Another disadvantage of the taller stubble left by the stripper front is slower germination caused by the shading."
Noel is considering how to address this at his new farm – where it can get a bit wet at seeding – possibly by seeding earlier to get some early growth before it gets cold.

Effects of stubble retention on frost impacts

In some environments across southern Australia, frost at anthesis, or soon after, can reduce crop yields, and the impact of a frost can be increased when heavy stubble loads are present. Jenkinson and Biddulph (2014) demonstrated that high stubble loads at York and Wickepin in Western Australia increased the impact and duration of frost events with respect to the crop. Where stubble was present, crop canopy temperatures were up to 0.5°C cooler than those where stubble had been removed before seeding by raking or blanket burning. Sub-zero temperatures lasted longer in trial plots with stubble than in plots without stubble. As a result, plots with stubble suffered more frost damage (measured by floret sterility and/or lower harvest index) and lower grain yield than plots without stubble.

The economic benefits of reducing stubble loads in areas subject to severe frost events may well outweigh the costs associated with nitrogen loss and other stubble management issues. However, in regions where there are fewer severe frost events, there is no agronomical or financial impact from stubble removal (Table 1). The analysis also does not take into account long-term benefits of stubble retention in relation to wind erosion, soil moisture and soil health.

At sites that experienced severe frost damage (Cuballing and York in 2016) and moderate frost damage (Cuballing in 2014 and 2015), increasing stubble loads reduced gross income in the range of $30 to $40/ha (for moderate frost) and $40 to $70/ha (for severe frost). The greatest reduction in gross income occurred where there were stubble loads above 2t/ha. At sites that experienced low-to-no frost damage (Cunderdin and Tincurrin in 2014), there was no opportunity cost from stubble management, and similar gross incomes were generated across all levels of stubble retention.

Table 1: Achieved gross income with increasing stubble loads in environments across the Western Australian wheatbelt grouped by yield potential and frost intensity.*

Trial	Production environment	Frost intensity	Maturity biomass (t/ha)	0t/ha	1t/ha	2t/ha	4t/ha	8t/ha
Cuballing 2016	high	severe	13	$105	$65	$57	$28	–
York 2016	high	severe	13	$138	$84	$66	$29	–
Cuballing 2015	medium	moderate	6.6	$207	$158	$164	$176	$129
Cuballing 2014	medium	moderate	6.8	$634	$570	$723	$679	$660
Cunderdin 2014	medium	low	6.3	$709	$674	$621	$692	$609
Tincurrin 2014	medium	low	6.1	$971	$973	$979	$991	$1,049
Average				$461	$421	$435	$433	–

* Note 1: Reducing stubble loads did not reduce gross income with no-to-low frost damage (even after taking into account the nutrient removal) and increased gross income by $30 to $40/ha in areas of moderate frost and $40 to $70/ha in areas of severe frost.

* Note 2: In areas that experience moderate and severe frost events, the highest gross income was generated by using a blanket burn to achieve complete stubble removal (control). The labour cost of removing the stubble through burning was estimated at $2/ha. Reducing stubble load by harvesting low and windrow burning, slashing or mulching was estimated to cost $6/ha and retaining stubble was assumed to cost $0/ha. The nitrogen nutrient removal cost was calculated at 4kg of nitrogen per tonne of wheat stubble (Scott et al., 2010). Average urea and grain prices ex-Kwinana from 2015 and 2016 were used in the calculation. It was also assumed that stubble was removed at the optimal time (just before opening rains) to ensure no potassium loss occurred (soil test results at seeding were consistent across treatments and supported this assumption).

Source: Jenkinson and Biddulph (2014)

Effects of stubble retention on heat stress

Information on the relationship between crop residues and plant heat stress is limited. Researchers have found that heat stress increases pollen sterility and reduces grain numbers per head and size across several crop types, including wheat, chickpea, maize and sorghum. However, there is no research investigating the relationship between stubble management (amount, cut heights, location) and heat stress associated with high soil and air temperatures during the reproductive phases of different crops. Also, as reported by Wang et al. (2007), no attention has been paid to temperature effects on the root system (specifically root heat stress), including in no-till systems where stubble retention has been found to affect the exchange of thermal energy between soil and atmosphere. So, while one would assume that stubble retention could reduce heat stress on plant root systems, and on growing plants, generally, it is not possible at this stage to quantify these benefits.

Managing high stubble loads with stripper fronts

Noel Keding, a strip-and-disc grower from Kojonup, WA, has observed that another benefit of retaining high stubble loads is lower soil temperatures over summer. While soil sampling with his agronomist after a run of three 40°C days, they measured the soil temperature in the top 10cm of a pasture paddock at about 33°C, compared to about 27°C at the same depth in a paddock where the stripper front had been used (leaving taller standing stubble in the paddock).

Noel suspects that the soil biology would benefit from lower soil temperatures over summer and that not 'cooking' the soil may help with issues such as non-wetting, which is an issue in the area, particularly in forest gravel soils. Noel believes that keeping the soil covered (with crop residues) stops the sun from baking it, which may help over time with the non-wetting.

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Chapter 5: Ecology and weed management in a stubble-retention system

Key messages

- Keeping weed seed banks low is achievable in stubble-retained systems.
- The presence of stubble can reduce herbicide efficacy, but this can be managed by selecting the appropriate pre-emergent herbicide, manipulating stubble loads and using spray technologies to improve herbicide coverage.
- Harvest weed-seed management is highly effective at intercepting and destroying seeds before they enter the soil's weed seedbank.

Interactions between stubble and weeds are complex and can be both beneficial to growers – contributing to weed suppression and decay – and a hindrance – contributing to herbicide interception and reduced adsorption. This chapter looks at weed ecology and control in areas with high stubble loads and investigates how to work with stubble loads and fractions to manage weeds, without the loss of critical ground cover.

Weed seed ecology

Crop residue present on the soil surface can influence weed ecology (germination and biomass) in reduced tillage systems by altering weed seeds' physical and chemical environment (Chauhan et al., 2006). According to Chauhan et al. (2006), weed response to crop residue depends on the quantity, position, allelopathic potential of the stubble, and the weed species' biology. In general, large amounts of residue (greater than 4t/ha) are needed to suppress weed emergence. These levels are achievable within windrows and chaff lines. High stubble loads can lead to optimal conditions for decay where micro-environments are created that promote bacterial, fungal and insect attack on weed seeds, leading to reduction in the weed seedbank. Stubble residue also reduces light penetration and reduces daytime soil temperature, which may also assist in reducing weed seed emergence of light-sensitive species (Chauhan et al., 2006).

Residue amount and crop type can also affect weed seed predation by ants and other insects in Western Australia (Minkey and Spafford, 2006). Research by Minkey and Spafford (2006) showed that too much residue reduced ant species diversity and reduced ants' sight lines to weed seeds impacting their ability to forage. Canola stubble was also shown to reduce ant species numbers and abundance, reducing weed seed predation rates. However, large numbers of seeds can nevertheless be foraged (removed from the soil surface) in a no-tillage system in areas of low residue, meaning that a no-tillage operation can be effective in minimising the weed seedbank.

High stubble loads can create an environment where fungi and other microorganisms can thrive, breaking down weed seeds before they germinate.

Source: David Minkey

The benefits of stubble retention on weed suppression and seed death, while acknowledging that this cannot be relied upon entirely for weed control, mean that it can play a key role within a fully integrated weed management program.

Improving herbicide efficacy in stubble

Chemical weed control in stubble-retained systems can be compromised when stubble and other organic residues intercept herbicides and prevent them from reaching the desired target. Herbicide efficacy can also be reduced when herbicide becomes tightly bound to the organic matter (Table 1). Reduced herbicide efficacy in the presence of higher stubble loads is a particular issue when using pre-emergent herbicides because stubble loads can intercept between 15 and 80 per cent of the applied chemicals (Chauhan et al., 2006; Buhler, 1995; Banks and Robinson, 1982).

However, not all forms of stubble are equal in their capacity to intercept and adsorb herbicide. Wet stubble, for example, has been shown to adsorb less herbicide, while partially decomposed older stubble was shown to adsorb more herbicide (Unger, 1994). When older stubble loads are sufficiently decomposed to constitute a reduction in biomass, this also decreases their adsorption capacity (Khalil et al., 2018; Selim et al., 2003).

Several factors affect the efficacy of pre-emergent herbicides in stubble.

Table 1: Pre-emergent herbicide mobility in the soil is primarily influenced by solubility and binding.				
TIGHT BINDING	RELATIVELY TIGHT BINDING	LOW MOBILITY	SOME MOBILITY	MOBILE
pendimethalin **trifluralin**	**prosulfocarb** **tri-allate**	**diuron** **propyzamide** **flumioxazin** **napropamide**	**atrazine** **simazine** **terbuthylazine** **pyroxasulfone** **bixlozone** **cinmethylin**	**Group 2 (B)** **metribuzin** **mesotrione** **Group 4 (I)** **metazachlor** **s-metolachlor**
Won't wash off stubble after spray has dried.	More difficult to wash off stubble after spray has dried.	Requires significant rainfall to remove from stubble.	Will wash off stubble with adequate rainfall.	Relatively easy to wash off stubble.
Suited to IBS (incorporate by sowing) with knife points and press wheels				Higher potential for crop damage

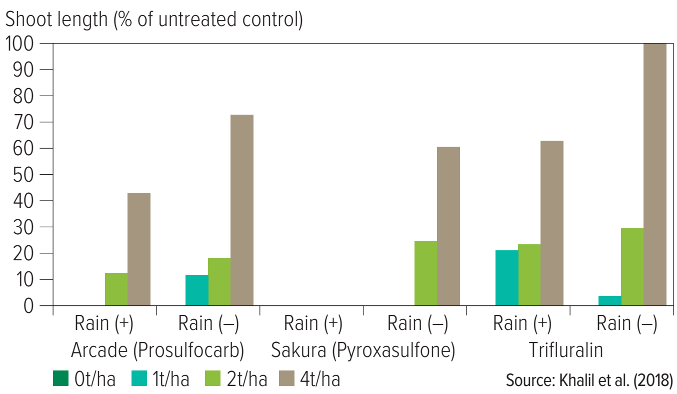
Source: Congreve (2022)

High stubble loads can reduce the efficacy of pre-emergent herbicides, especially trifluralin. Source: Nicole Baxter

1. Stubble load

Herbicides can be intercepted by, and bind to stubble, reducing the amount that reaches the target plant. Of the three most commonly used pre-emergent herbicides, trifluralin is the most tightly bound by stubble, followed by prosulfocarb and pyroxasulfone (Table 1). The tighter the herbicides bind to stubble, the smaller the amount that can be washed off into the soil with rain (Khalil et al., 2018). This can be seen in Figure 1 where the effect of 20mm of rain was measured in a paddock setting. However, loosely binding herbicides can also be lost to photodegradation and the evaporation of volatile ingredients (Congreve and Cameron, 2014).

Figure 1: Effect of wheat residue density (0–4t/ha) and +/– rainfall on the leaching of three pre-emergent herbicides and their effect on annual ryegrass shoot length.



Source: Khalil et al. (2018)

2. Crop type and age

When residue mass was the same, Khalil et al. (2019) found that barley and wheat residue intercepted more herbicide than canola, chickpea or lupin residue. In this study the effect of residue age on herbicide interception and leaching was relatively small and variable, which differs from other studies. However, with age comes decomposition, which leads to lower residue mass and less interception.

3. Stubble architecture

Khalil et al. (2019) showed that cutting wheat crops high left less crop residue on the soil surface and improved spray coverage onto the soil. This increased herbicide efficacy compared to short-cut residues.

The higher the crop biomass, the greater the benefit of cutting high, with respect to herbicide efficacy. As the amount of horizontal wheat residue increased from 0t/ha (all residue standing to a harvest height of 30cm) to 4t/ha (harvested at ground level so all residue lay horizontal on the ground), less and less Sakura reached the soil surface. When all wheat residue was standing, spray coverage on the soil was 14.6 per cent compared to 7.5 per cent when 4t/ha of stubble lay horizontally on the soil surface.

Similarly, when 1t/ha wheat stubble was left horizontal on the soil surface, spray coverage of the soil was 10 per cent but when the 1t/ha stubble load was left standing, an extra 5 per cent of herbicide spray was deposited onto the soil surface.

In another study from Ghadiri (1984) it reported that 60 per cent of applied atrazine was intercepted by standing (3t/ha) and flat (3.4t/ha) wheat stubble immediately following application. Three weeks later, after cumulative precipitation of 50mm, 90 per cent and 63 per cent, respectively, of the initially retained atrazine washed off the standing and flat residue.

Other stubble characteristics that affect herbicide interception and persistence are residue wetness, age and type. In the same study, Khalil et al. (2018) found less herbicide leached after rainfall when prosulfocarb and trifluralin were applied to wet residue rather than dry residue, but the initial moisture condition did not affect the leaching of pyroxasulfone from wheat residue (Khalil et al., 2018).

4. Herbicide technology

When spraying, a crucial factor is to get the chemical to its target, whether it be on the soil surface or covering emerged weeds. Spray droplets have a forward momentum when ejected from the sprayer. It has been found that the higher the ejection speed, the greater the spread of droplets that are intercepted by residue, causing less chemical to arrive at the specified target. This is exacerbated when the sprayer ejects fine, 'light' droplets.

Several practices can be used to mitigate stubble interception of herbicides and therefore maximise target application.

a) Water volume

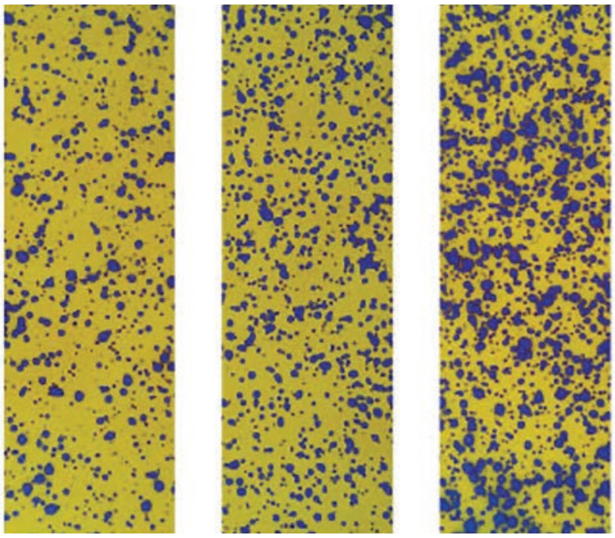
Borger et al. (2013) found that increasing the carrier volume from 50 to 100L/ha significantly increased ryegrass control by trifluralin and Sakura (Table 2) due to better canopy penetration of the herbicides to ground level.

Table 2: Spray coverage (%) of water sensitive cards and surviving annual ryegrass (plants/m²) for a range of carrier volumes (L/ha) at Cunderdin and Wongan Hills in Western Australia. Where P is the probability and SE is the Standard Error.

Site	Measurement	Carrier volume (L/ha)			P	SE
		50	75	100		
Cunderdin	Spray coverage (%)	9.5	17	25	<0.001	1.0
	Annual ryegrass (m^2)	14	11	8	0.023	0.1
Wongan Hills	Spray coverage (%)	8.4	13	26	<0.001	1.9
	Annual ryegrass (m^2)	34	26	14	<0.001	0.3

Source: Borger et al. (2013)

Figure 2: Spray cards set up in stubble by the Lower Eyre Agricultural Development Association showing that spray coverage increases with water rate.*



* Note: (from left) 60L/ha gave 11% coverage, 100L/ha gave 16.5% coverage and 140L/ha gave 26.5% coverage.

Source: Blake Gontar, SARDI

b) Sprayer speed

A FarmLink, CSIRO and GRDC Fact Sheet (2017) reported that only 10 per cent of herbicide reached the soil when it was sprayed at 30km/h, compared to more than 20 per cent when it was travelling at the slower speed of 20km/h. Spraying in the direction of the stubble rows maximised the herbicide reaching target plants or soil. Using reverse-facing, angled nozzles can reduce the speed somewhat, however the main factor is simply the sprayer speed. A speed of 15km/h is recommended when there are high stubble loads. Higher water volumes can also be achieved by using slower speeds.

c) Nozzle selection

Bigger droplets have been shown to penetrate canopies and 'splash' upon impact with the soil surface, therefore targeting weeds more effectively, however a large water volume, between 80 and 100L/ha, is required to achieve good coverage and efficacy. For more detailed information on nozzle selections see https://grdc.com.au/resources-and-publications/all-publications/factsheets/2022/maintaining-efficacy-with-larger-droplets

Herbicide efficacy can be increased in paddocks with high stubble loads by:

- increasing chemical and water rates;
- using nozzles that create larger droplets to increase spray coverage;

- confirming the optimal height of the boom is suitable for the nozzle selection and nozzle spacing for your spray rig, ensuring an even spread of droplets across the soil (or target) surface.
- slowing spray speeds to 15km/h.

Rules of thumb to follow when using common pre-emergent herbicides (sourced from WeedSmart pre-emergent herbicide guide)

Trifluralin:

- is most effective where there is little to no crop residue present;
- washes off most effectively when applied to dry crop residue; and
- requires incorporation into the soil by rainfall or mechanical means with 24 hours of application, which is not ideal for some disc seeders.

Prosulfocarb:

- is most effective where crop residues are less than 2t/ha;
- washes off most effectively when applied to dry crop residue; and
- provides some control of annual ryegrass if 5mm or more rain falls within seven days of application.

Pyroxasulfone:

- is effective, even at a crop residue load of 4t/ha;
- washes off easily when applied to either wet or dry crop residue;
- provides good control of annual ryegrass when just 5mm of simulated rainfall is applied 14 days after herbicide application; and
- reaches the soil at sufficient levels when the harvest height is 30cm or less (however higher harvest heights can reduce the amount of herbicide reaching the soil surface).

Harvest weed seed control

(Source: WeedSmart)

Herbicides are only one way of controlling weeds within a stubble-retention system and it is important to adopt an integrated system of weed control. While some methods are more effective when stubble loads are decreased, they allow for the retention of enough crop residue to prevent erosion. Several methods are available that kill weed seeds that mature in-crop, later in the season.

These are:

1. hay cutting
2. narrow windrow burning
3. using weed seed-destructor technology
4. chaff lining
5. chaff decking.

All of these methods can be grouped under the banner of 'harvest weed seed control' or HWSC. Walsh et al. (2017) showed that hay cutting provided the best weed seed control, provided a follow-up spray was done to control any escapees. All remaining HWSC methods resulted in very similar degrees of weed control, though their efficacy declined in higher-rainfall zones or where weed seed shatter had occurred before seed collection.

1. Hay cutting

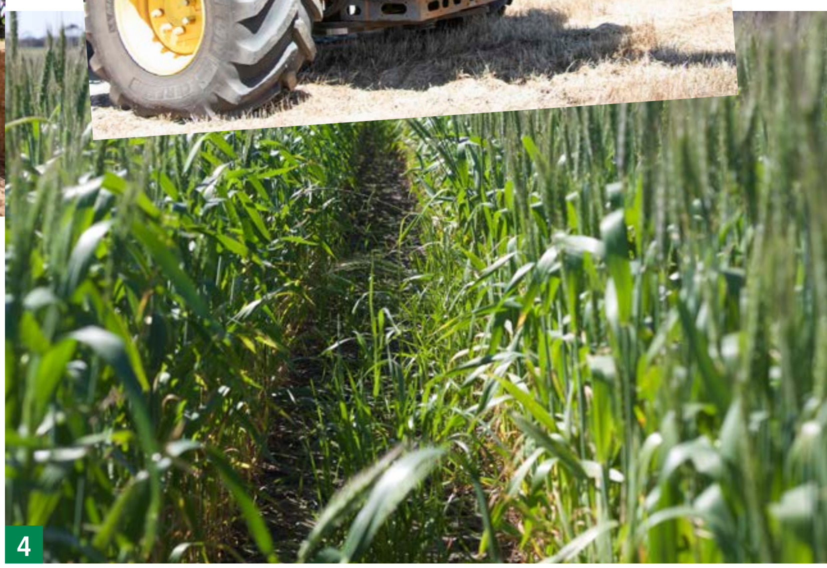
Herbicide application in conjunction with hay cutting reduces the ryegrass seed set. Cutting hay before weed seeds mature results in a more significant reduction of the weed seedbank than baling straw after harvest, due to the shattering of weed seeds upon maturity.

1

2

3

4



Harvest weed seed control (HWSC) captures and destroys weed seeds at harvest. Harvesting low maximises weed seed collection. Source: WeedSmart

2. Narrow windrow burning

The efficacy of weed management through windrow burning is dependent on the temperature of the burn.

The temperature needs to exceed 400°C for 10 seconds to kill ryegrass and 500°C to kill wild radish (Table 3).

Table 3: Effects of temperature and duration of exposure on the percentage germination of annual ryegrass and wild radish.

Annual ryegrass						
	Temperature (°C)					
	200	225	250	275	300	400
Duration (seconds)	Survival (%)					
10	–	–	–	–	77	0
20	92	70	55	57	5	0
40	90	26	15	6	0	0
60	89	1	0	0	0	0
80	74	0	0	0	0	0
Wild radish						
	Temperature (°C)					
	300	350	400	450	500	–
Duration (seconds)	Survival (%)					
10	89	88	85	22	0	–
20	89	67	1	0	0	–
60	1	1	0	0	0	–

Source: Walsh and Newman (2007)

3. Weed seed-destructor technology

To manage herbicide-resistant weeds, seed-destruction technology (seed mills) offers an alternative to other HWSC methods. Seed mills grind the chaff and weed seeds coming through the header, enabling weed seeds that are picked up with the crop to be eliminated. The kill rates for most weed species are high (Table 4) but overall efficacy is determined by how much weed seed is collected at harvest. In one study, about 93 per cent of ryegrass seed was retained at wheat crop maturity (Walsh et al., 2017). However, the proportion of ryegrass seed sitting above 15cm can differ from season to season (Broster et al., 2015). The timing of collection is also critical. Walsh and Pwles (2014) found the retention of wild oat seed was above 80 per cent, but if harvest was delayed for 28 days, seed retention fell to 39 per cent.

Table 4: Number of weed seeds placed in wheat chaff and percentage destruction of seed from 11 weed species using the integrated Harrington Seed Destructor test stand.

Weed species	Seed No.	Seed kill (%)
Annual ryegrass	1000	96
Wild oats	200	99
Brome grass	200	98
Awnless barnyard grass	1000	99
Flaxleaf fleabane	25000	99
Sow thistle	3000	99
Wild radish	200	99
Indian hedge mustard	2000	99
Windmill grass	3000	97
Barley grass	500	99
Feathertop Rhodes grass	3000	98

Source: Adapted from Walsh et al. (2017)

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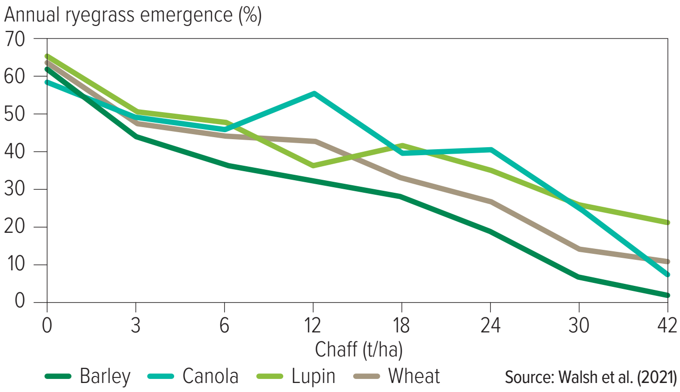
4. Chaff lining

Chaff lining concentrates weed seeds collected in the chaff fraction into a line behind the header. These seeds fail to germinate due to suppression from high residue levels (which form a light and physical barrier), predation or decay (Figures 3 and 4). While weeds will still germinate, interspecific plant competition reduces their number and fecundity, and these areas can also be targeted with herbicides.

Figure 3: Graph showing the emergence of annual ryegrass through wheat, lupin, barley and canola chaff at eight different rates (t/ha) in a pot trial conducted at Wagga Wagga, NSW.

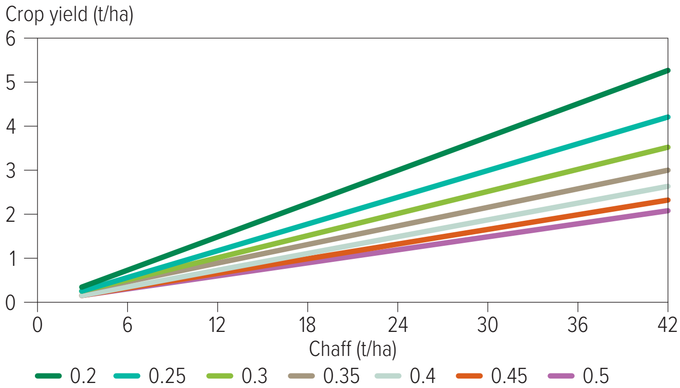


Source: Walsh et al. (2021)

5. Chaff decking

An alternative to chaff lining is chaff decking, where the chaff fraction is placed on the wheel tracks of a controlled-traffic system. The disadvantage of this system is that it halves the chaff fraction biomass, which lessens the suppression effect of the residue on weed germination. Anecdotally, the advantage of spreading the chaff on wheel tracks is that the weeds are driven on and compacted by machinery throughout the year, which creates a hostile environment for growth.

Figure 4: Graph showing the estimated crop yield for various chaff rates at different chaff widths for a 12m-wide harvester and 0.3m chaff line.*



* Note: This was calculated irrespective of header type, but the different chaff proportions could relate to different fronts, that is:
20% = stripper front, 40% = draper front.

Source: Walsh et al. (2021)

Chaff lining concentrates the chaff fraction (and weed seeds) into a narrow band behind the harvester. Source: WeedSmart

Chaff decking. Source: AHRI

Cost of harvest weed seed controls

Every weed-management tool comes at a cost. Table 5 summarises the cost of the different HWSC techniques.

Table 5: Cost of harvest weed seed control methods.

	Windrow burn	Chaff cart	iHSD	Seed terminator	Bale direct	Chaff tramlining	Chaff lining
Capital cost	$500	$80,000	$160,000	$120,000	$340,000	$20,000	$5000
Depreciation (10% per year)	$50	$8000	$16,000	$12,000	$34,000	$2000	$500
Depreciation ($/ha)	$0.02	$2.67	$5.33	$4.00	$11.33	$0.67	$0.16
Extra fuel (L/t)	–	0.2	1.5	1.5	0.4	–	–
Extra fuel ($/ha)	–	$0.55	$4.12*	$4.12*	$1.10	–	–
Annual repairs and maintenance	–	$2000	$9000	$9000	$9000	$500	–
R&M ($/ha)	–	$0.67	$3.00	$3.00	$3.00	$0.16	–
Reduction in harvest capacity	–	5%	16%*	16%*	16%	–	–
Reduction in harvest capacity ($/ha)	–	$1.67	$5.33*	$5.33*	$5.33	–	–
Nutrient removal cost ($/ha)	$20.62	$6.25	–	–	$20.62	$6.25	$6.25
Burning cost (labour $/ha)	$2.00	$1.00	–	–	–	–	–
Total cost ($/ha)	$22.64	$12.81	$17.78	$16.45	$41.38	$7.08	$6.41
Income from bales ($/ha)	–	–	–	–	$75 – $125	–	–

* Note: prices change over time. Source: WeedSmart (2019)

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Chapter 6: Stubble retention and crop disease

Source: GRDC Stubble Initiative - edited by Geoff Thomas, Department of Primary Industries and Regional Development, WA (DPIRD)

Key messages

- monitor crops and determine disease risk through Predicta® B testing;
- keep inoculum levels as low as possible by including non-host crops in rotations and controlling grass weeds early in break crops;
- select paddocks with low disease risk;
- manage summer weeds and the green bridge;
- consider stubble management and inter-row sowing for some diseases; and
- incorporate a combination of resistant varieties, crop rotation and fungicide management.

Stubble retention can increase the risk of carryover of many crop diseases, as many stubble-borne diseases are necrotrophic and do not need a living host to survive. This makes disease management an important priority when retaining crop residues. In cereal-dominant rotations, incorporating a break crop is often the most effective way to manage disease risk; fungicides may provide an economic method of control for some diseases, but not for others.

Practices that reduce surface stubble – such as cutting low, incorporation, grazing and burning – or mechanical practices that increase the rate of stubble break down, can reduce disease inoculum levels. However, removing stubble increases the risk of erosion and removes the source of carbon associated with healthy biological activity and general benefits to soil.

Environmental conditions in the preceding summer and during the growing season are important in determining the impact of soil-borne diseases on yield. For example, low summer rainfall reduces the potential for breakdown of pathogen inoculum, lowers stored moisture within the soil profile, reduces breakdown of herbicide residues and limits nitrogen mineralisation. These all limit the ability of the crop to tolerate soil-borne pathogens.

Risks of stubble-borne and crop residue-borne diseases such as crown rot (*Fusarium pseudograminearum*), take-all (*Gaeumannomyces graminis var. tritici*), rhizoctonia root rot (*Rhizoctonia solani* AG8), common root rot (*Bipolaris sorokiniana*), eyespot (*Oculimacula yallundae*), yellow leaf spot (*Pyrenophora tritici-repentis*), spot form net blotch (*Pyrenophora teres f. maculata;* SFNB) and net form net blotch (*P. teres f. teres*; NFNB) can increase with stubble retention, particularly in continuous cereal-cropping systems.

Suppressive soils

Conservation systems can also increase beneficial microbial and fungal populations that suppress soil-borne and stubble-borne diseases. Disease-suppressive soil is defined as soil in which pathogens cannot establish or are maintained at a low level. Complete control of rhizoctonia root rot (*Rhizoctonia solani* AG8) and take-all (*G. graminis var. tritici*), has been established after five to 10 years of no-till and stubble-retaining management. The development of suppressive populations occurred independently of the rotation. Roget (2006) found that balancing carbon (C) and nitrogen (N) inputs via stubble quality, and promoting high carbon turnover and low nitrogen mineralisation altered soil composition and promoted the activity of suppressive microorganisms.

Managing stubble for disease

Yellow leaf spot

Yellow leaf spot (YLS) is stubble-borne and dispersed by rain within a paddock but can also be blown in from nearby paddocks. YLS can persist for two years on stubble, although a one-year break from wheat with a pulse or canola crop will generally lower inoculum levels, except in very dry conditions. Practices that reduce surface stubble such as grazing or tillage will reduce inoculum levels.

Eyespot

Eyespot is an emerging stubble-borne disease that is increasing in prominence due to the increased practice of stubble retention, direct drilling and the inclusion of more cereals in rotations. The fungus can survive in the stubble for two years or more but including break crops in rotations reduces inoculum levels. Burning stubble can reduce the inoculum level but does not eliminate the disease.

Septoria

Septoria spores can travel large distances via wind and as such are not solely related to within-paddock or within-farm management. Stubble reduction by burial, burning or grazing can reduce inoculum but will not reduce disease caused by spores blown in from other paddocks early in the season. In most instances, a one-year rotation away from wheat is highly effective in reducing early disease occurrence.

Net and spot forms of net blotch

The net form of net blotch (NFNB) and the spot form of net blotch (SFNB) can survive on infected barley stubble for up to three years. Reducing stubble loads can help speed disease breakdown (by reducing inoculum levels) reducing the time that the paddock remains in a high-risk category for net blotch.

Chocolate spot and Ascochyta in faba bean

Chocolate spot *(Botrityis fabae* and *B. cinerea*) and Ascochyta on faba bean (*Ascochyta fabae*) can carry over from one season to the next on bean stubble, infected seed and volunteer plants. Stubble reduction, incorporation of resistant varieties, crop rotation and implementing a sound fungicide program can help manage the diseases.

Blackleg in canola (take-all)

Blackleg survives on canola stubble, producing fruiting bodies that contain large quantities of airborne spores that can travel several kilometres. To control the disease, it is important never to sow canola into the previous year's canola stubble. Sow canola at least 500m away from the previous season's stubble to reduce blackleg severity and use resistant varieties. Two-year-old stubble may cause disease if canola is sown on previous stubble rows or if cultivar resistance has been overcome. Stubble destruction is not effective in reducing blackleg infection.

Crown rot

Crown rot fungus survives in winter cereal residues and dense stubble cover, or where dry conditions have made residue decomposition slow. Stubble-management practices such as spreading and slashing through cultivation can increase the rate of stubble decomposition but can also spread infected residues across the paddock due to loss of soil moisture. Where there is no stubble moisture or inadequate time to accelerate stubble breakdown, these practices can increase infection rates in the next winter cereal crop. Grazing stubble can also spread inoculum.

Stubble and crop pests

Pests such as mice, snails and slugs, earwigs, millipedes and other invertebrate species are attracted to stubble. Stubble retained on the soil provides food, shelter from predators and a microclimate away from harsh extremes. To control pests, control their sources of food and shelter. In the high rainfall zone, canola is especially vulnerable to pest damage.

An integrated approach to pest management achieves the best control. Regular paddock monitoring is essential for a proactive approach to pest and insect management. Baiting, strategic tillage and burning are still valid management options to reduce pest numbers but must be done correctly.

Mice have also become more of an annual, rather than a cyclical, problem in cropping systems. Source: Nikki Van Der Weyer

Italian white and conical snails attached to stubble have the potential to affect crops at all stages of development and are found Australia-wide, especially closer to coastal areas. Source: Kym Perry, SARDI

Russell and Graeme Dunlop from Rupanyup in Victoria:

"We spread mouse bait behind the seeder via the small seed box for all crop types, with the exception of canola, where it is spread following sowing. If snails are an issue, baiting will be done," Russell said. Although they are aware that burning would be the most effective method of snail control, this is something the Dunlops try to avoid. "It doesn't align with our long-term goal of stubble retention," Russell said. "When it comes to insect pests, seed is treated and application of broad-spectrum insecticides is avoided if possible."

Snails and slugs have the potential to affect crops at all stages (initial germination, plant growth, maturity and grain development), and snails can also contaminate grain at harvest. Different species have different movement patterns, habitats and preferred food sources. Knowing which snail and/or slug species are present and understanding their behaviour is critical to selecting the most effective control methods.

The key factors to consider when managing snails and slugs include: paddock history, soil type, environment, weather conditions, existing stubble and stubble management, as well as crop management, including time of sowing, seed source and potential seeding treatments.

Monitoring their activity and implementing control measures before they mate and lay eggs is crucial for minimising numbers. The best time to monitor snails is when they are on the move, specifically when relative humidity levels are high (about 90 per cent – such as on dewy mornings and evenings, or during showers). The key monitoring periods are pre-sowing, in-crop, spring and post-harvest.

A rule of thumb is that grain contamination at harvest will be likely if snail numbers are above 20/m² in cereals and 5/m² in pulses and canola.

Key points to know when controlling snails are:

- **combining cultural and chemical methods will provide optimal snail control;**
- **controlling snails before egg laying commences is essential for successful integrated control;**
- **cultural control methods including cabling, rolling, slashing and grazing are effective;**
- **strategic burning remains the most effective method of pre-breeding snail control – provided that a hot, even burn is achieved;**
- **there are currently no means to control juvenile snails (less than 7mm) after sowing – the key is to start baiting before snails lay eggs; and**
- **stop baiting eight weeks before harvest to avoid contaminating grain, and only use registered products.**

Snails love summer weeds as they provide shelter, moisture and food through the summer. Controlling summer weeds removes an important source of moisture. Snail management using several practices over the summer period, well ahead of crop establishment, is vital, especially as limited control methods are available following crop seeding and establishment.

Research into the biology of snails is ongoing and aims to identify the environmental factors that lead to snail activity and the optimum timings for bait application.

Slugs are common in high-rainfall areas and damage emerging crops, particularly canola.

Slaters in stubble. Source: Cesar Australia

Earwigs, millipedes and slaters

Earwig damage looks similar to slug damage, and mostly occurs in high-rainfall regions. Little research has been done on their risk to cropping situations. Earwigs mainly attack canola but have been known to attack cereals, lupins and some legumes. There is anecdotal evidence that bean stubble increases earwig abundance.

Millipedes are present in most regions across Australia. Although they rarely damage crops, most reports in which they have caused crop damage come from areas with medium-to-high rainfall, and correspond with:

- **stubble loads greater than 5t/ha (because as high stubble levels are depleted, large populations of millipedes that have fed on the stubble then seek a new food source);**
- **the growth of young canola plants; and**
- **the presence of heavy soils.**

Slaters have been observed causing damage to canola seedlings, wheat, lentils, lucerne and chickpea crops.

Black Portuguese millipedes in stubble. Source: GRDC

Monitoring for invertebrates is difficult and large invertebrate populations do not necessarily translate to crop damage. The only known threshold of damage is 8 earwigs/m². There are no registered chemicals for control of these types of invertebrates in broadacre cropping.

Manage invertebrates by cultivation, removing summer weeds and reducing stubble residue through burning, incorporation or grazing. Windrow burning may reduce millipede populations, and strategies that increase emergence, such as higher seeding rate, can offset any damage caused.

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Chapter 7: Machinery solutions and stubble management for crop establishment

Key messages

- Full stubble retention can create challenges at seeding and during crop establishment, especially when stubble loads are high.
- There is no single solution to managing heavy stubbles; stubble management decisions may need to be reviewed each year. In some seasons, stubble removal can be a good agronomic option.
- Stubble management requires a systems approach that takes into account seeding technique, herbicide application and crop type.
- Managing stubble for seeding needs to start with the seeder and end with harvest.

It does not matter where you are in your farming system to a complete no-till/stubble-retention system; everyone can improve their system in some way, and it does not have to be expensive. There is no one rule to suit all farming systems. Each grower must weigh up the options and choose the practices that suit their enterprise.

Seeding into retained stubble is likely to be difficult if:

- there is more than 3t/ha of stubble;
- stubble is flattened or wet;
- stubble is long and loose;
- stubble has not broken down; and
- soils are wet and loose.

There are six 'best bets' to focus on when moving towards a full stubble retention system:

1. Start with the seeder
2. Spread the residue load
3. Try residue managers
4. Adjust the cutting height to suit the stubble load
5. Keep the stubble standing
6. Sow between the stubble rows

Start with the seeder

Residue management begins at harvest, for the benefit of the seeding operation. If the seeder can handle the residue, then fewer compromises will be needed at harvest. However, despite one's best efforts at harvest, there will always be clumping. A bar that can cope well with residue will save a lot of time at seeding time.

Adjustments can be made to the existing seeder, or it may need replacing. A seeding bar with five ranks is the best option, allowing the tynes across the seeder to be one row space and two ranks apart, or two row spaces and one rank apart.

Questions to consider:

Does the seeder have adequate clearance under the frame?

Minimum clearance of 50cm is required. If clearance is inadequate, considerable work will be needed to make effective changes.

Are the rank spacings adequate?

Minimum 50cm rank spacings are required. Most modern seeder frames have ranks 65 to 80cm apart. Narrow rank spacings may mean the bar needs rebuilding.

Does the bar have a good tyne layout?

In general, more ranks are needed for narrow row spacings; allow tynes to be at least one row space and two ranks apart, or one rank and two row spaces apart. Most seeders are between 3 to 5 ranks.

Is the tyne cross section suitable?

A curved shape on the leading edge with a diameter of 40 to 85mm is best. 'Flat on' tynes are better than 'edge on'.

What is the tyne shank angle?

The best tynes are vertical or tilted backwards. High 'C' shapes, where the tight part of the 'C' is above the stubble flow, work well.

Is the drawbar long enough to add an extra rank at the front?

Turning radius will be compromised if the drawbar is too short.

Are the wheels in a good position within the frame?

Wheel position can limit tyne mounting options. Blockages can occur if residue flows onto the rear half of a wheel.

Are the wheels outside the frame?

Seeder bars with the wheels outside the frame offer greater flexibility for changing the position of tynes.

Will the length of the seeder impact on seeding-depth precision?

Long seeders can compromise seeding-depth precision. Press wheel-controlled seeding depth is an advantage.

Can you increase row spacing as an alternative to increasing seeder length?

This reduces tyne and point numbers, but generally results in slightly reduced yields.

What if you cannot get a good tyne layout, even with five ranks?

Consider cutting the frame to correct the layout. Leave a row out, or change the row spacing in the difficult row. Disc coulters or residue manager wheels can help troublesome rows. Put more tynes at the front, where they are working in undisturbed material. Set a shallower depth for rows that get a lot of residue placed in them by the following tynes.

Are there any catch points that will cause residue clumping?

Look for the manufacturers that make a neater product (for example, recessed bolt heads for point mounts). Knifepoints are generally less likely to catch residue than wide sweeps.

Can the seeder be operated more efficiently?

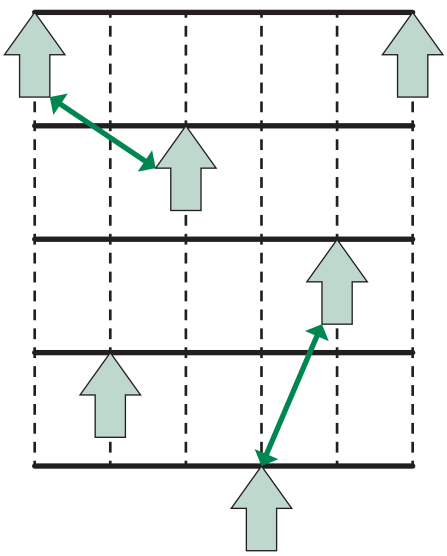
Generally, working more shallowly and at lower speeds will lead to less clumping as there will be less soil throw.

Tynes vs disc seeders

Tyned sowing equipment can be cost effective and suit a large range of soil types. However, when sowing into stubble, the effective use of a tyne system relies on clean stubble flow, as there is no cutting mechanism on the actual tynes.

Seeding into stubble is likely to be more difficult with conventional tyne implements if the stubble load exceeds 3t/ha. Seeding difficulties can be exacerbated if the residue has been flattened by traffic, if the stubble is longer than 250mm or if the stubble is prone to dislodging and clumping due to wet soil. In these situations, residue can catch and build up on the seeder and cause blockages.

Figure 1: Tyne layout over five ranks showing the ideal inter-tyne spacing for improving drill capacity.



Source: J Desbiolles (undated). Adapted from GRDC, 'How do I set up my seeder to handle stubble?'

Tyned seeders are not as good as disc seeders at handling longer straw.

Wider tyne spacing across and along the bar will improve stubble handling. Modifying the profile and tyne layout of the seeder bar can reduce stubble clumping and blockages (Figure 1) and improve the machine's ability to cope with the heavy stubble loads (5 to 10t/ha) often found in high rainfall areas.

To minimise residue clumping and maximise uniform crop establishment for tyned seeders:

- cut the stubble short;
- chop and spread residue evenly unless using weed seed capture;
- maximise tyne spacing on the seeder to prevent clumping and blockages;
- operate in dry stubble at a lower speed;
- sow between the rows or sow diagonal to stubble rows or in the same direction as the stubble lean; and
- remove some straw and bale it to reduce stubble quantities to manageable levels.

Tyne seeders need to be set up to maximise tyne drill capacity. The vertical clearance of the seeding tyne should be at least 1.5 times the height of standing residue. The stubble height should be no more than 65 per cent of the vertical height between the ground surface and tyne shank or mounting head. Tyne layout should be spread over three or four ranks to maximise the inter-tyne spacing (Figure 1).

Disc seeders have less difficulty seeding through residue because they roll through the stubble, while tynes tend to rip it up, creating clumps and blockages. They are generally regarded as better able to handle heavy/tall stubble and stony soils than tyne-and-press wheel machines. However, they are less efficient when soils are wet or compacted.

Disc seeders can handle heavy crop residues without clumping or blocking. However, they can result in uncut residue being pushed into the furrow by the disc opener ('hair-pinning'), which results in poor furrow closure and compromised seed-to-soil contact.

Controlling hair-pinning is critical to the success of a disc-seeded operation and is achieved by minimising the need to cut residue and maximising the capacity to cut residue.

The requirement to cut residue can be minimised in several ways.

- Harvest stubble at the maximum possible height for your seeding system and spread straw and chaff uniformly to minimise residue load on the ground.
- Practise inter-row seeding using precision guidance to avoid the bulk of standing stubble. This is best achieved at wider row spacing (30cm) as disc seeders often do not track as well as tyne seeders, especially in hard soils.
- Seed in the same direction as harvest to control potential residue blockage with low-clearance disc units.
- Use controlled traffic farming with bare wheel tracks to take full potential of inter-row sowing.
- Use residue managers (row cleaners) to remove excess residue in the path of the disc opener. Row cleaners can be used to complement inter-row sowing when dealing with matted loose residue, such as on header trails.

Table 1: Advantages and disadvantages of various disc openers.

Disc opener	Example Advantages	Disadvantages
Double disc	Sows at a precise seed depth subject to seed landing between the discs Lowest footprint with least soil and residue disturbance Most compatible with narrow row spacing and compact frame	Limited fertiliser crop safety Higher tendency to hairpin (NB: Staggered double disc blades improve residue cutting ability) Limited ability in compact soils
Triple disc	Sows at a precise seed depth subject to seed landing between the discs Leading coulter improves residue handling and provides sub-seed furrow tilling Coulter disc blade design allows for variable furrow disturbance	Deep banding coulter option Disc coulter option requires extra frame weight to secure penetration in compact soils, with additional implement draft. Disc coulter blades generate significant soil throw and may limit seeding depth in compact and moist soils Coulter creates challenge in sticky soils
Vertical single disc (breast angle)	Depth gauging can be independent of furrow pressing Breast angle improves disc drive in soft soil Low disturbance especially when shallow seeding Compatible with wet soil when surface is dry Option for mid-row fertiliser banding exists	Side forces must be balanced Hairpinning tendency associated with shallow seeding, unless row cleaners are used Fertiliser toxicity risks in single shoot systems Some depth gauging wheel designs limit performance in sticky soils and may create bulldozing tendency in soft soils
Undercut single disc (combined tilt and breast angle)	Tilt angle reduces weight requirement for penetration, with potential for lower draft Depth gauging can be independent of furrow pressing Option for mid-row fertiliser banding exists Compatible with wet soil when surface is dry	Side forces must be balanced Large tilt angles reduce disc blade speed ratio, which can mitigate residue cutting capacity Fertiliser toxicity risks in single shoot systems Large tilt angle increases soil disturbance Some depth gauging wheel designs limit performance in sticky soils and may create bulldozing tendency in soft soils
Disc and blade	In furrow double shoot options combine fertiliser access efficiency with seed and fertiliser separation Seed slot moisture conservation benefits under some conditions. Any hairpinning of residue occurs away from the seed zone Sub-seed furrow tilling ability	High wear of blade and disc in abrasive soils. High weight needed for penetration where soil cutting extends to below the seed zone. High draft requirement in compact soils.

Source: Ashworth et al. (2010) and Desboilles (2023, pers. comm.)

The capacity to cut residue can be maximised by:

- operating with dry stubble on firm soil;
- using a sharp cutting edge with a shallow disc wedge angle to deliver an effective parting cut during residue cutting;
- operating at the correct depth for disc size;
- using an unconstrained disc drive to maximise the sliding cut component during residue cutting;
- using enough downward pressure on disc units to cut through matted residue; and
- driving in the same direction as the leaning stubble so that stems are cut at an angle.

Avoid post-harvest working operations as residue handling is significantly impaired in soft soil conditions. This is particularly noticeable for first time growers moving to disc seeding systems.

Discs produce minimal soil disturbance, reduce draft requirements and make it easier to produce narrower row spacings. The cost of purchasing disc openers, along with issues to do with penetration, compaction, hair-pinning, and seed and fertiliser placement, have restricted uptake in the past. But with greater recognition of the value of stubble retention, disc seeders are being reconsidered. New designs, including ones with residue manager wheels, offset disc mountings and different disc sizes, are addressing issues that have previously been obstacles to uptake (Table 1).

Standing stubble is much easier to seed into than stubble that has been trampled by livestock or compacted by machinery. Only make wheel marks where necessary, and in the same direction as the rows, and where possible, keep sheep off the paddocks.

Spread the residue load

Modern harvesters are designed to reduce straw to small pieces and spread it over the whole width of the harvester front, but the result is often an uneven spread. Making some adjustments to the harvesting operation to ensure straw pieces are short and evenly spread will make seeding a much smoother operation (Table 2).

Table 2. Advantages and disadvantages of different strategies to improve straw spread across the harvester front.

Strategy	Advantages	Disadvantages
Spinners	Cheap Low power demand	Inadequate spread
Choppers and spreaders	Better spread performance	More expensive; more power needed
Stripper front	Less material through harvester (increased capacity).	Head loss with brittle straw; may need seeder change to cope with tall straw
Chaff-cart, chaff deck, chaff lining	Collect harvested weed seeds can form basis for animal feed	Disposal of chaff heaps is an issue; low and early-shed seeds missed
Chaff top	Adds to bale weight	Can lose weed seeds
Baling	Could be good weed seed remover if baled off harvester	Removes organic matter and ground cover
Chaff on tramline	Reduced handling of chaff	May spill off tramline

Source: Ashworth et al. (2010)

Residue distribution is improved when large volumes of straw are thrown (Left) whereas wind can play a big factor in residue distribution with low volumes (right).

Source: Ashworth et al. (2010)

Use a residue manager

Residue managers can make the difference between successful seeding or having to stop and burn the residue. They should be considered if seeding problems persist. A range of newer residue management tools can be fitted to the seeder.

- Stubble tubes are a cheap and simple tube to stop stubble wrapping around tynes; these are helpful if made and fitted well.
- Row-cleaner residue manager wheels are a more expensive option that is better suited to wide row spacings.
- Disc coulters are wavy, big (50cm) coulters that throw soil (incorporate herbicides) and cut residue more effectively.
- Treadwheel residue manager wheels are an experimental concept that pins the residue where it lies rather than moving it out of the way.

Adjust the cutting height

Cutting stubble high is preferred as it makes for more efficient harvesting and generates less residue to be spread. But high-cut stubble only works if the seeder can get through it. For a seeder that is struggling, shorter standing stubble will be easier to get through. There are three main options for reducing cutting height (Table 2).

Table 2: Advantages and disadvantages of three different ways of reducing the cutting height of stubble.

	Advantages	Disadvantages
Cut low with harvester	No extra operations	Higher wear and fuel use by harvester; reduced harvester capacity with possible extra grain loss due to cleaning overload; poor spread likely
Use a second cutter bar	No extra operations; faster harvesting; better straw spread	Poor action at speed or when straw is damp; easily damaged by rocks
Use a slasher	Faster harvesting; better straw spread; spreads labour demand	Extra operation; fire risk on hot days; straw break-up is poor on cool days

Source: Ashworth et al. (2010)

Keep stubble standing

A crop seeded in the middle of standing stubble; an example of inter-row sowing.

Source: Ashworth et al. (2010)

GRDC

Implement auto-steer and seeder tracking for precise row sowing

(Author: Jack Desbiolles, AMRDC, University of South Australia)

Auto-steer offers an effective method for seeding into the previous year's residue. It is now possible to steer between last year's rows and reduce clumping to nil where stubble has been left standing.

The following approach is best with auto-steer:

- Establish an 'up and back' pattern.
- Implement 2cm accuracy, if possible, though many are finding that 10cm accuracy is adequate.
- Use a balanced tyne layout (left and right of centre to ensure accurate tracking behind the tractor).
- Match the length pairs of points left and right of centre.
- If steering manually, ensure you create very straight lines.

Navigating in heavy stubbles, at night or when using discs, can be difficult. The problem is easily solved using auto-steer or GPS guidance. A seeder that maintains precise pass-to-pass accuracy regardless of the terrain opens the door for guided sowing relative to existing stubble rows. Accurately sowing in relation to previous stubble rows can be critically important to successfully establishing crops in low or uneven moisture situations. In high-residue loads, inter-row sowing into standing residue with tyne seeders can decrease or eliminate residue clumping and interference over the seed rows.

With disc seeders, inter-row sowing help controls residue hair-pinning, where discs fail to cut through the stubble resulting in residue build up below the disc, especially when used in combination with residue managers. It also ensures good soil-to-seed contact. In both cases, inter-row sowing significantly improves the efficiency of crop establishment, enabling lower seed rates, and higher speeds at similar pre-emergence herbicide safety and efficacy. At the same time, the intact stubble can effectively shelter seedlings against wind damage and soil moisture loss. Inter-row sowing also reduces take-all and crown rot disease pressure and makes it easier to harvest pulse crops.

Alternatively, in non-wetting soils and low-fertility sands it is often advantageous to place the seed in proximity to the previous stubble row rather than in the middle of the inter-row because more moisture and nutrients are present in an existing furrow compared to the inter-row zone. This approach results in drastically improved germination, a longer sowing window, more even crop development and increased grain yield. While near-row (or edge-row) seeding and centre-row (or on-row) seeding can both be used to generate these benefits, edge-row seeding is preferred to retain stubble integrity with tyne seeders, and to minimise the hair-pinning sometimes associated with disc seeders. Overall, better results are achieved with a side banding configuration.

With accurate implementation guidance, contiguous row sowing within a dedicated permanent seed zone may, over time, create improved fertility strips. While there are a number of guidance technologies with various capabilities, implementing tracking stability is the necessary starting point.

Seeder tracking stability

Accurate, sub-inch, real-time kinematic (RTK) guidance of the tractor and stable implement tracking are both necessary for achieving guided-row sowing. Tractor guidance systems increasingly use sophisticated 'terrain compensation' software to accurately steer the tractor hitch along the guidance path. Different towed seeder bars have different tracking abilities, so accurate auto-steering of the tractor alone may not always be sufficient. The stability of the seeder is influenced by the forces applied onto the bar in relation to the tractor pulling force.

The forces applied on the seeder bar include:

- forces at the implement hitch, including tractor pull;
- the weight of the seeder bar;
- tyre reactions, including rolling resistance;
- opener draft, penetration and side forces; and
- drag forces from a tow-behind the air-cart.

An air-seeder fitted with a steerable draw-bar hitch for active implement guidance.
Source: Desbiolles (2017)

An imbalance in horizontal forces (also called 'draft' or 'side' forces) creates drift as the implement's centre of draft tries to line up with the tractor centre of pull. This drift can be random (in response to hanging soil conditions or working depths) or systematic (when the implement is set incorrectly or its weight causes the implement to crab downhill when operating along a side slope). Random drift is a significant issue when trying to practise accurate inter-row sowing, while systematic drift may sometimes be managed by following the same seeding pathway, season after season.

Implement drift is measured by the degree of skew angle in relation to the travel direction. While at work, forces from the implement's wheels and the furrow openers create 'restoring' forces that stabilise the bar and limit drift within a maximum skew angle. Successful guided row sowing requires the bar to travel in a straight direction. With large multi-rank bars, even a small skew angle, such as on a side slope, quickly becomes incompatible with guided-row sowing because it creates variable seed furrow spacings.

A small skew angle with very compact bars (one or two ranks) is generally acceptable and guided-row sowing can be achieved by following the same seeding pathway, season after season.

A balanced bar design is the first requirement for good tracking stability. This includes symmetrical layouts of both openers and wheels, and a uniform distribution of the seeder bar weight, including over the wing sections.

The position of the wheels relative to the tynes can improve or worsen tracking. For example, working depths will be affected if they ride into the furrow or over soil throw ridges during skewing. Wide tyres placed on a walking beam are typically least prone to these issues. A longer A-frame has the advantage of stabilising drift at smaller skew angles. A common rule of thumb is that the draw-bar length should be half the implement width to give sufficient restoring power to rigid frame wheels.

Constant tillage depth across the bar is critical. It is best achieved by openers that follow ground contours. This is especially important on wider, less-stable bars and undulating land. A poorly set-up bar or inadequate floatation in soft soils can create a constant force imbalance that causes systematic drift to the left or right. You can check the extent of systematic drift by sowing up and back on flat land and checking for alternate 'closed' and 'open' spaces between adjacent passes.

The use of a pointer and dial kit (a pointer fitted to the tractor over a dial fitted to the implement) can provide a reference for assessing and/or filming the extent of skewing movements while at work. Rigid wheels, either singles or as a walking beam on the bar, act as rudders and provide restoring forces. Their 'restoring power' is improved by a greater loading weight, a larger wheel skid angle, and a greater distance behind the tractor's towing point. Larger skid angles can be obtained by positively steering frame wheels to keep the bar on its intended path. This can be done manually or automated with sensor or GPS input (see below).

To maximise the stability of a tyne seeder bar, avoid steep, narrow openers because they absorb some of the bar weight by generating an upward soil reaction, especially when dry seeding in hard soils. Conversely, shallow rake angle points (less than 60°) with optimum wear at the cutting edge can both add to the existing frame weight and decrease the seeder draught requirement. Avoid castor wheels because they take on the weight of the frame but do not help restore tracking.

A fully mounted air-seeder box placed near the rear-most supporting (rigid) wheels of the seeder bar and openers placed close to the towing tractor can improve tracking. A tow-between air-cart adds another 'link' to the tow-chain, and places the implement further behind the tractor. On side slopes, this can increase the extent of implement drift downslope, especially when the air-cart is near-empty.

On the other hand, a tow-behind air-cart acts as a damping force on the flat. It tends to reduce the amount and suddenness of random implement drift by decreasing the impact of a force imbalance. However, when operating on a side slope, the tow-behind cart drag force increases the downslope-pull on the seeder, which increases its skew angle. Twin axle air-carts with steerable wheels can minimise this impact relative to single axle carts.

Field operation

Working at slower speeds can improve the accuracy of guided-row sowing. In practice, inter-row sowing is easier to achieve than near-row sowing because of the larger margins of error, especially at row spacings of 300mm or more. Edge-row sowing is suitable to narrow row spacing (180 to 200mm) with accurate guidance and stable tracking.

A common source of implement drift is the tendency for the openers to return to last year's row when inter-row sowing, especially in harder soils. Force imbalances push the openers away from the harder inter-row zone into the weaker furrow side. This problem is more significant with lighter weight seeders, and stability can be improved with a higher load on the seeder wheels and the use of steering hitches guiding the implement.

Implement guidance

Guiding implements to targeted pathways gives the most accurate implement control. Implement guidance falls into two categories. The first is passive guidance in which systems combine GPS data from mounted receivers on both the tractor and implement to auto-steer the tractor, such that the implement always remains on the intended guidance path.

This is the cheapest option but requires the tractor to move on and off track to keep the implement on the target path. It is best suited for managing gradual and systematic drift, so it is combined with a stable seeder bar to minimise transient and sudden random drift. Example technologies include the John Deere Guide and the Trimble TrueGuide.

The second system is active implement guidance, in which systems guide the implement independently of the tractor. Active implement guidance is more expensive but the extra accuracy may be worthwhile, when it comes to improving cropping returns.

This technology is based on dedicated 'auto-steering' systems for the implement, of which there are two main types: 1) hitch correction, and 2) an implement steering kit.

Hitch correction is where the tractor draw-bar or the implement hitch tongue is hydraulically adjusted side-to-side to guide the implement. A system controller reacts to GPS receiver position data from the implement itself or to data from a stubble row or furrow/ridge tracking sensor fitted to the implement.

This approach adjusts implement position up to a maximum offset but without correcting any skew angle. With large-offset drift (such as on a side slope), this approach may not always be sufficient. Example technologies include SunCo Farm Equipment AcuraTrak guidance system, the John Deere hitch-based iSteer, MBW ProTrakker Guidance Systems (GPS, Side-Hill Sensor and Sonic Trakk), Seed Hawk SBR technology, SeedMaster SmartHitch and AgriParts I-till.

An implement steering kit actively directs the implement frame over the guidance path using steerable wheels or disc blades to generate a corrective force. Their action is controlled by GPS position data from both the implement and the tractor.

This approach corrects any implement skew angle in order to track squarely behind the tractor over a common guidance path. Provided they achieve sufficient penetration, piloted disc blades can generate larger restoring forces than steerable, surface running wheels. Example technologies include the John Deere wheel-kit iSteer, and the Orthman Agriculture Shadow Tracker and Tracker IV.

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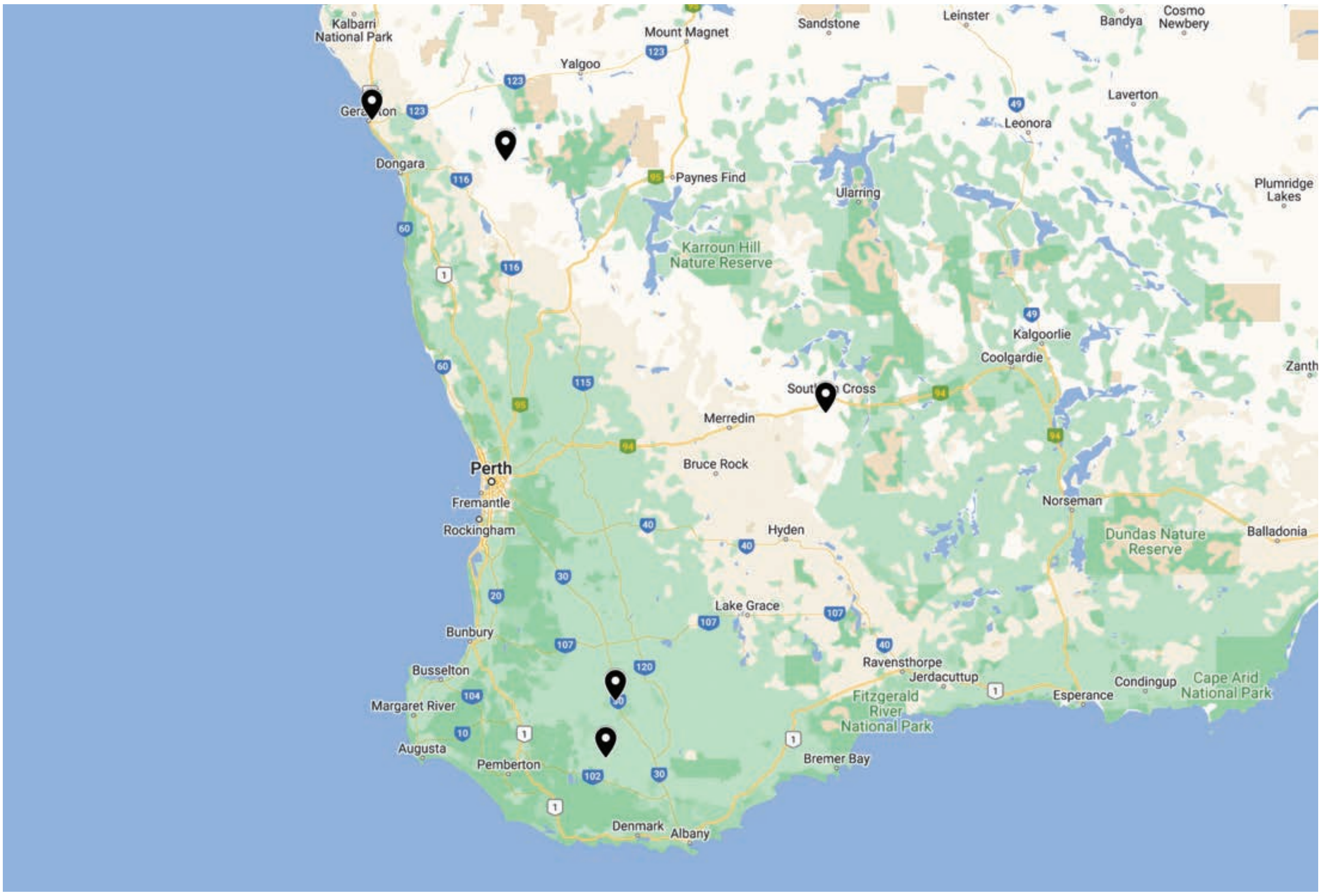
Case Studies



https://www.google.com/maps/d/edit?mid=1bUr-_tu0H0cBfBiicNCdODmh-BSS7jc&usp=sharing. Source: Google Maps

Craig Topham walking through a wheat crop sown over canola stubble in Dandaragan, WA. Source: Evan Collis

Stubble management, Craig Topham, agronomist, Agrarian Management

Growers in the northern sandplain part of the WA wheatbelt are used to wind erosion and patchy seasons and many find ways to reduce soil erosion and moisture loss with innovative sowing configurations and retaining stubble.

In May 2020, however, growers east of Geraldton were hit with what can only be described as a super windstorm that lasted eight hours and shifted countless tonnes of sandy soil.

"It was a serious blow that really focused the minds of growers," said Craig Topham from Agrarian Management.

On the 23rd May 2020 a cut-off low ex-tropical cyclone came down from the north-west and hit the northern wheatbelt of WA. For eight hours there were sustained winds with an average wind speed above 80km/h and gusts above 100km/h. The wind from the north to the north-west for a sustained period caused a huge amount of erosion, with anything that was likely prone to erosion suffering a huge amount of damage.

"It was just the length of time of that sustained wind that made it so damaging," Craig explained.

The northern wheatbelt is used to wind during the summer months but to get that sustained wind over a long period in May was quite unusual. This event caused a lot of damage, with erosion in the field and structural damage with sheds losing roofs and silos being blown away. The soil erosion was severe and any soil that was lightly disturbed or bare moved. There were a lot of examples of wind damage: blowing sand over fencelines, burying fences, and burying roadways. The Geraldton region is renowned for its sandplain farming, so anything that was left a bit exposed, was impacted by wind erosion.

Highlighting the value of soil cover

This event highlighted the value of soil cover with stubble cover and standing stubble significantly reducing erosion. The orientation of workings also had an effect on erosion as anything worked 90° to the prevailing winds (in an east–west direction) showing significantly less erosion than anything that was worked north–south.

When the wind event occurred, a large proportion of the crop was seeded and, as it had not rained, it had all been dry sown, which left the soil exposed after disturbance from the sowing operations. Machinery and seeding systems that left as much stubble standing as possible obviously had far less erosion and the simple things – like stubble height, the orientation of the working, the amount of disturbance the seeding machinery produced – all had a significant effect on reducing the amount of soil that moved. With all that soil moving around and the reliance on pre-emergent herbicides, there was a lot of crop damage due to herbicide moving into the furrow.

The benefits of soil amelioration are significant so there were some growers that were unfortunately caught out by this event. Soil amelioration is always risky – and even more risky on lighter sandplain soil.

"There are a lot of small things growers can do to reduce the risk such as, how you leave the soil after the amelioration processes" noted Craig.

"The timing of the amelioration process and where you implement it in the rotation is critical. The more stubble and ground cover you have before the soil amelioration process, the better. Some of the soil amelioration techniques (like ripping, spading, mouldboard ploughing, one-way plough, and the Plozza plough type option) all involve significant soil disturbance, so having multiple cereal stubbles is helpful – and the taller the stubbles were left at harvest the year before, the better.

"More stubble and the taller that stubble is above the ground before we implement one of these practices, the better" said Craig.

A lot of growers are looking at changing their rotations so they might have a wheat followed by a barley or a double wheat crop prior to implementing amelioration.

Another factor that added to the severity of the May 2020 event was the 2019 season was severely drought-affected, which left little stubble cover. This meant there was less soil cover before the amelioration processes were implemented. If possible, soil amelioration should be avoided if the soil is bare or has low stubble cover but the responses to deep ripping are significant on the sandplain soils in the Geraldton region so having ripping somewhere in the rotation can be beneficial.

Keeping the cover

The key to avoiding the issues caused by erosion events – particularly with the increase in the amount of soil amelioration and ripping – is to get as much stubble cover as possible. Instead of harvesting at 'beer can' height, growers are now trying to lift up where possible and cut the stubble as tall as possible. This increased stubble cover helps with moisture conservation and reducing wind erosion but the trade-off is that the higher the stubble is cut, the more issues there are with stubble handling the following season.

This increased stubble or crop residue on the surface at seeding time means growers need to adjust their machine to handle this. Growers are looking at wider row spacings and machinery modifications to improve trash handling. This increased stubble cover also has implications for herbicide applications with less pre-emergent herbicide hitting the ground. To address this, growers need to look at the system as a whole, not just individual components. It is about keeping as much cover on the soil as long as possible in all stages of the rotation.

"We need to change the way we look at herbicides, the way we look at our tillage, and the way we set our machinery up to handle that trash on the soil surface. It's a big cultural shift in the way we manage our farming practices," Craig added.

One of the major advantages of increasing stubble cover is increased water use efficiency. If the stubble is standing, less wind and sunlight is hitting the soil surface and that reduces evaporation. This can help to retain more of the summer rainfall and more moisture closer to the surface.

The northern region of WA along with the whole of the wheatbelt has seen changes in rainfall patterns. There is a tendency for less rain in May to June, more summer rain and less heavy rainfall events. The rainfall events tend to be lighter and less frequent, so retaining moisture nearer to the surface can help with establishing crops on these lighter rainfall events. If the growers can get the crop out the two to three weeks earlier on a small rainfall it can provide a substantial yield increase.

As in many parts of the wheatbelt, growers in the northern region are looking at stripper fronts and the strip and disc systems. It is one of the hot topics at field days around the northern agricultural region of WA, "How do we get stripper fronts into our farming system?"

"We may not be as advanced as some of our counterparts in the east of Australia, but I think it's one of the things that will be brought into the system over the next three to five years," Craig said.

"Growers are accepting that the climate is changing. They are seeing more variable rainfall events with a distinct increase in summer rainfall and a decrease in the May-to-June crop establishment rainfall. Anything we can do to keep moisture close to the surface has to be implemented into our system – and the biggest part of that is keeping mulch stubble cover on the soil."

"The taller that stubble is above the soil surface, the less wind hits the soil surface, helping conserve more moisture," said Craig.

Along with stripper fronts there is the need to implement a seeding system that can handle the tall standing stubble. A number of growers in the northern region are trialling seeders that will handle increased stubble loads. A lot more growers are maintaining stubble with less livestock on the sandplain soils, both of which help make soils less vulnerable to erosion.

"The amount of people who are prepared to see a paddock blow is diminishing rapidly. It's becoming socially unacceptable to have erosion," Craig concluded.

Bill Crabtree, Mullewa no Tillage farmer with 100% stubble retention. Source: Bill Crabtree

Conservation agriculture, Bill Crabtree, Mullewa grain grower

Bill Crabtree has been a champion of conservation agriculture since it began in WA. He has been farming near Mullewa in the northern wheatbelt, but has recently headed off to Africa to spread the word on conservation agriculture on that continent.

The initial motivation for Bill to get into no-till farming was seeing the wind erosion on the south coast of WA. The soil was blowing away, fences were being buried by the soil and the growers said, "We've just got to learn how to stop this erosion". They also wanted to grow more crops because the prices for crops were good whilst the sheep price was poor in the late eighties. The solution came from keeping the residue to protect the soil as well as being food for the soil.

An adventure

Since Bill has been farming in Mullewa, he has seen many changes on his farm, which is located in one of the driest parts of the wheatbelt.

"It's been an amazing adventure. I've seen the soil become more fertile. I've had to battle subsoil acidity, so I've had to put a lot of lime on, and I've struggled to get the lime on delicate sites because of the wind erosion," Bill said.

One of the issues in low rainfall areas is that when the soil is very acidic you cannot grow much residue. The residue not only protects the soil but also helps keep the lime from blowing away. Stubble cutting height is more critical in a low rainfall area: if you cut too low it will blow and also the ground can become hard. Bill observed this during one harvest when the front cut low for a period.

"At the end of summer, that ground was hard because it had lost all the residue, and that residue is needed to protect the soil from rain impact," he noted.

Along with cutting too low, Bill noted that cutting too high can make it difficult to get the seeder through the residue. He recommended cutting at least 15 to 18cm high in his type of environment.

Rotation or continuous?

Rotation is an important part of conservation agriculture, but in the low rainfall environment, Bill has found continuous wheat is the winner, although he does grow canola on 10 per cent of the land.

"I don't believe in rotations if it's going to lose you money. I've grown chickpeas, lupins, barley, and a couple of other crops, and they've always lost me money."

There is also little benefit from any extra nitrogen these crops may provide in the low rainfall environment, which is often droughted. The reluctance to use rotation is only a reflection of farming in a low rainfall environment and Bill acknowledges if he were farming in a higher rainfall area, he would definitely use break crops in his rotation.

The annual average rainfall in the Mullewa area is 305mm – but in 2011 there was 470mm and crops yielded three tonnes per hectare. This meant higher levels of residue than usual which Bill made sure was chopped and spread evenly. Bill prefers not to use windrows. Instead, where problems arise, he uses tools such as Roundup Ready® canola and Clearfield® wheat. He also uses herbicides like pyroxasulfone, prosulfocarb and bromoxynil in patches where the problem weeds grow. Bill has found the strategy of using effective herbicides, rotating herbicides and being aggressive with the weed seedbank has been successful in battling weeds with full stubble retention.

According to Bill, "The tools are there, they're available, they're not hard. It just takes a little bit of thinking."

One of the issues in a low rainfall environment, maintaining residue with frequent summer storms of 20 to 30mm of rainfall (with sometimes as much 60mm), is termites eating the residue. Residue in a low rainfall area is critical and Bill demonstrated this on-farm in 2011. He performed an experiment with 16 burnt and unburnt areas in a checkerboard pattern. In the following year he grew wheat and found that the burnt areas yielded around half that of the unburnt areas. The year after that, Bill grew canola which failed to germinate on the burnt plots, even though it had been two years since the burning had occurred, which shows the benefits of residue retention. In a low rainfall environment residue is critical and there is no need to remove it. Bill states, 'There's enough good advice out there, and there are enough different chemical groups that can do the job for you on weeds. Keeping the residue is worth an extra 100, 200, 300, 400 kilos per hectare of yield, which can more than pay for the more expensive herbicides that may be needed.'

If Bill were to continue farming at Mullewa, he would continue to keep the residue and mix up weed control techniques.

"Where I really do have a problem – like barley grass jumping into my wheat – I'll swing over to Clearfield. Or if I've got other grasses that are a problem, I'll swing over to canola. And if you only use those once every five to ten years, they're very powerful strategies."

Managing residue retention

In the higher rainfall areas of the wheatbelt, Bill explains that residue retention is more difficult to manage, but tools such as harvest seed impact mills that help with weed control can make it more viable. There are four different seed crushing mills available and the price will start to come down, making them even more workable as an option and it is a tool he would definitely invest in if he farmed in a higher rainfall area.

Bill also says he would be prepared to remove some residue in a higher rainfall environment as the residue can affect some crops, plus issues such as hair-pinning and crop establishment in high residue can be a problem. He notes that there are some new seeders coming along, and disc seeders that perform in high residue, so he recommends growers do their homework on the different seeders available. There are also new herbicides available or coming soon with others coming off patent, which may improve affordability and provide more options for weed control in high residue.

Bill thinks one of the main reasons people burn residue is not because of poor crop emergence, which can be managed by GPS 2cm autosteer and shifting off the old rows, but because of weed control. Despite this, Bill believes there are enough tools in all types of rainfall zones to retain residue, including herbicide tools and seed crushing impact mills.

"Seed crushing can allow people to keep at least 90 per cent of their residue, which I think they need to do, and they need to spread it evenly as well. You don't want to just spread it 90 per cent: you want to spread it 100 per cent across the profile," Bill explained.

He went on to describe how there are many different issues affecting a grower's ability to retain residue. For example, on the south coast it often rains during harvest so it can be moist at harvest. Growers often use European-made harvesters which are designed for these conditions, but they tend to break and rip up the residue, which makes it quicker to break down. Bill says growers could get around this issue by increasing harvest capacity or going to a strip and disc system. Overall, there are a range of tools that can be used across different climatic zones to retain residue in the system.

"I don't think anything's going to be the same in any one area and everyone should be at liberty to try different things because that's how we all learn. Everyone is trying something different."

Clint Della Bosca, Southern Cross No Tillage farmer with 100% stubble retention. Source: WANTFA

Residue management in the eastern wheatbelt, Clint Della Bosca, Southern Cross grain grower

For growers on the very edges of the Western Australian grains belt, maintaining some form of cover on their paddocks over summer is a crucial part of their long-term management. Clint Della Bosca is part of a family farm business at Southern Cross with his parents, wife and their two children. The farm is approximately 400km from Perth on the edge of the eastern wheatbelt.

Adjusting to changing rainfall patterns

The Della Boscas farm about 9,000 hectares with very variable soil types from heavy, high pH, sodic clay, through to Wodjil sand over gravel, which is very low pH with acidity and soil depth issues. The long-term annual average rainfall for the area is 300mm per year, although the Della Bosca's records show this has declined to about 275mm, particularly in the last 10 years.

Along with the declining rainfall the split between summer and winter rainfall has changed, with more summer rainfall and less in the early winter from the end of April through to June. The summer rainfall is relatively consistent with 60mm to 100mm rain from January to March, but the lower early winter rainfall is proving harder to manage.

"Quite often we've got moisture at depth, but we've got no surface moisture to get plants up and away to take advantage of this – or lengthen the season out," said Clint.

The decline in rainfall and the changing rainfall patterns has meant Clint has moved to a strategy of dry seeding with the seeding start date determined by the available soil moisture and crop types being grown.

"We'll pick a date and start sowing on that date rather than waiting for moisture. We're very confident, particularly in cereal varieties, in them being able to stand up to a long dry spell and then still germinate when the rain comes and produce a decent crop stand." In recent years, this strategy of dry seeding has resulted in a short growing season with the opening rains not coming until late May and little rainfall after August. This has meant a growing season of about three months – and in 2019 it was even shorter – with this trend becoming the norm over the last 10 years.

Crop rotations proving a challenge

In their low rainfall environment, crop rotation is challenging. The Della Boscas mainly grow wheat and barley although they have started growing oats with newer varieties coming through. They have also gone back to lupins due to the ability to use metribuzin to control wild radish. Clint has also been trying to keep canola in their system for weed control and early sowing opportunities but the economics on canola can be very variable. With regard to keeping canola in the rotation, Clint noted that, "It can either be the best or the worst, depending on the season and how the scenarios play out. So last year's was the only crop that didn't make a profit on our farm."

Soil amelioration proving beneficial

The Della Boscas were running sheep up until recently but, due to three to four dry seasons, they decided to roll out of sheep for a short period.

"We were just seeing they were baring our soil types up too much and they were getting hard to manage. Obviously, water in dams has become an issue, so we've decided to roll out of sheep for a short period and just let our land recover – and try and get some more biomass and cover on the soil."

The short break from sheep has provided an opportunity to increase their soil amelioration program. It was proving difficult to manage with the sheep reducing soil cover and biomass. Once the soil amelioration program is completed, they may look at bringing strategic grazing back into their system, provided there is some seasonal rainfall too.

The soil amelioration program involves deep ripping and mixing lime. They aim to rip approximately 10 per cent of their cropping program of 5500/ha (550 to 600/ha per year) and lime from 550/ha up to 800/ha, if possible.

"We'd love to do more. It's showing up to be very successful," Clint said.

Putting a high price on residue

Up until the last five years, erosion has not been a major issue, but a combination of drier seasons, sheep removing cover and more intense wind events (particularly in the last two seasons) has seen it become more of a concern.

"Last year was terrible: we had three or four quite big blows. So anywhere – particularly on our Wodjil sands – anywhere that did not have any sort of cover or protection, we did get hurt quite badly."

Soil amelioration can pose a risk for wind erosion. This was highlighted in 2019 where Clint tried to establish canola on a ripped paddock… "We ripped it and we tried to establish canola on it in 2019. Obviously, the canola crop failed because of the dry start, or it was a sparse germination, and we didn't have enough residue then to hold the paddock down for the following year. So even though we did get a wheat crop out of it and it's probably sort of safe now, the wheat did struggle for probably six weeks at the start to get established and to get enough biomass to beat the wind."

Stubble management is important to help avoid these issues. As Clint explained, "We place a very high price on our residue in our stubble management, even to the point where we're looking at strategies on where we can lengthen the stubble or cut the crops higher, particularly in the low-yielding crops and areas to allow more soil cover."

Over the past six to seven seasons, the Della Boscas have been using harvest weed seed management by putting their chaff onto their tramlines using chaff decks. This strategy has meant they have been cutting around 'beer can' height to try and get as many weeds into the machine as they can, which has been successful. This is showing with lines of ryegrass in the tramlines in known weedy patches. One of the downsides of cutting low and putting all that residue through the harvester is that it does bash it up and degrade the value of the stubble. In a low yielding environment this sometimes results in low stubble levels after harvest.

With this in mind, the aim is to clean up the paddocks and then cut the stubble longer. To be able to seed into the taller stubble the Della Boscas have widened their row spacing from 300mm to 375mm and gone to a hybrid seeder that runs a coulter in front of the tyne. This allows them to get through the thicker stubble as well as where it has been knocked down. The removal of sheep has also meant there is more standing stubble rather than stubble that is knocked over.

The aim of the increased stubble level is moisture retention from the summer rainfall and to maintain the moisture levels near the surface to get the crops established. The stubble will also protect the seedlings as they germinate, particularly with canola, lupins and the legumes that do not stand up to wind as well as cereals. The strategy is seeing a build of residue particularly on their more productive soils.

"It's quite significant – we wouldn't be able to get through them with a standard no-till seeding system without the coulter disc at the front, that's for sure," said Clint.

Summer spraying is vital in the Della Bosca's low rainfall environment to protect every bit of moisture they can. If they have summer rain, they try to control the weed germinations as quickly as they can.

"We're very mindful of the moisture and the nutrition those summer weeds take out," Clint noted.

The higher stubble loads that the Della Boscas have been able to build up mean they have to use a higher water rate to make sure they good get penetration and weed contact with the herbicides. They are also finding with the use of chaff decks that they are getting self-sown cereals, along with weeds, after summer rain. This germination of self-sown cereals has meant they quite often have to put a second nozzle or a bigger nozzle on the tramlines to make sure they are getting adequate chemical to those high plant numbers. Along with the increased chemical rates they are finding the tramlines are a hostile environment with plants competing against each other on fairly compacted soil. Clint says they are finding this system with the chaff decks is cost-effective, although he believes killing the weeds out the back of the harvester would be the ideal system.

"At least you're collecting them and putting them where you know they are," said Clint about the cost effectiveness of the chaff deck system they use.

Stubble management in a high rainfall zone, James Heggaton, Kojonup grain grower

In the past three years, grower James Heggaton has gone from a full stubble burn each autumn to 100 per cent stubble retention, minimum tillage and controlled traffic across his entire high rainfall, mixed farming enterprise.

"We found stubble burning a hazardous process and environmentally unfriendly," says James, who works with his parents on their mixed-farming enterprise. "The new system has delivered soil moisture benefits, with canola now germinating and establishing on just 5mm of rainfall, compared to the 20mm required a decade ago."

A three-year transition to new stubble management practice

The Heggatons, who farm 20km south of Kojonup in a 500mm rainfall zone, now cope successfully with wheat and barley stubble loads of 5+ t/ha each year as James started making changes to their residue management practices back in 2014.

"It was a three-year transition to put the new stubble management practice into place, beginning with altering practices slowly, piecing together information from attending field days and discussing with trusted advisers," James says.

James uses a Claas Lexion 770 Header with radial spreaders and chaff decks for harvest weed seed control.

"The big trick to inter-row sowing is that it starts well before harvest. You need an inter-row clean of weeds – especially grass weeds. This is our third harvest with the chaff decks, and they are a very cost-effective simple weed seed control measure."

James says using canola as a break crop between the cereals keeps the tramlines clean and they have not yet seen any grass weeds on the tramline.

Crop diversity is also a major factor to good stubble management for the Heggatons. Using a rotation of faba beans, wheat, canola and barley assists in managing stubble loads as the break crops – canola and faba beans – produce less stubble.

Chopping and spreading the crop residue is extremely important and James says there is 'a fair bit of science' in terms of cutting height and spreading to get the system to work properly. The harvest residue covers any bare earth, improving water retention and capturing summer rains, preventing wind and rain erosion, and smothering any summer weeds. The remaining standing stubble acts as a wick for moisture into the soil. The goal at harvest is to generate a clear path between each stubble row so that the seeding tynes can slot down easily between the rows.

"This keeps the nutrient cycling consistent and the mulch layer a consistent depth and helps with water retention over the summer months," says James.

The Heggatons operate a Boss engineering bar with an Equalizer tyne set up on a 300mm row spacing at seeding. Their system also uses near-furrow sowing to overcome non-wetting soils, which are a big issue on the farm.

James Heggaton, grain grower from Lumeah (south of Kojonup, WA) inspecting retained stubble. Source: Evan Collis

"By sowing about 30mm from last year's stubble row using GPS we can take advantage of the moisture pathway that the previous year's stubble creates – it's a wicking effect and creates a pathway directly below last year's stubble so we can get crops established on lots less rainfall," James explains.

"Near-furrow sowing can be a bit tricky with the topography of our farm – rolling hills makes it harder to keep the bar sitting exactly where you want it – but as an 80:20 rule, it's doing a fantastic job," he added.

Constraints

High stubble loads and high rainfall means disease is a major constraint for the Heggatons.

"All our crops get very robust fungicide packages," says James.

The main disease issues are septoria Nodurum blotch and yellow spot in wheat, spot type fungal diseases in barley, rhizoctonia root disease and sclerotinia and blackleg in canola.

"Managing disease is more challenging with stubble but we plan to have a break crop every second year."

Implementing CTF

James says the main reason for implementing controlled traffic across the farm was to pursue water use efficiency.

"We wanted to improve soil structure across the farm to allow deeper rooting and enable crops to access moisture at depth later in the season."

Knowing there is extra moisture at depth has allowed the Heggatons to push crop yields. "We are really loving what the controlled traffic is doing for the overall farming system – and for profitability," says James.

James says there can be a fine line between the new system working well or causing issues at sowing but, in his mind, there are hardly any drawbacks.

"Our water use efficiency numbers are blowing us away each year – we are getting so much better at turning water into grain."

Noel Keding with his stripper header front. Source: Evan Collis

Stripper front harvesters, Noel Keding, Franklin River grain grower

In recent years, there has been an increasing level of interest amongst growers in Western Australia in the potential benefits of using a stripper front on harvesters. A stripper front strips the grain from the stem, rather than cutting it. The result is quite a tall-standing stubble as compared to the more common practice of cutting stubble at 'beer can' height.

Stripper front delivering multiple improvements

Noel Keding is one of the few growers in Western Australia with experience using stripper fronts, having used them in both higher rainfall and lower rainfall environments. Originally, Noel farmed at Gairdner, between Albany and Esperance where he first tried out stripper fronts. His initial interest was due to two aims: the first was to improve harvesting efficiency in an area, which received a lot of summer rainfall making it hard to get the moisture right at seeding time in his wheat and barley; and the second part was to increase stubble cover.

With the increasing cost of harvesters, improvements in harvesting efficiency using a stripper front meant Noel could get increases in tonnes per hour from a smaller machine. The previous machine he used with a MacDon front cutting at beer can height was harvesting about 35 to 40 tonnes per hour, while the same machine with a stripper front was getting 70 to 90 tonnes per hour – and it used less fuel.

"Why put the straw through it if you don't have to?" said Noel, remarking on the improvements in harvesting efficiency.

The fuel savings were also significant. The previous harvester he used had a 1200 litre tank, which would do about a day's work or 100 hectares in a 2.5 tonne wheat crop with the normal MacDon front. The stripper front would harvest about three days or 300 hectares before needing to be refuelled. Along with the fuel savings, the increased capacity meant the harvester could cover more hectares.

"You just found yourself not having to chase the diesel tank every day – you could leave it for a couple of days, which is unusual for a harvester," Noel noted.

The stripper front has also seen increases in yield due to conserved moisture from summer rainfall. In a trial on Noel's old farm half a paddock was conventionally harvested, and half stripper front harvested, with both halves then seeded at the same time. The following year there was about half a tonne difference in the stripper front plot versus the conventionally harvested plot.

New area, new challenges

About 12 months ago the Kedings moved to a new property about 15km north of Franklin River and 50km south of Kojonup into higher rainfall environment with annual rainfall of about 500mm. The extra rainfall grows thicker and heavier crops, which has increased the stubble load and has created new challenges compared to his old farm. The increased quantity of stubble looks to have created an environment suitable for mice (with some evidence of this being the case) and with snails in the area, Noel is also concerned these may also become an issue in the future.

Noel's Gent Disc seeder required to sow through higher stubble loads.

Source: Evan Collis

Another disadvantage of the taller stubble left by the stripper front is slower germination caused by the shading. Noel will address this at his new farm – where it can get a bit wet at seeding – possibly by seeding earlier to get some early growth before it gets cold.

Harvest weed seed control is an important part of the system and when Noel purchased a new harvester in the previous year, he looked at different harvest weed seed control options like a chaff cart or the weed seed impact mills. He finally settled on chaff decks as they still have sheep in their system and putting the chaff on the wheel tracks was beneficial.

"We're finding the sheep are walking up and down the tramlines and getting a lot of benefit out of that chaff," he said.

With the increased amount of stubble, Noel suspects that nitrogen tie-up will probably be an issue, with the nitrogen being used by the soil microbiology to break the stubble down, making it unavailable for crop growth early in the season.

Frost is also a concern with increasing the stubble loads in an area that can be frost-prone.

The final issue Noel was concerned about, with the increased stubble loads, was hair-pinning of the stubble when using his 40-foot Gent disc machine. 2021 was the first season of seeding into the higher stubble loads and it raised a number of challenges. In 2020 seeding was not much of an issue as the farm had been grazed extensively by sheep, so there was not too much stubble left behind. In 2020, Noel's first harvest at the new farm using the stripper front on the wheat and barley crops created much higher stubble loads at seeding. In 2021, Noel was keen to try canola to see how it germinateed and responded to a heavy stubble load.

"There's nothing like trial and error: you just have a go and see what happens," Noel said.

Getting advice

With no one using stripper fronts around Franklin and with only a couple of people from the area around his old farm with stripper fronts who are also just starting out, there are few people to ask for advice locally. Luckily, Noel had friends over east around Wagga Wagga who were using stripper fronts and sowing into five to six tonnes per hectare of barley and wheat stubble. A common problem for growers seems to be seeding through wet stubble and at night-time, as opposed to when stubble is dry in the heat of the day.

Potential benefits

Noel has observed that another benefit of the high stubble loads are lower soil temperatures. Whilst soil sampling with his agronomist after a run of about three 40°C days, they measured the soil temperature in the top 10cm of a nearby pasture paddock at approximately 33°C compared to about 27°C at the same depth in a paddock where the stripper front had been used. Noel suspects that difference in soil temperature would help with the soil biology activity over summer and that not cooking the soil may help with issues such as non-wetting. Non-wetting is an issue in the area, particularly with the forest gravels, and Noel feels by keeping the soil covered it will stop the sun baking the soil, which may help with the non-wetting over time.

A lot of growers around WA have issues with wind erosion, and this was part of the decision to purchase a stripper front in the lower rainfall environment of Gairdner as they had sandier soils. Noel also noticed the wind also dried out the soil quickly after a shower of rain and thought that by keeping the stubble cover this would help in conserving moisture.

At the old farm in Gairdner, Noel also thought that the increased stubble cover was helping the soil biology by increasing the organic carbon. Noel also noticed signs such as more spiders and quails in the tall straw at the new farm.

"I've got a lot to learn yet but I'm just starting to know some things that I think will be beneficial down the track," Noel concluded.

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