CROP ESTABLISHMENT AND PRECISION PLANTING

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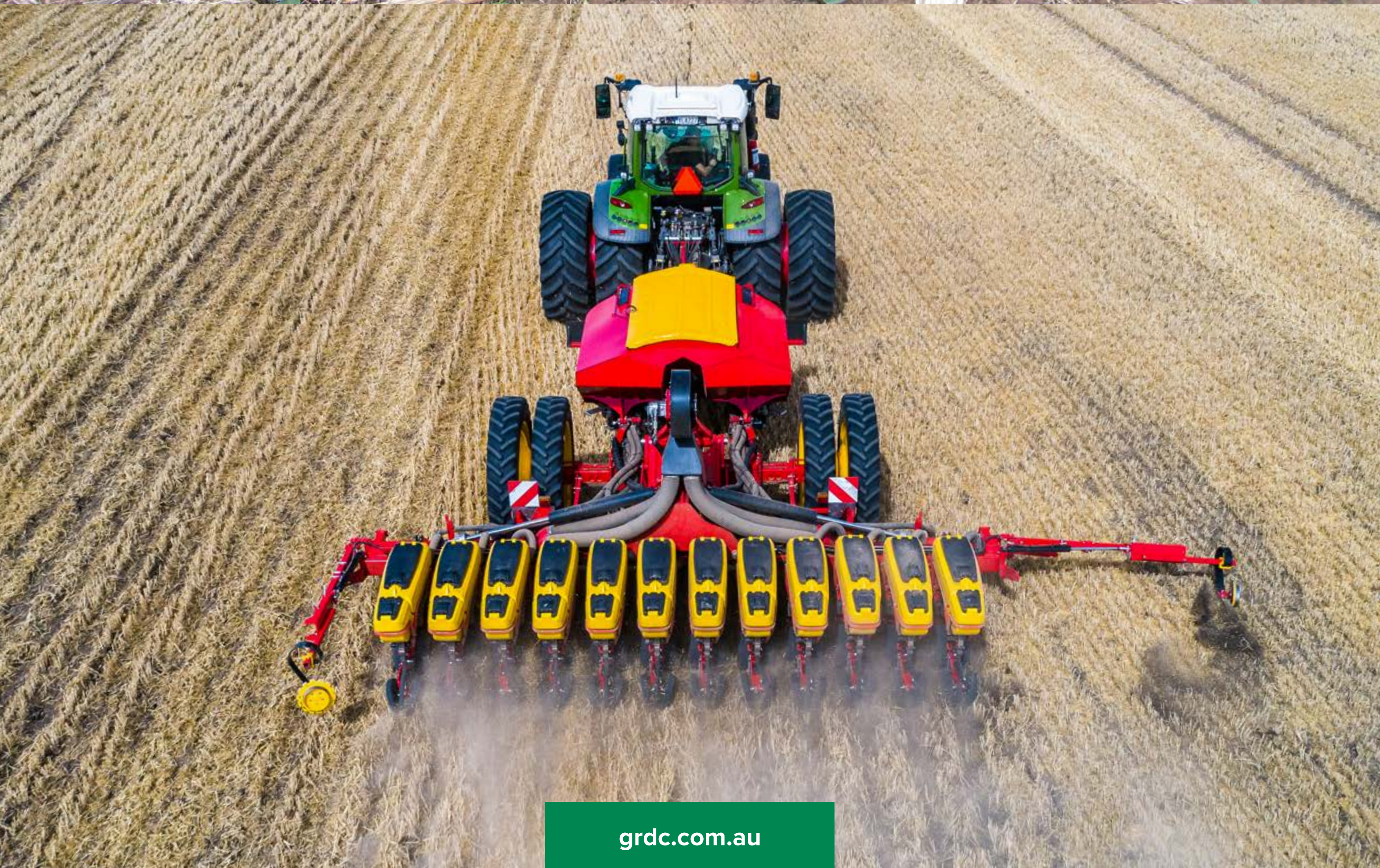
SOUTHERN AND WESTERN



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Authors: Dr Glenn McDonald, School of Agriculture, Food and Wine, The University of Adelaide, 08 8313 7358, glenn.mcdonald@adelaide.edu.au;
Dr Jack Desbiolles, Agricultural Machinery and Design Centre, University of South Australia, 0419 752 295, jacky.desbiolles@unisa.edu.au.
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OR

Ms Maureen Cribb
GRDC Manager Integrated Publications
PO Box 5367
KINGSTON ACT 2604

Telephone: 02 6166 4500

Email: Maureen.Cribb@grdc.com.au

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COVER: Top: Field establishment of precision-planted faba bean.
Source: Jack Desbiolles
Bottom: Precision planter technology has now evolved to suit the no-till sowing of winter grain crops in broadacre context.
Source: Väderstad International

Contents

Introduction

The time from sowing to crop establishment is a critical phase in the life cycle of a crop. Poor early development can have long-lasting effects as low and uneven establishment reduces crop growth and yield. Ideally, crops should emerge rapidly and evenly and grow vigorously as this improves crop water use efficiency and yield, and helps crops to compete with weeds.

However, the rate of crop establishment is not the only factor affecting crop yield and profitability. Although much emphasis has been placed on the rate of crop establishment in the past, the consistency of seed placement along the seeding row and the uniformity of the crop stand also influences interplant competition and crop yield.

Seeding technology is changing rapidly and is improving crop establishment and seeding efficiency. Although precision planting is a sowing technique that is used extensively in summer row cropping, there is growing interest in adapting precision planting to winter crops. A handful of innovative growers who use precision planting in winter crops have reported improvements in the rate and uniformity of establishment, which allows sowing rates to be reduced and savings on seed input costs achieved. However, there has been limited assessment of the benefits of precision planting in different crops across the southern and western regions. Precision planting by itself will not overcome problems of poor and uneven establishment, and other aspects of paddock management need to be considered. To achieve the benefits of precision planting, first the seeder set-up and operation parameters that affect crop establishment need to be optimised.

This booklet consists of three sections:

- The first section summarises some of the environmental and management factors that influence the rate and uniformity of crop establishment.
- The second section presents six grower case studies from the southern and western regions who share their tips and crop establishment experiences.
- The third section describes recent experimental work that has assessed the benefits of precision planting in winter grain crops in the southern and western regions.

The purpose of this booklet is to provide information to growers on crop establishment and how it can be improved. This will allow them to better understand reasons for poor and uneven establishment. The description of results of recent research on the effects of precision planting will allow growers to assess the benefits of improvements in crop stand uniformity. The results also show that while there is a benefit to having equally spaced plants in a crop stand, there is more work to be done in assessing the yield and profitability benefits of different sowing technologies – both precision planting and a range of intermediate technologies.

SECTION 1

Maximising crop establishment uniformity

Key points

- High levels of crop establishment and uniformity are the foundation of a productive crop.
- Maintaining good soil structure, maximising water infiltration and retention, and minimising surface soil crusting are key to high levels of crop establishment and uniformity.
- Low levels of crop establishment will not always cause a reduction in yield as crops have considerable potential for compensatory growth. Conditions that promote vigorous growth will help crops adjust to low crop establishment levels.
- The decision to resow needs to be weighed against the potential yield penalty from a delay in sowing.
- Care in setting up and operating seeding equipment is important. A seeder that is poorly set up and calibrated can lead to high variation in establishment and seedling depth.
- Carefully select paddocks when dry sowing. Avoid paddocks with moderate to high levels of salinity or sodicity. Set up paddocks to maximise soil moisture storage and retention, and to minimise in-crop weed burdens.
- Establishment with dry sowing can be improved by using water-harvesting furrows and increasing press wheel pressures in cloddy conditions; avoiding high rates of fertiliser; separating seed and fertiliser; and treating seed with an appropriate seed dressing.
- Deep sowing increases the risk of low and uneven establishment. To further mitigate this risk, use large, high-quality seed; ensure sowing depth does not exceed the coleoptile length of cereals or hypocotyl length of canola; use deep furrows; and ensure there is moisture at depth.
- Avoid sowing canola into marginal soil moisture or a drying profile unless rain is forecast. Increase the seeding rate if conditions are marginal or wait until conditions improve.

Germination, emergence and establishment

Seed germination and seedling emergence are critical phases of crop development. Low plant densities caused by poor establishment can reduce yields, while very low establishment may mean crops need to be resown.

Germination occurs after a seed has absorbed sufficient moisture to activate the enzymes that break down starch, protein and mineral storage reserves within the seed. This can occur even under dry conditions. Until the seedling emerges at the soil surface, its growth depends completely on the seed reserves. The development of the first leaves after emergence allows the seedling to start photosynthesising and its dependence on seed reserves declines. At this point, the seedling has established.

How is crop establishment measured?

Crop establishment depends on the germination rate of the seed and the proportion of seedlings that fail to emerge or are lost soon after emergence. Two measures of crop establishment are:

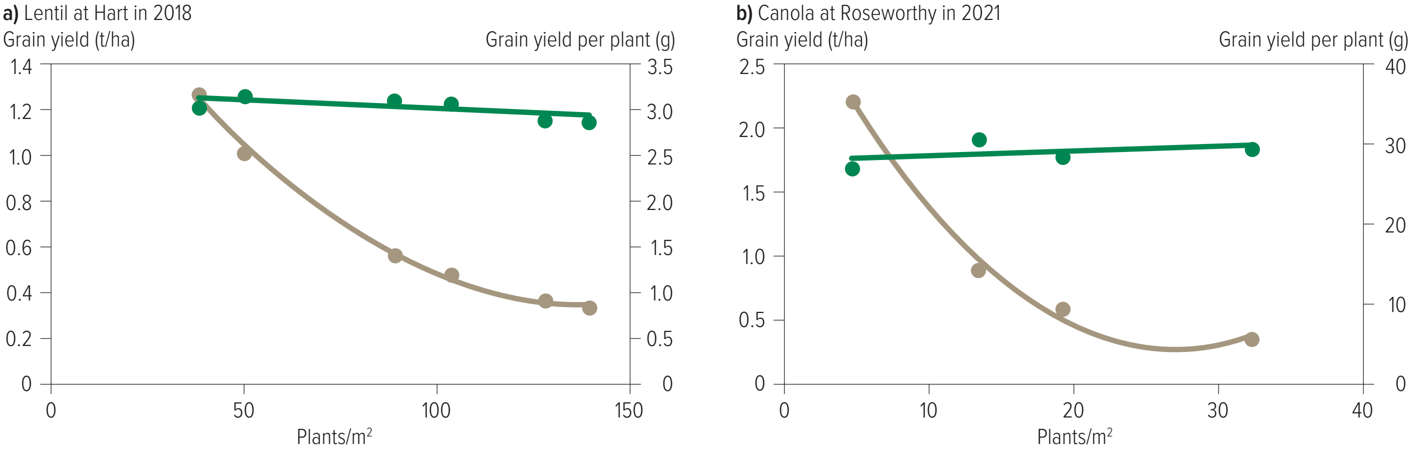
- the proportion of seeds sown that emerge and produce a viable seedling, commonly referred to as the ‘crop establishment percentage’ or, more simply, ‘crop establishment’; and
- the time over which crop establishment occurs, or the rate of establishment.

Factors that influence crop establishment percentage and the rate of establishment include seed quality, seedbed moisture content and temperature, soil properties such as surface crusting, and crop residues. Mice, birds, snails, slugs, invertebrate pests and seedling disease can also reduce establishment.

What is staggered emergence and why is it an issue?

Staggered emergence is when seedlings emerge at varying rates. It extends the time over which emergence occurs and can lead to a high proportion of small seedlings that may not be productive. A wide range in time to emergence can also make post-emergence herbicide management more difficult as there may be plants at different growth stages.

Figure 1: The response in crop grain yield (tonnes per hectare) (green) and grain yield per plant (grams) (brown) to plant density: a) lentil at Hart in 2018; and b) canola at Roseworthy in 2021 illustrating the compensation in yield per plant with declining plant density. There was no significant response in yield to plant density (plants per square metre) due to the ability of lentil and canola to adjust their growth to the variation in plant density. Growing season (April–October) rainfall was 218 millimetres (Hart) and 298mm (Roseworthy).



Source: McDonald (2022)

Figure 2: Variation in the time to emergence and distance between canola plants along a row results in seedlings of different sizes and interplant competition. Seedlings that emerge much later will generally be less vigorous and produce lower yields.

Source: Glenn McDonald

Does poor establishment always reduce yields?

Although a high rate of crop establishment is desirable, poor establishment will not necessarily reduce yield. At low plant densities, yield per plant increases, with the result that grain yield can show relatively little variation over a range of plant densities (Figure 1). How effective this compensatory growth is depends on the capacity of the plant to adjust to differences in interplant spacing.

How can growers reduce the effect of low plant numbers?

Compensation for low plant numbers mostly occurs naturally, through:

- increased tillering and seeds per plant in cereals; and
- greater branching, pod production and seeds per plant in canola and pulses.

However, there are management practices that promote vigorous growth, helping crops adjust to low plant densities. These include:

- maintaining good soil fertility, especially nitrogen and phosphorus fertility;
- having a long growing season or growing mid-season and long-season varieties that allow time for compensatory growth to occur; and
- ensuring diseases and weeds do not limit growth.

Soil moisture is another important influence. The ability of the crop to compensate for low densities is limited by low rainfall or soil properties that restrict water availability and uptake.

There are recommended target plant densities for crops in different regions and, in general, if the established plant density is within this range, there may be little effect on grain yield and no need to resow.

The importance of crop stand uniformity

Variability in crop stand uniformity is caused by:

- variable distribution of seed along the row at sowing;
- poor crop establishment that causes gaps along the sowing row; and
- variation in the time to emergence.

High levels of variation in interplant spacing and time of crop emergence can lead to variation in the degree of interplant competition (Figure 2). Having a crop in which plants are evenly spaced reduces interplant competition and allows more uniform growth.

Experiments have been undertaken in which the evenness of the crop stand has been controlled by carefully spacing plants. The results have shown that increased uniformity can lead to improvements in grain yield and often, the greatest improvements occurred at low plant densities (Table 1).

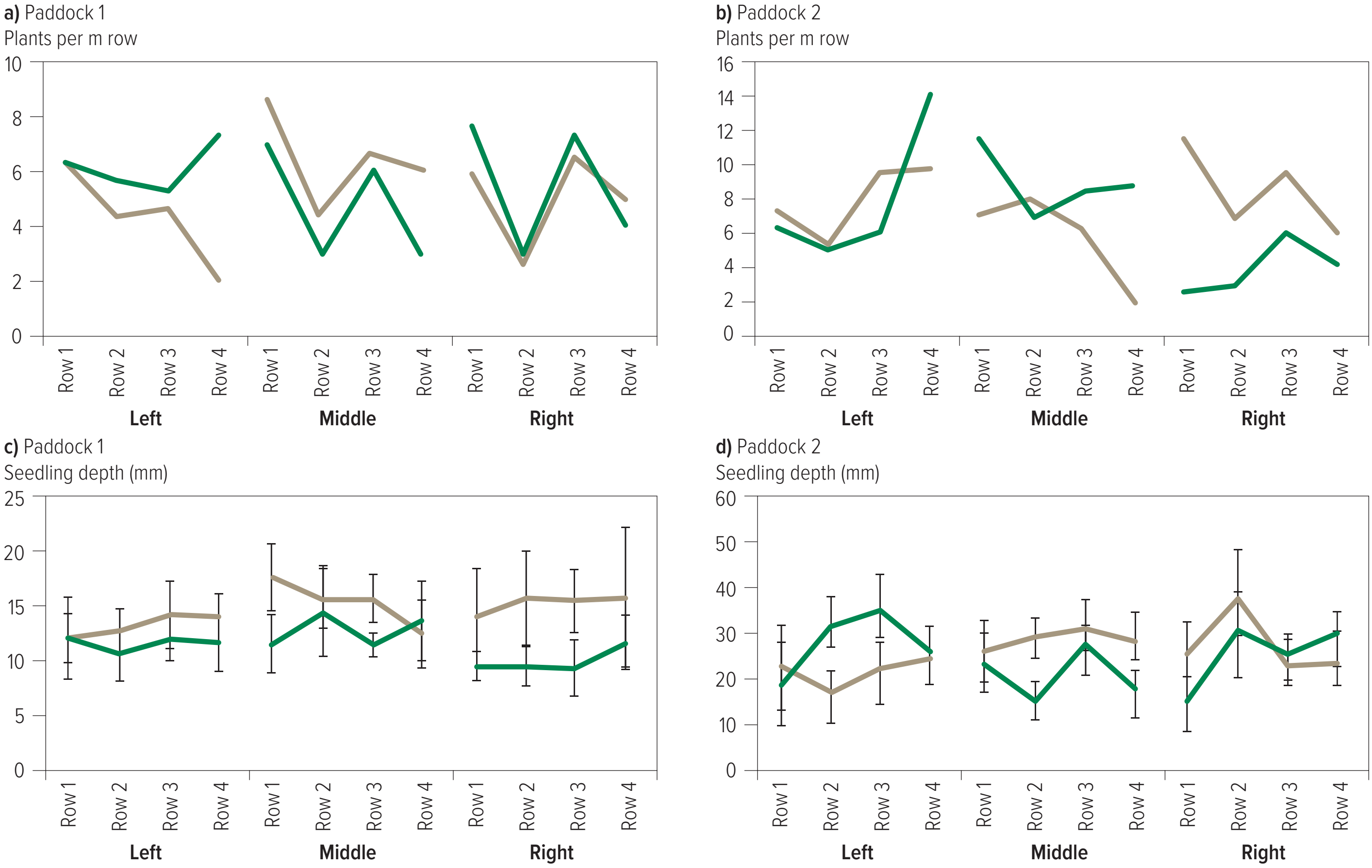
Table 1: The effect of crop uniformity on yield in canola and lupin. The treatments were hand-thinned to specific plant densities to provide a highly uniform crop canopy. They were then compared with unevenly spaced plants.

Site	Crop	Site mean yield (kg/ha)	Yield improvement	Reference
Geraldton, WA	Canola	2878	8–17%	Harries et al. (2019)
	Lupin	3175	7%	
Wongan Hills, WA	Canola	3000	5%	Harries et al. (2018)
Hart, SA	Canola	838	24%	McDonald et al. (2022)
Merredin, WA	Canola	1450	18–54%	Minkey and Riethmuller (2022)

Variation across the seeder bar

Variability in establishment and sowing depth across the seeding rows of a seeder can be high and this can reduce crop uniformity. Plant establishment and seedling depth can vary twofold to threefold between rows within a seeder (Figure 3) and this variation between rows can be as high as the variation across a paddock. Seeder set-up and operation contribute to this variation. Growers who have achieved consistently good establishment take care in setting up and calibrating their seeders and in adjusting the seeder to suit conditions during sowing (see Section 2: Grower case studies).

Figure 3: Variation in plant establishment and seedling depth in two crops of canola sown with Flexi-Coil seeders. The green and brown lines are two locations within the paddock. The data are for four adjacent sowing rows in three sections of the seeder bar. The error bars for seedling depth are the standard deviations within each row. Average sowing depths were 20mm (Paddock 1 – a and c) and 25mm (Paddock 2 – b and d).



Source: McDonald (2022)

Factors influencing germination and establishment

Many factors can affect crop establishment (Table 2). Although some are related to seasonal or soil conditions and may largely be outside growers' control, other factors can be managed to enhance germination and emergence.

The remainder of Section 1 outlines some of these factors affecting seed germination, crop emergence, crop establishment and seedling survival phases and, where appropriate, how to mitigate them. The factors that will be focused on are:

- soil moisture content;
- soil temperature;
- seed quality;
- sowing depth; and
- sowing rate.

This is followed by case studies (Section 2) in which growers from the southern and western regions explain how they maximise their chances of cropping success by maximising crop establishment.

Soil moisture availability and crop establishment

Uptake of water is the first necessary step for germination. In dry soils, crop establishment is reduced and emergence is delayed because the soil holds the water strongly and the seed and developing seedling take up water slowly (Figure 4). In low soil moisture conditions, the time between first and final emergence may lengthen from about five to seven days to several weeks.

As the soil dries below field capacity, final emergence decreases quickly and the time to emergence can lengthen (Figure 5). These changes can occur over a relatively narrow range in soil moisture content. Therefore, sowing into a drying profile can result in poor establishment as the soil moisture content quickly drops below values suitable for high establishment rates. This may be exacerbated by soil constraints, such as water repellence, that affect how well rainfall infiltrates the soil and wets the seedbed, and in sandy soils that have a lower water-holding capacity and that can dry quickly.

SOIL SALINITY

One important factor related to soil moisture is soil salinity. High concentrations of salts in the soil solution slows the uptake of water by seeds and seedlings, which can reduce the rate of germination and emergence. Water uptake occurs by a process called osmosis and the strength of this effect is measured by the osmotic potential of the soil solution. As soil dries, salts become more concentrated in the soil solution and osmotic potential decreases, reducing the uptake of water. This effect is greater in soils with high electrical conductivity (EC; Figure 6).

Achieving high and even establishment in a soil with high EC can be challenging and, in these paddocks, crops need to be sown when soil moisture is high. Dry sowing in soils with high EC should be avoided.

IMPROVING ESTABLISHMENT AND UNIFORMITY IN DIFFERENT MOISTURE CONDITIONS

ESTABLISHMENT UNDER DRY CONDITIONS

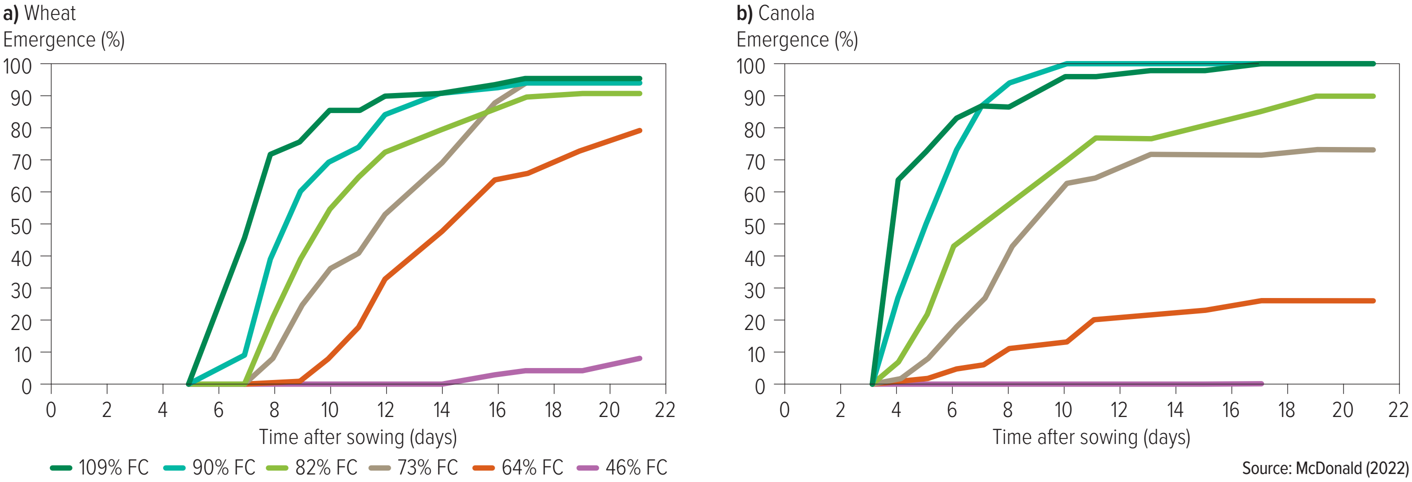
Dry sowing occurs when seed is sown in soil in which available moisture is very low and the uptake of water is not sufficient to allow complete germination and normal seedling growth. A risk with sowing in dry soil is that even when soil is dry, seeds can still take up water, triggering germination, but with little subsequent growth (Figure 7). Fertiliser placed close to the seed can exacerbate the problem as the fertiliser can also reduce soil water availability by osmotic effects. Seed placed in dry soil for long periods can become colonised by soil-borne fungi that can cause decay of the seed. However, treatments with fungicide dressings are effective in reducing such seed losses.

Another risk associated with dry sowing is poor weed control. With dry sowing, there can be a reduction in the effectiveness of pre-emergent herbicides and an increased reliance on post-emergent herbicides for weed control. It is therefore important that there is a low weed burden in paddocks that are sown dry.

Table 2: Factors that influence seed germination, crop emergence, crop establishment and seedling survival phases. The factors have been divided into four categories: soil properties, seed properties, agronomic factors, and pests and disease.

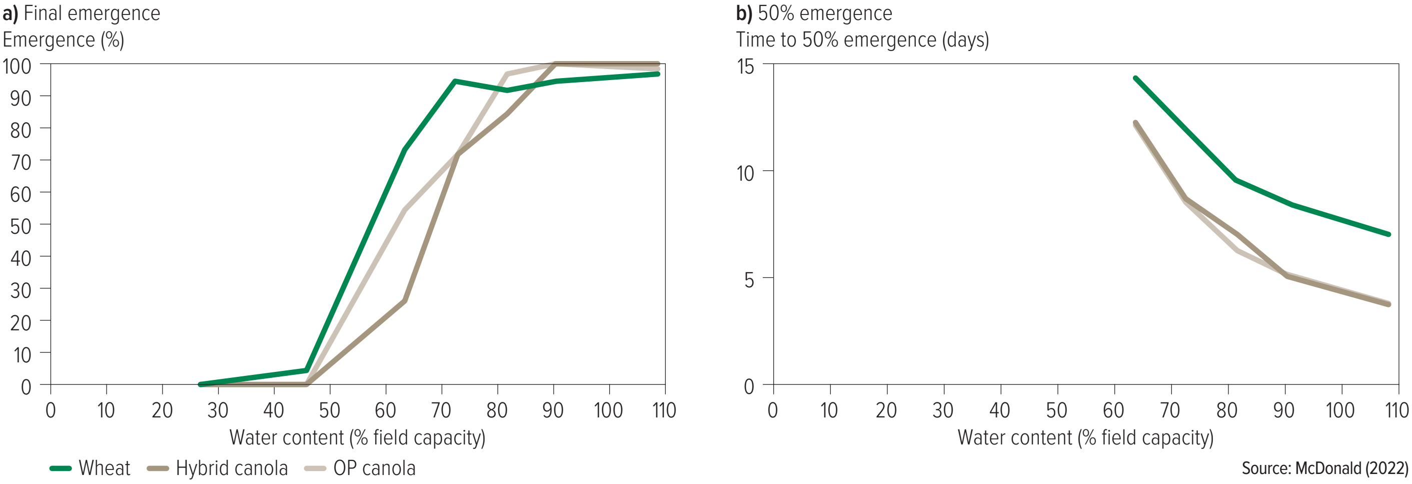
Category	Seed germination	Crop emergence	Crop establishment and seedling survival
Soil properties	Moisture content Salinity Sodicity Temperature Aeration	Moisture content Temperature Aeration Texture Soil strength Surface crusting Residue allelopathy	Compaction Surface crust
Seed properties	Quality Seed damage Weather damage	Seed size Nutrient concentration Coleoptile/ hypocotyl length	
Agronomic factors	Seed grading Seed dressings Fertiliser toxicity Seed–soil contact	Sowing depth Herbicide Fungicide and insecticide Seed coverage Fertiliser toxicity	Sowing rate Sowing depth Row spacing Weed competition Sowing method
Pests and disease		Soil pathogens Insects	Slugs and snails Mice Soil pathogens

Figure 4: Examples of the effect of soil water content on seedling emergence in wheat (25mm sowing depth) and hybrid canola (15mm sowing depth) in a sandy-loam soil. The soil water content is expressed as a percentage of field capacity (FC).



Source: McDonald (2022)

Figure 5: The effect of soil water content on: a) final emergence; and b) the time to 50% emergence in wheat (green) and a hybrid and OP variety of canola (brown) in a sandy-loam soil. The soil water content is expressed as a percentage of field capacity (FC).



Source: McDonald (2022)

PRACTICES TO IMPROVE ESTABLISHMENT IN DRY CONDITIONS

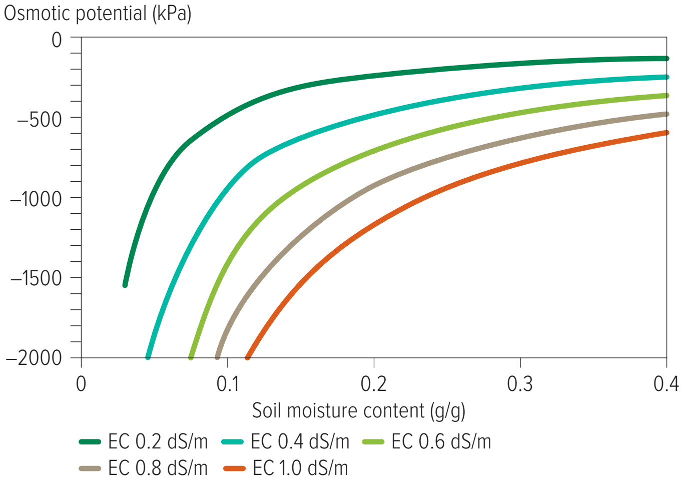
Deep sowing is sometimes used when crops are sown dry, partly to mitigate the risk of poor establishment from false breaks with shallow sowing. However, there is a trade-off between sowing depth and crop establishment and there may be little advantage from deep sowing when soil moisture is low. Deep sowing should occur when there is sufficient moisture at depth to allow the seed to germinate and the seedling to establish.

Using water-harvesting furrows to capture showers of rain and concentrate moisture at the base of the furrow is another approach used to improve establishment when soil moisture is low (Figure 8). Water-harvesting furrows can be used on a range of soil types but are particularly effective in sandy soils that dry quickly and in water-repellent soils that do not wet up uniformly.

When sowing into a drying soil profile, placing seeds into moisture at the bottom of a tilled furrow promotes sustained access to deeper soil moisture via capillary rise. Under marginal moisture conditions, this is especially effective when combined with deeper sowing to reduce seed zone drying rates. This technique, also known as 'moisture seeking', is most successful when sufficient moisture is present at depth to sustain full germination without relying on post-seeding rainfall.

In contrast, deep furrow till seeding systems can be set up to lift deeper soil moisture into a shallower seed zone. This technique however dilutes existing furrow moisture and breaks the pore continuity below the seed zone that drives capillary rise.

Figure 6: The effect of soil moisture content on the osmotic potential of a soil solution in soils with different levels of salinity, measured as EC. The more negative the osmotic potential, the less soil moisture is available to the germinating seed and emerging seedling. The permanent wilting point is equivalent to a water potential of minus 1500 kilopascals (kPa). EC is based on 1:5 soil:water extract.



Source: McDonald (2022)

Figure 7: Seed of Scepter[D] wheat after three weeks in a sandy-loam soil at a water content equivalent to 25% of field capacity. Seed has absorbed water and germination has started but there has been no or little root or coleoptile elongation.

Source: Glenn McDonald

In terms of furrow shape, press wheel furrows shaped as a wide 'V' capture showers of rain and concentrate moisture deeper below the base of the furrow. This improves crop establishment and helps maintain crop vigour when soil moisture is low and rainfall is limited. This technique is most effective where some degree of surface water repellence – even transient – is present, to maximise water harvesting from surface run-off. Care is needed to manage risks associated with this technique, namely the erosion of water-repellent furrows facing downslopes and harvesting of soluble pre-emergence herbicides that are soil applied.

The benefits of using water-harvesting furrows are best achieved by:

- a stable furrow shape, ideally sown between rows of standing stubble for protection against in-fill during the season (Figure 8);
- wide 'V' press wheel tyre shape promoting greater harvesting width, with sides to also firm the shoulders of the furrow;
- a suitable opener size and operating depth creating a matching tilled furrow size and shape; and
- a centre row seeding configuration.

Tips for dry sowing are provided in Box 1.

ESTABLISHMENT UNDER WET CONDITIONS

Germination and crop establishment are very sensitive to wet soil conditions. Excess water in the soil causes the soil pores to become filled with water, displacing oxygen and reducing the gas exchange between the soil and the atmosphere. Biological activity continues to use up the oxygen in the soil and eventually the soil becomes deficient in oxygen and therefore anaerobic. There can also be a build-up of other gases, including ethylene and carbon dioxide, that are detrimental to germination and seedling growth. In contrast to germinating seed and emerging plants, established seedlings are more tolerant of waterlogging.

PRACTICES TO IMPROVE ESTABLISHMENT IN WET CONDITIONS

Maintaining good soil structure is important to reduce the adverse effect of wet soil on establishment. Small pores in the soil drain slowly, whereas well-structured soils with large pores drain more freely, minimising the effects of wet soil. Maintaining soil organic matter and correcting crusting and clay dispersion caused by sodicity improves soil structure and establishment. Cropping under raised-bed systems allows drainage of excess water away from the establishing seedlings. Some benefits may be obtained from deep furrow side banding seeding configurations where some of the excess water can bypass the seed zone.

However, the most effective way of improving establishment in wet soils is avoidance; that is, by sowing early and having the crop established and growing before the soil becomes too wet. This may also mean selecting a mid-season or long-season variety suited to early sowing.

Adjusting seeding rates is another approach to improve plant densities in wet soils. Increasing seeding rates to compensate for an expected reduction in establishment may increase the established plant density but it will not alter the establishment rate.

Another cause of poor establishment in wet soils is damping off disease. This is caused by soil-borne pathogens such as *Pythium* sp., *Rhizoctonia solani*, *Fusarium* sp., and is more common under wet conditions. Seed dressings can help to reduce the impact of these pathogens and increase establishment.

BOX 1: TIPS FOR DRY SOWING

- Choose appropriate paddocks if possible. Avoid dry sowing in soils with high salinity. Producing a friable seed bed in the seeding row may be difficult in hard-setting and heavy soils.
- In non-wetting soils, sowing close to the previous year's rows can help with accessing moisture from subsequent rain. Other tactics for non-wetting soils can include deeper sowing and increasing sowing speed to throw non-wetting topsoil out of the furrows.
- Set up the paddock to minimise in-crop weed burdens. This includes a compatible pre-emergence herbicide and prioritising paddocks with low weed seedbanks.
- Manage the fallow to maximise deep moisture retention.
- Select varieties suited to early sowing and sow different varieties to reduce the risk of frost damage.
- Avoid high rates of fertiliser applied with the seed at sowing and ensure seed and fertiliser are well separated at sowing, especially on lighter soil and in sensitive crops.
- Use good-quality seed.
- Apply an appropriate seed dressing at the recommended rate.
- Ensure the seeder is set up to allow effective furrow penetration and achieve accurate and consistent seed placement. This is especially important with deep sowing.
- Increase press-wheel pressure in cloddy conditions and seek to maximise water-harvesting furrows for effective early wetting beyond the seed zone.

Figure 8: Wide water-harvesting furrows protected by standing stubble in a highly wind-erosion-prone sandy soil environment.

Source: Jack Desbiolles

Soil temperature

Soil temperature affects the rate of germination and emergence and also the growth of seedlings. Three key measurements are used to describe the effects of temperature on the rate of germination:

- the base temperature below which germination will not occur;
- the optimum temperature where the rate of germination and emergence is greatest; and
- the maximum temperature above which germination will not occur.

Germination and emergence rates increase as temperatures increase to the optimum temperature and decline as temperatures increase beyond the optimum to the maximum temperature. Reported values for these temperatures vary among crops, but in general for winter crops the minimum temperatures are 0°C to 5°C, optimum temperatures are 15°C to 25°C and maximum temperatures are commonly 35°C to 40°C.

Between the minimum and optimum temperatures, emergence is hastened as temperature increases, but the accumulated temperature (the sum of the average daily temperature over time, or the thermal time) for emergence is relatively constant. Thermal time is based on average daily temperature. The thermal time for emergence has been reported to range between 100 and 130 degree-days (°C.d) in wheat, between 90°C.d and 115°C.d in canola and between 90°C.d and 115°C.d in lentils. Table 3 provides examples of the thermal times required for emergence in a range of crops and the corresponding days to emergence at different soil temperatures.

Sowing depth and time of sowing influence the temperature at which a seed germinates, due to the changes in soil temperature (Figure 9). The variation in the maximum soil temperature is greater than the variation in the minimum soil temperature. Soil temperatures are warmer during March and April but shallow sowing at 2.5 centimetres can expose the seed to temperatures greater than the optimum temperature, which can lead to reduced establishment.

Table 3: The thermal time (degree-days,°C.d) for emergence in different crops and the corresponding time (days) to emergence at three soil temperatures.

Crop	Time to emergence (°C.d)	Days to emergence at soil temperature		
		25°C	15°C	10°C
Wheat and barley	130–150[A]	5.2–6.0	7.0–10.0	13.0–15.0
Canola	105–115[B]	4.2–4.6	7.0–7.7	10.5–11.5
Pea	94–130[C]	3.8–5.2	6.7–8.6	9.4–13.0
Lentil	94–116[D]	3.8–4.6	6.3–7.7	9.4–11.6
Faba bean	150–208[E]	6.0–8.3	10.0–13.9	15.0–20.8
Chickpea	93–190[F]	3.7–7.6	6.2–12.6	9.3–19.0

[A] GRDC GrowNotes: Wheat (2106); GRDC GrowNotes: Barley (2016); AHDB (2018)
[B] NSW Department of Primary Industries (2011); Hertel (2012)
[C] Olivier and Annandale (1998); Gan et al. (2002); GRDC GrowNotes: Peas (2017)
[D] McKenzie and Hill (1989); Safahani et al. (2017)
[E] Ellis et al. (1987); Ellis et al. (1988); McDonald et al. (1994)
[F] Gan et al. (2002); Bas Nahas et al. (2019); Verghis et al. (1999); Rajin Anwar et al. (2003)

Figure 9: Maximum and minimum air temperatures and soil temperatures at 2.5cm and 15cm depth between January and June in Adelaide.

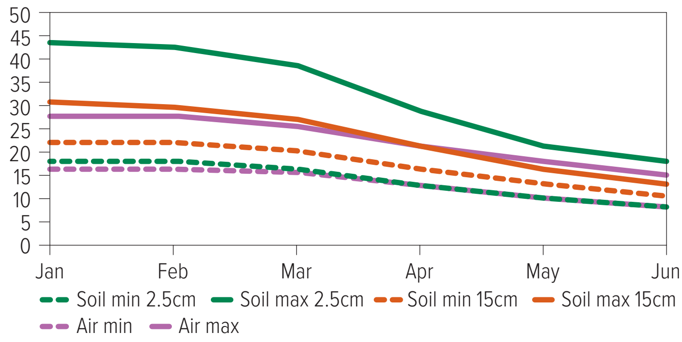
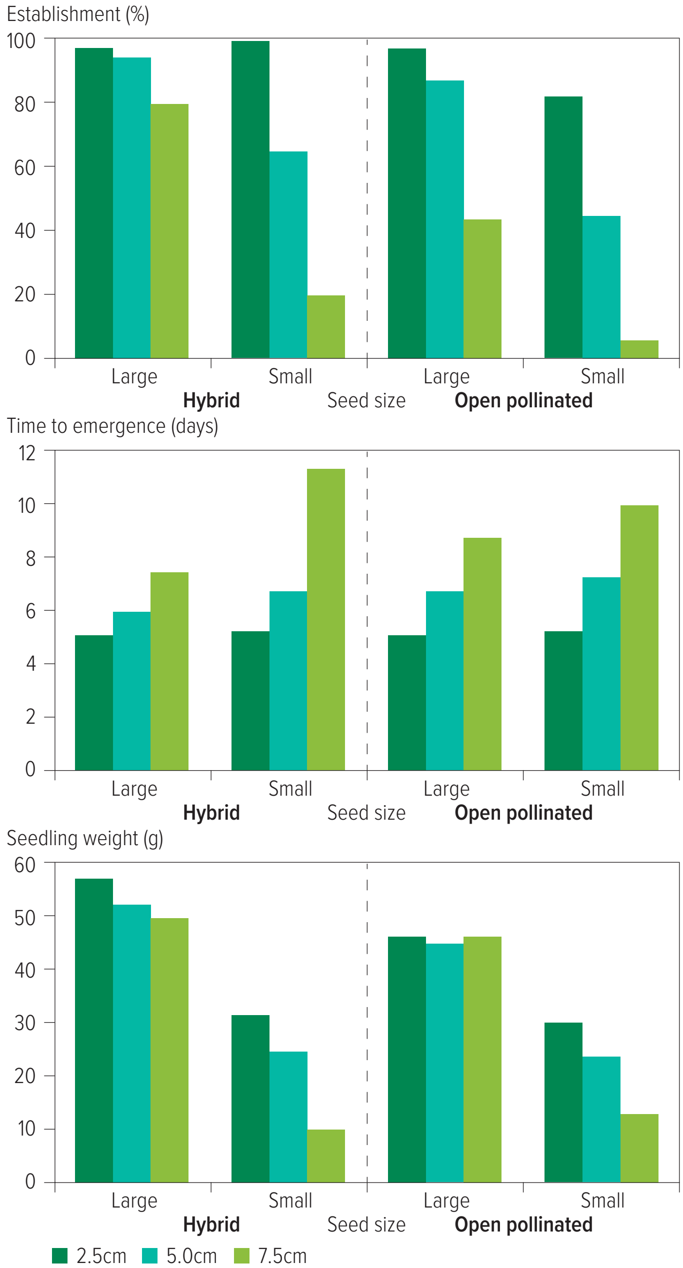


Figure 10: The effects of seed size and sowing depth (2.5cm, 5.0cm and 7.5cm) on the emergence and seedling growth of hybrid and open-pollinated canola. Seedling weight is based on 100 plants 15 days after emergence. Small seeds had a diameter of 1 to 1.4mm and large seeds had a diameter of 2 to 2.4mm.



Source: Adapted from Brill et al. (2014)

Seed quality

Seed quality is an important factor affecting germination, emergence and establishment. Plump, well-filled grain with a high nutrient content will promote germination and establishment and improve seedling growth. A large seed is also better able to emerge from deep sowing; this is especially important in small-seeded crops such as canola (Figure 10).

Sowing depth

In general, sowing seed deeper than the recommended depth can delay emergence, reduce crop establishment and reduce stand uniformity. Deep sowing is suited to sandy and friable soils where seedling growth is not impeded, and to early sowing when soil temperatures are high and there is sufficient soil moisture to cause germination and seedling growth. Shallow sowing is suitable for late sowing into cold and moist soil when the rate of germination will be slow, and in soils that are heavy, poorly structured or hard-setting where resistance to seedling growth can be high.

Crops can be sown deeply to access subsoil moisture but slow emergence and poor establishment may occur. Seeding depth is also used as a strategy to reduce losses from mice and to avoid damage from some pre-emergence herbicides.

Tips for deep sowing are presented in Box 2.

BOX 2: TIPS FOR DEEP SOWING

- Use good-quality seed with high seedling vigour.
- Sow early into warm soils.
- Avoid deep sowing into dry soil unless there is moisture at depth.
- Use deep seeding furrows to reduce the amount of soil cover, however this strategy may not be suited to short crops.
- Avoid hard-setting soils and, in the longer term, look to improve surface structure.
- Use cereal varieties that have long coleoptiles or canola varieties with long hypocotyls.
- Increase the seeding rate to compensate for expected poorer crop establishment.
- Monitor press-wheel packing pressure to avoid over-consolidating the furrow.
- Minimise the cloddiness of the furrow tilth by targeting optimum soil moisture.

Sowing rates

Achieving high rates of crop establishment at the target plant density requires adjustments to seeding rates to account for variation in crop establishment and it also requires accurate calibration of seeding equipment. The key factors to consider for crop establishment and for estimating sowing rates include:

- seed germination percentage (proportion of normal seedlings);
- paddock losses during germination and establishment, which will vary according to conditions at sowing; and
- thousand seed weight.

Table 4: The effects of cereal grain weight and crop establishment on the sowing rate (kg/ha) needed to achieve an established plant density of 150 plants per square metre.

Crop establishment (%)	1000 grain weight (g)				
	30	35	40	45	50
55	82	96	109	123	136
60	75	88	100	113	125
65	69	81	92	104	115
70	64	75	86	96	107
75	60	70	80	90	100
80	56	66	75	84	94
85	53	62	71	79	88
90	50	58	67	75	83
95	47	55	63	71	79
100	45	53	60	68	75

Crop establishment takes into account the germination rate of the seed and the paddock losses and can be estimated from the following formula:

$$\text{Crop establishment (\%)} = \text{Seed germination (\%)} \times (1 - \text{Paddock losses (\%)})$$

Paddock losses will be specific to crop, soil type, seeder setting and seasonal conditions but, over time, growers will be able to estimate paddock losses more accurately by monitoring crop establishment and accurate seeder calibration, explained below.

SEEDING RATE CALCULATIONS

Being able to sow seed consistently at a specific seeding rate is critical to achieving the optimum established plant density. It is important to know what sowing rate is required for your target plant density. This will be influenced by seed quality (grain weight and germination percentage) and paddock losses. The seeding rate to be delivered by the seeder can be calculated using the following formula:

$$\text{Seeding rate (kg/ha)} = \frac{\text{targeted density (plants/m}^2\text{)} \times \text{thousand seed wt (g)}}{\text{\% crop establishment}}$$

Table 4 illustrates how thousand seed weight and crop establishment rate influence sowing rates in cereals. It highlights how seeding rate can change considerably depending on grain weight and expected crop establishment.

CALIBRATION OF BULK SEED METERING SYSTEMS

Reliable calibration of seeding equipment is an important first step in achieving good crop establishment. Accurate calibration of a seeder ensures the actual delivery of seed matches the target seeding rate. The target seeding rate should reflect the optimum agronomic recommendation for each crop and be adjusted to suit paddock and seasonal conditions. Modern airseeders often use an electronic rate control system with a simple screen-guided routine that growers can use to quickly calibrate the seeder, with the key steps being described in the operator's manual.

An initial calibration is required for every crop type and seed batch as the seed metering system is designed to provide a volumetric output, and the seed delivery weight per metering roller revolution is affected by seed size.

After the initial calibration, rates for specific seed batches can be calibrated either through a control system or manually. Using the control system, the grower then dials up or down to a different rate. In manual calibration, the grower uses manufacturer-supplied reference seed rate charts to work out the new sprocket settings required.

A GRDC survey of crop establishment found that higher rates of establishment were achieved by seeders in which the control system was used for calibration, rather than the manual calibration (McDonald 2022).

UNIFORMITY OF SEED DISTRIBUTION IN AIRSEEDERS

With a centralised seed metering system, airseeders rely on the splitting uniformity of the primary splitters and distribution heads to deliver uniform rates to the individual seed rows. The uniformity of seed distribution can be affected by the design, assembly and operational settings of the seeder. Imbalance in back-pressure across outlets can also be important. For example, obstructions causing uneven terminal hose back-pressure can distort the distribution uniformity, especially with lighter seeds and under higher air velocity. Seed damage and high seed spread in-furrow are also associated with excessive air velocity.

Row-by-row calibration checks across the seeder width should be done once a year to assess the variation in seed and fertiliser delivery rates. The measured coefficient of variation (CV)[1] should be less than five per cent and 10 per cent for excellent and good ratings, respectively. Single-row delivery that deviates by more than five to seven per cent from the mean should be investigated and rectified where possible.

Box 3 presents an example of how to check seeder uniformity.

PADDOCK OPERATION: SPEED AND SOIL THROW

High sowing speed can reduce crop establishment by reducing the uniformity of seed placement and increasing soil throw out of the furrow (Table 5). The layout of narrow point openers over multiple ranks results in seed row ridging when operating at excessive speed. Furrow ridging can increase seed soil cover beyond an acceptable depth and concentrate pre-emergence herbicide, affecting crop safety on these seed rows. Although furrow ridging is worsened with deep furrow tilling depths, low soil disturbance openers and wide row spacing minimise these limitations.

Sowing speed should always be controlled to achieve uniform seed furrows across the seeder bar as this is proven to optimise seeding performance. Thresholds for row spacing that control the risks associated with furrow ridging have been determined (Table 6). As the table shows, the increased risk of excessive soil throw at high speed and with deep furrow tilling requires a wider row spacing to maintain crop safety.

[1] Coefficient of variation = (standard deviation / mean seed rate) x 100%

BOX 3: EXAMPLE OF CHECKING SEEDER UNIFORMITY

Uniformity across a 32-row tyned seeder was checked by measuring the weight of seed delivered by each row. The CV for the seeder is 4%, rating it as excellent, although two rows (tynes 5 and 14) that deviated by more than 5% of the mean could be checked.

Tyne	Seed weight	Tyne	Seed weight	Tyne	Seed weight	Tyne	Seed weight
1	9.7	9	10.3	17	10.3	25	9.7
2	9.8	10	10.4	18	9.9	26	10.3
3	10.3	11	9.7	19	9.7	27	9.7
4	9.8	12	9.9	20	10.2	28	10.3
5	9.3	13	10.3	21	9.6	29	9.8
6	9.6	14	11.2	22	9.7	30	10.4
7	10.3	15	10.3	23	10.3	31	9.7
8	10.3	16	9.6	24	9.5	32	9.6

Average weight of seed per row: 10kg
Standard deviation: 0.4kg
CV% = 0.4/10 x 100% = 4%
Mean ± 5%: 9.5 to 10.5kg

Table 5: Effect of sowing speed on the establishment of canola for two crop surveys.

Victoria, SA and WA		Central and northern NSW	
Sowing speed (km/h)	Establishment (%)	Sowing speed (km/h)	Establishment (%)
6–8	71 ± 4.8	6–8	52
8–10	73 ± 4.2	9–12	48
11–17	59 ± 5.6	12–17	36

Source: McDonald (2022) GRDC paddock survey 2018-2019 (for Victoria, SA and WA) and McMaster et al. (2018) for central and northern NSW

UNIFORMITY IN SEED SINGULATION SYSTEMS

Seed-by-seed metering and delivery, or seed singulation, is a reliable technique used by precision planters to achieve perfect uniformity in seeding rates across seed rows for a target plant density, as well as consistent interplant spacing along the seed row. The use of precision planters in winter crop production is limited at present, although there is growing interest in adapting the technology to sow winter crops. Further details are provided in Section 3.

Box 4 provides tips to achieve good crop establishment.

BOX 4: TIPS TO ACHIEVE GOOD CROP ESTABLISHMENT

- Address soil constraints such as surface crusting or water repellence.
- Avoid marginal moisture conditions unless rain forecast is favourable. It is better to seed into dry soil than marginal moisture, especially for small-seeded crops such as canola.
- Avoid dry sowing in soil with high salinity.
- Use high-quality seed (high germination rate and large seed size).
- Calibrate the seeder, preferably using the control system, to ensure accurate seed rate delivery on average across the seeder.
- Keep the row-to-row variation in seed and fertiliser delivery low. Single rows that differ by more than five to seven per cent from the seeder mean should be investigated and rectified where possible.
- Separate seed and fertiliser placement in-furrow, especially with sensitive crops such as canola.
- Keep sowing depth to within the maximum limits of the coleoptile/hypocotyl length of the cultivar.
- Check the seeding performance throughout the sowing operation and adjust to suit conditions when required.
- Check crop establishment once crops have emerged to ensure that target densities have been achieved.

Table 6: Safe row spacing threshold required to limit the proportion of an adjacent seed row length affected by soil throw to a maximum 25% coverage, for a range of furrow openers operating under compacted test track sandy-loam soil conditions.

	Sowing speed and depth			
	6.5km/h		10.5km/h	
Opener type	90mm	130mm	90mm	130mm
16mm knife-point	23cm	29cm	35cm	41cm
50mm inverted T point	27cm	29cm	35cm	46cm
Rippled disc blade	6cm	7cm	6cm	7cm
25 wave disc blade	12cm	8cm	14cm	10cm

Source: Adapted from Desbiolles and Saunders (2006)

SECTION 2

Grower case studies

SNAPSHOT

GROWER: Luke Simon

PROPERTY NAME: 'Talksim'

LOCATION: Halbury, SA

FARM SIZE: 1800ha

ANNUAL RAINFALL: 400mm

SOIL TYPES: Sand, sand over clay, loam, red loam and black clay

ENTERPRISES: Wheat, barley, beans, canola and field peas

SEEDING EQUIPMENT: 15.24m (50ft) Boss Bridge frame planter with TX45 openers on 23cm (9 inch) spacings and Simplicity 9000 tow-behind air cart

Luke Simon believes crop establishment is key to providing a good return on crop investment. Photo: Rebekah Allen

LUKE SIMON

50-foot Boss Bridge frame planter improves productivity across diverse soil types

For Halbury grower Luke Simon, farming land across a variety of soil types is one of his family's greatest challenges. The family's mid-north property, 'Talksim', ranges from non-wetting sands through to heavy black clays that become problematic in wet conditions, an issue particularly difficult to manage at critical times such as seeding.

A recent switch from their disc seeder to a 50ft Boss Bridge frame planter has enabled the Simon family to improve productivity. Luke believes crop establishment has also improved as a result of their purchase, made approximately 12 months ago. The rig includes a TX45 parallelogram tyne unit for minimal soil disturbance and consists of narrow, single-shoot points on 23cm row spacings.

Improvements through better stubble management

The 'Talksim' farm is split across two properties and, for the Simons, this can become particularly challenging, working with varying rainfall and soil types. With the disc seeder, logistics can become difficult. "We would have to try and guess when the rain was coming and work around it, as one block is defined by heavier clays," Luke says. "Following 15mm rainfall on our heavier country, we have been able to sow the next day with our Boss seeder bar and keep working. With the disc seeder, we would have been waiting a week to get back on that ground."

Luke has found simplicity is key when it comes to choice of seeder bar. "We chose this seeder not only to improve establishment in crop stands, but for ease. We found we were having to rebuild our disc each season, where the Boss machine is much easier to maintain."

The improvement in crop establishment has come from the ability to better manage stubble loads. Luke has also found the Boss Bridge frame TX45 tyne system delivers better results and ensures more seed gets in the ground at seeding time, particularly in

GRDC

paddocks with a higher stubble load. "We have definitely noticed an improvement in crop establishment. The disc system at the front of the machine allows the seeder bar to cut and sow through heavy stubble loads, which was an issue with our previous disc," he says.

Luke is happy with the new machine, which has only required some minor adjustments. These include modification to tynes behind the tractor wheels and the addition of guards on the shank to stop stubble catching.

Advantages of a small seeds box

In addition to the Boss seeder bar, Luke uses a Simplicity 9000 tow-behind quad with a TopCon X20 in-cab monitor. The air cart comprises two sealed and pressurised bins plus a small seeds box, which is injected into the secondary manifold. Luke purchased the box after encountering issues with small seeds such as canola, and says it's "worth the money". "The most common issue we had with canola was finding missed strips in the paddock, as a result of blanking off rollers during seeding," he says.

He is now able to better manage canola seeding rates and is no longer needing to source additional seed to ensure all rollers are full of seed, which also saves time. "Now that we have the small seeds box, we no longer have issues with fine seeds," Luke says.

In addition to the small seeds box, blocked row sensors have been a consideration for the Simons. "Blocked row sensors would be great, but they can be a hassle as they narrow the inside diameter of the hose and that's why we haven't given them a go," Luke says.

The Simplicity 9000 has provided good air conveying capacity and is excellent at varying speeds; however, Luke says he would like to see a more consistent seeding rate out of them. "I think that the metering accuracy and distribution of the machine could definitely be improved," he says.

Defining 'success'

To Luke, successful plant establishment is important for two reasons: to ensure a good crop yield at the end of a given season and to ensure good weed control. "Crop inputs can be high, especially when we can be spraying three to four times in one year," he says. "It is important to ensure a good return at the end of the year and that is why establishment is imperative to us. We were noticing that not only was the ground getting hard, but we were having trouble getting everything to come up, which is why we sold the disc seeder."

The Simons' Boss TX45 parallelogram unit is followed by a press wheel system. Photo: Luke Simon

To maximise crop establishment, Luke says selecting a good seed source and managing soil herbicide residues are of great importance. "We also ensure all seed is treated prior to seeding, to try and promote good crop health and establishment." Luke believes it is important to note that good rainfall, both early and in-season, plays an important role in the success of crop establishment.

The importance of pre-seeding checks

Luke knows that taking time to set up equipment correctly at seeding time can go a long way in improving establishment. Seeding depth is a critical part of set-up, but with the new seeder bar Luke has found he rarely needs to adjust seeding depth. "We normally check depth twice a day and as we come across different soil types. Minimal time is spent doing this, but we assess as we go," he says.

Seeding rates at the 'Talksim' property vary, but normally range between 110 and 115kg/ha for wheat and between 85 and 90kg/ha for barley. Now they are using the Boss seeder bar, Luke says they would like to reduce these rates. "We also ensure the calibration of equipment occurs every two to three days to achieve consistency across our farm."

The Boss seeder bar, which is a 30-tonne rig, has approximately 370kg of downward force on each tyne. This setting has not changed since the family purchased the machine early last year. "Due to logistical constraints, we were required to set up the seeder bar ourselves. At first, we used half the downforce pressure, but found the seeder was blocking up. This was a result of not being able to cut through stubble, [which meant straw was pushed] into the seed slot," Luke says.

In the future, adjustments to tyne pressure may be required due to softer, worked soils. "We are also able to adjust the pressure manually as we go, which is particularly handy if we hit a sandy area in the paddock."

Next steps

For Luke, the next step to improve crop establishment on their property will be to use a liquid injection system to make it easier to apply blended liquids. "We are currently set up for liquids but we haven't used them yet," he says. "Previously, we have had issues where moisture collects dust from the fertiliser and seed, blocking up heads." He says the liquid injection system will make his job easier and mean he will no longer need to pickle grain. Luke has the equipment for variable-rate technology and says it is something they may look at using more often, although he would only use it on a very small area of the farm.

Considering singulation planters

Luke believes seed singulation precision technology would suit his property well if it could be adapted to current equipment, such as a tyne system. "It would be nice to have the option to sow with either option, but that comes at high cost."

Luke's top tips to improve crop establishment

1. Do not rush; take your time seeding.
2. Select a good fertiliser to suit your needs – this could include a custom blend.
3. Keep paddocks clean and weed free.

MORE INFORMATION:
Luke Simon, 0437 060 920, lukesimon@hotmail.com

Stuart Robinson, pictured with Ashley Amourgis (Southern Farming Systems), ranks good crop establishment as the number one factor in the success of cropping on 'Titanga', with increased weed control front of mind. Photo: Ashley Amourgis

STUART ROBINSON

Good crop establishment is the number one factor in cropping success

Since starting as farm manager at 'Titanga' ten years ago, Stuart Robinson has been impressed with the property's seeding equipment. Although yearly maintenance has started to increase on the 2006 model, the simplicity of the machine is working well in the current farming system.

SNAPSHOT

GROWER: Stuart Robinson

PROPERTY NAME: 'Titanga'

LOCATION: Lismore, south-west Victoria

FARM SIZE: 2640ha

WINTER CROPPING AREA: 700ha

SUMMER CROPPING AREA: 150ha

AVERAGE GROWING SEASON RAINFALL: 550mm

SOIL TYPES: Light gravels and basalt clays

ENTERPRISES: Wheat, barley, canola, faba beans, broad beans and Merino wool production

SEEDING EQUIPMENT: 8m (26ft) Horwood Bagshaw Scaribar 350 with 30cm (12in) spacing, Knuckey knife-point and press wheel system, Knuckey coulters on the front and Horwood Bagshaw 400L air cart

Strengths and weaknesses of coulters

One change Stuart made to the seeder was to add Knuckey coulters. He undertook this about five years ago with the aim of improving seeding through stubble, which he is trying to retain, rather than burn. They built their own toolbar and put Knuckey coulters across the front. "The coulters chop through the trash sitting on the surface and clear the way for the tyne to break through without dragging, which has certainly helped with sowing into big stubbles," Stuart says. "One limitation the seeder still has is the coulters are not as effective when stubbles are wet, which can be a challenge in the high-rainfall zone of the western districts."

Another limitation of the seeder that Stuart identifies is how much trash it can get through it. "If we have stubble that's 30cm (12in) and the trash has been well spread, we don't have too many issues with dry sowing. But the moment we start getting some moisture, even at 30cm we can get issues." To manage this limitation, Stuart spends a lot of time around sowing watching the weather forecasts. When a rainfall event is predicted, he will try to dry sow before the rain arrives.

Good crop establishment for weed control

Stuart ranks good crop establishment as the number one factor in the success of cropping on ‘Titanga’, with increased weed control front of mind. “We are looking for rapid, early establishment and trying to get crops to shade over as quickly as possible to keep the ryegrass at bay,” Stuart says. Producing a good, thick canopy has been an effective early season weed control method.

Changing the set-up for faba bean

Using plant density for weed control, particularly in bean crops, has meant Stuart sows faba beans at 18 to 20 plants/m^2. Planting faba beans at these sowing rates can present some challenges with the seeding equipment and tubes getting blocked. To combat this, Stuart says he swaps his seed and fertiliser around. “We put the beans down the fertiliser shoot, which is the shoot on the tyne, and we put the fertiliser down the seed tube, which is on the press wheel that runs behind the tyne. We put the beans down that shoot because it’s a much larger shoot and we don’t get blockages,” he says.

This simple alteration allows Stuart to achieve high sowing rates and provides another tool for managing early season weed control in the bean rotation, which is particularly important in his high-rainfall environment.

Seeder operation and set-up

Stuart says he places a lot of emphasis on ensuring things such as the seeder set-up and operation are correct, as they are parts of farming you can have some control over. He considers these two factors as paramount to success during sowing at ‘Titanga’.

Stuart says he spends much of his time during sowing out in the paddocks with his operators, working with them to optimise the sowing operation by regularly checking sowing speeds and seed depth. “I find the seeder performs best at around 7km/h, but we do drop back to around 4km/h when sowing faba beans,” he says. “I am a bit fussy about the speed. It is a spring-release machine and it’s not hydraulically controlled, so if we do operate at a speed that is too high, much above 7km/h, we start to get pushback on the tynes.”

Stuart says he also regularly works with his operators to check the seed depth. “We adjust depth depending on the soil conditions. If we have rain during seeding, then I will be out there watching things pretty closely, as we’ll usually drop the seed in a bit deeper after a rain event. We have this system where the seeding depth is determined by the press wheels, but after rain, especially if we have gone too early, the press wheels will build up a bit, which can be a bit of a problem. So that’s a good indicator to back off and wait for it to dry out a bit.”

Controller system set-up

The controller system used on the seeder is a Horwood Bagshaw mechanical metering system. Stuart says it is a far simpler system than what is available on the newer models. One thing he does consider important in the tractor cab, however, are cameras. “We’ve got in-box cameras and cameras on the delivery shaft … because it is a mechanical system, we can be confident the operator should know if something breaks and the seed stops going out,” he says.

Plans for the near future

Although it does have some limitations, Stuart says overall he is incredibly happy with his seeder’s performance and has no plans for additional modifications or an upgrade soon. “It’s basic, it’s simple and pretty low maintenance and seems to work well. That’s why it’s 15 years old I suppose.”

Stuart’s top tips to improve crop establishment

1. Get the seeding depth right and check it regularly.
2. Control weeds.
3. Monitor the seeder closely when it is operating.

MORE INFORMATION:

Stuart Robinson, 0407 319 196, robinson-caruso@bigpond.com.au

One change Stuart Robinson made to the seeder was to add coulters to aid with seeding through retained stubbles. They built their own toolbar and put Knuckey coulters across the front.

Photo: Ashley Amourgis

For Trevor Syme, even though 100 per cent establishment is the aim, he's happy with 70 to 80 per cent as long as minimum plant numbers are met for optimal yield. Photo: Dani McCreery

TREVOR SYME

Finding success with non-wetters

Balancing establishment and even distribution of plants

For Trevor Syme, even though 100 per cent establishment is the aim, he is happy with 70 to 80 per cent as long as minimum plant numbers are met for optimal yield. What is more important to him is an even distribution along the row to maximise weed competition. "The aim is to get the plant numbers required for maximising yield while minimising the impact of weeds," Trevor says. He admits it is hard to put a dollar value on good establishment, but it sets growers up for the season. "You can't control what comes after seeding, but with good crop establishment you can then manage accordingly, knowing the money you invest will be rewarded," Trevor says.

The importance of early establishment

Early establishment is important in Trevor's environment. "Canola is a good example where you can double your yield by getting the crop germinated early," Trevor says. Trevor now seeds by date. He does not necessarily have a starting date but he aims to finish seeding by 30 May to avoid compromising the growing season and potential yield.

Key strategies to maximise crop establishment

Trevor's key strategies to reliably achieve good crop establishment are, first, to have a weed-free summer so there are no large weeds to interfere with seeding. Second, he recommends controlling weeds and retaining stubble to retain as much moisture as possible over summer and autumn. Third, he advises being ready to seed on time to take advantage of available soil moisture. His fourth piece of advice is to pay attention to detail – always check for moisture depth and seedbed conditions (Trevor is constantly jumping out of his tractor to check these things). Lastly, Trevor says to set up seeders early to make sure they are working properly. Some of the strategies Trevor uses to maximise crop establishment include:

- keeping fertiliser away from seed and minimising nitrogen when seeding canola (Flexi-N is too hot);
- retaining good seed – he puts his seed over a gravity table to ensure it is a good size;
- strategic use of a wetting agent – he does not use wetting agents when dry sowing but does when there is subsoil moisture, to draw moisture into the seed and minimise poor germination; and
- chasing moisture when it is available at a reasonable depth, although this is season-dependent – if the soil is totally dry, keep seed at the optimal depth.

SNAPSHOT

GROWER: Trevor Syme

PROPERTY NAME: 'Waddipark'

LOCATION: Bolgart, WA

FARM SIZE: 4000ha

ANNUAL RAINFALL: 400mm

AVERAGE GROWING SEASON RAINFALL: 300mm

SOIL TYPES: Deep white non-wetting sands (many ameliorated to overcome non-wetting and acidity), loamy clays, forest gravels, gravelly sand over clay

ENTERPRISES: 3600ha wheat, barley, canola and lupins

SEEDING EQUIPMENT: Custom-built 12.5m Gessner Bar with Equalizer disc coulters and row units, tyne seeder with both single and dual boots on 38.1cm (15in) row spacing.

Challenges to crop establishment

Trevor's greatest challenges to good crop establishment are:

- non-wetting soils – he ameliorates his non-wetting soils to remove this constraint;
- moisture availability at seeding – lack of May rainfall has been an issue for the past 10 to 20 years; and
- soil structure where clods result in poor seed–soil contact.

Stubble is not an issue for Trevor, even in paddocks where he has retained residue for more than 20 years. He is a controlled-traffic grower. He sows seeds inter-row on relatively wide row spacings and ensures residue is chopped and spread evenly at harvest. At this stage, Trevor does not use variable-rate technology to sow crops but he is looking into it. "It's very important to have a seeder that can seed at varying depths and is easy to adjust like my seeder bar does," Trevor says.

Success with non-wetters

Trevor used non-wetters for the first time in 2020 and intends to continue using them in lupin and canola crops in the future, even on good soils, unless they are wet. "They were excellent on everything. I will be using the product in future on lupin and canola, even on good soils (unless wet). It's like turning a 5mm rain event into a 10mm rain event," he says.

Trevor places the wetter behind the seed tube in front of the press wheel to get the product as close to the seed as possible. "Otherwise you are drawing water away from seed," he says.

Trevor also uses soil amelioration to overcome non-wetting and undertakes claying where there is no clay at reasonable depth, delving when clay is deep and spading when clay is near the surface.

Seeder bar set-up

Trevor uses a Gessner Bar with Equalizer disc coulters and row units, which was built in 2017 to suit his soil types and farming system. He uses both single and dual tynes, but rarely uses the dual tyne as he finds it disturbs more soil and creates more weeds. If needed, he can sideband where there is plenty of moisture as it presses seeds into the side of the wall. When dry seeding, Trevor furrow sows. The seeder bar operates on 38.1cm row spacing with 33 rows in one year. As he inter-row sows, Trevor uses 32 rows every other year. "If I'm not moisture seeking, I sow wheat at 3cm, barley at 3cm, canola at 1cm and lupin at 4cm at 11km/h," Trevor says.

Use of chemicals

Trevor uses a mix of Sakura®, trifluralin, simazine, atrazine and propyzamide at label rates for the appropriate crops. As he has relatively wide row spacings, he has not seen any crop damage from soil throw. He also maximises stubble retention so rarely has herbicide wash-off issues.

Seeder set-up

Trevor chose the Equalizer as it has an independent tyne, unlike DBS, that is better suited to rocks in the paddock. It is also suitable for all soil types on-farm so no set-up changes are needed mid-paddock, unlike when he used a disc seeder. When it comes to crop establishment success, Trevor feels it is not all about the seeder. "Once the seeder is set up, I believe it's the whole farming system, including soil amelioration, stubble retention and no-till that makes crop establishment easier," he says.

Trevor has not made any changes to his machine over the past four years, but he is putting air breaks (diffusers) on the seeder to reduce seed bouncing. He can now adjust air flow based on seed size, which results in more seed being placed where it should be.

Air cart performance

Trevor uses a tow-behind Boss Engineering air cart that has two liquid sections and one granular sealed section. He uses a roller metering system, which offers excellent distribution for all seed types, both fine and coarse, and has a metering system for every line.

Trevor has four primary dividers and eight secondary manifolds, which accommodate the 32 rows. The terminal lines are 32cm. The seeder has also been fitted with air diffusers to help with seed distribution.

Trevor has a John Deere Gen 4 SeedStar™ 3000 monitoring system in the cab. "Money well spent," he says. "The blocked row sensors are a must and the row-to-row distribution is excellent." Even though Trevor has not measured this, his neighbours have observed how even his runs are. "The system is excellent for low and high seeding rates, with no damage observed," he says.

Monitoring seed depth

When it comes to the seeding operation, Trevor monitors seed depth all the time. He oversees the seeding rather than driving the tractor but he is constantly checking on things. He pays special attention to seeding depth in canola, as the best sowing depth varies depending on seasonal conditions.

On soil types that have recently been ameliorated, Trevor sows shallower due to furrow fill and so the seeder does not dig in on the softer soil. He will also drive slower in these paddocks.

Trevor can change seeding depth in five minutes on his seeder, so timing is not a huge issue when he needs to adjust anything, which is another reason he has chosen the Equalizer. "I place fertiliser below seed for crop safety, with the mechanics of the seeder guaranteeing separation. I haven't needed to adjust press wheel pressure so far," he says.

Dealing with pests

Trevor does have a slug issue on his high-rainfall block, which he baits every year in canola and lupins with excellent results.

Trevor's top tips to improve crop establishment

1. Get your farming system right – use a no-till system.
2. Have a plan to work towards that system.
3. Attention to detail with correct timing is critical.
4. Bigger is not always best.

MORE INFORMATION:
Trevor Syme, 0407 999 536, waddiparkfarming@gmail.com

Row unit set-up showing independent press wheel regulated seed banding boot, opener. Photo: Trevor Syme

The McAlpines monitor seeding depth whenever conditions change, such as moving to different soil textures, soil types or soil moisture conditions. Photo: Liebe Group

STUART McALPINE

New seeding approach helps to optimise establishment in WA's shorter seeding windows

Stuart McAlpine finds that marginal moisture conditions are the primary factor limiting good establishment in his region.

The McAlpines' Buntine property is in an area where average growing season rainfall has been decreasing, with rainfall events becoming smaller and less frequent during the traditional growing period. There has also been a shift towards later and more variable season breaks. These factors combine to make it increasingly common for growers in the region to be seeding much of their program into marginal moisture conditions.

For Stuart, however, this problem has recently been lessened by switching from a tyne seeder to a new Horsch Pronto 12 NT disc seeder. The new seeder allows significantly increased efficiency at seeding, reliably operating at 18km/h without impacting seed placement, wheel slip, soil throw or seeding rate capacity.

With their 18m (60ft) seeding bar, the change from the standard 8km/h speed has more than doubled the McAlpines' seeding rate from 14ha/h to 33ha/h.

SNAPSHOT

GROWER: Stuart McAlpine

PROPERTY NAME: 'Cooinda'

LOCATION: West Buntine, WA

FARM SIZE: 4000ha

RAINFALL: 283mm

GROWING SEASON RAINFALL: 242mm

SOIL TYPES: Sandy-loam, gravel duplex, medium clay

ENTERPRISES: Wheat, barley, canola, lupins, sheep, cattle

SEEDING EQUIPMENT: 18.28m (60ft) Horsch Pronto 12 NT with undulated coulter/cutting disc on 30cm (12in) row spacings, TurboDisc coulter and in-built triple hopper seed/fertiliser unit

The overall picture

Stuart works his seeding program to an end date. This is the date by which his entire program will be seeded regardless of how the season has progressed. "A knockdown is preferred, and a double knock if possible, for some of the poorer paddocks. If rainfall allows, we will wait to get that knockdown and then start seeding and keep going until it's done," Stuart said. "But even if we haven't had a chance to do a knockdown, I have a date in mind of when I need to start seeding to have the entire program finished by the end of June."

With the new equipment, it takes Stuart half as long to implement the entire seeding program. Given their seeding strategy, this increased efficiency gives the McAlpines a much higher chance of achieving a comprehensive knockdown and seeding into more optimal moisture conditions.

More even establishment from the new disc seeder

The new disc seeder also achieves more even establishment overall. The wavy discs that pre-cut the seed row cope well with even a heavy stubble load. Stuart has not had any issues seeding into stubble since using the machine. The coulters also follow the contour well to achieve more even and more controllable seeding depth, despite uneven soils. The rubber coulter and rubber press wheel work to release high pressures, minimising the effects of speed on seeding depth. These factors combine to allow the disc seeder to achieve more even and reliable establishment across a range of conditions and soil types.

A limitation of the seeder

However, Stuart says a limitation of the seeder is that compared with a knife-point seeder, it has reduced capacity to achieve subsoil cultivation below the seed. He says the disc seeder can achieve cultivation of up to 100mm below the seed compared with at least 150 to 170mm for a traditional knife-point seeder. Stuart is not particularly impacted by this limitation as he is operating a minimum till farming system. However, it may be a significant consideration for others.

Achieving success

Stuart believes that achieving successful establishment depends on adequate soil moisture and having accurate seeding equipment. Both factors can be difficult to manage depending on the resources available. "The most important steps in maximising establishment are seeder calibration, starter fertilisers and seed treatments, specifically biological inoculants, as no pesticides or fungicides are used in our farming system," Stuart says. "Calibration is the most important step and is completely dependent on the disc seeder we use. I was especially drawn to the Pronto because it is well known for its accuracy and defined furrows."

Stuart McAlpine believes good establishment is crucial to the success of every other aspect of farming. Photo: Liebe Group

The McAlpines have found increased efficiencies and improved overall establishment from switching from their tyne machine to the new disc seeder. Photo: Liebe Group

Seeding preparations

The McAlpines monitor seeding depth whenever conditions change, such as moving to different soil textures (for example, ripped versus unripped), soil types or soil moisture conditions. Stuart is willing to spend as long as it takes to optimise seeding depth. However, with the new disc seeder, it has not taken long to adjust. On average, they spend 30 minutes to adjust to the correct depth.

Where to next?

Looking forward, Stuart wants to make a few changes, including starting to optimise his press wheel pressures and vary them more between soil types. This will help to optimise soil–seed contact. He will also purchase a new lead tractor more suited to pulling the disc seeder at higher speeds.

Stuart's top tips to improve crop establishment

1. Work to your soil type. Tailor everything you do to your soil type, from machinery choices to rotation to herbicide regimes.
2. Give disc seeders a go, even if you have had bad experiences with them previously – the new ones are very different from the old technology. This is especially true when seeding canola, which is a good place to start trying a disc seeder.
3. Make sure you get good, consistent weed control. It does not matter how well a crop establishes if it is contaminated and out-competed by weeds.
4. Try to maximise your accuracy. It can really increase your efficiency and crop consistency.

MORE INFORMATION:

'Seeding systems – case studies of growers in WA' and *'Golden rules for canola in the low-rainfall zone'* – see Useful Resources section.

The Sargents have improved seed placement and crop establishment through their purchase of an 18m seeder bar. Photo: Hart Field Site Group

ANDREW SARGENT

New equipment improves crop establishment

Farming on the sandy clay loams of Crystal Brook in the upper mid-north of South Australia, the Sargent family has been an early adopter of no-till farming (1999) and believes crop establishment is key for success.

The 'Brook Park' property is operated by Andrew and his parents Malcolm and Jane Sargent, with the broadacre cropping enterprise consisting of wheat, barley and oaten hay, followed by a break crop of canola or lentils. The average annual rainfall at the property is 400mm, with the program relying on an annual growing season rainfall of 300mm.

SNAPSHOT

GROWER: Andrew Sargent

PROPERTY NAME: 'Brook Park'

LOCATION: Crystal Brook, SA

FARM SIZE: 2000ha

ANNUAL RAINFALL: 400mm

GROWING SEASON RAINFALL: 300mm

SOIL TYPES: Sandy to clay loam

ENTERPRISES: Wheat, barley, lentil, canola and hay production

SEEDING EQUIPMENT: 18m (60ft) Flexi-Coil ST820 seeder bar with root boots on 30cm (12in) spacings and a Flexi-Coil 3850 tow-behind air cart

Seeder bar upgrade

About 10 years ago, the Sargents invested in a new seeding system after previously using a single disc seeder for two years. "We were not achieving the results we wanted, which is why we went back to a tyne machine," Andrew says. They decided on a Flexi-Coil ST820 seeder bar, which Andrew says has enabled them to improve crop establishment on-farm.

The new 18m (60ft) seeder bar has a knife-point press wheel system. It has double-shoot, paired-row ribbon points and is on 30cm (12in) row spacings with root boots. The inclusion of root boots to the machine has allowed the Sargents to improve seed and fertiliser placement.

The Sargents' move away from a single disc seeder to the knife-point press wheel system was prompted by stubble handling issues, in addition to poor seed placement and herbicide damage. "By moving away from the disc seeder, we were able to improve overall crop establishment by better managing large stubble loads at seeding time," Andrew says. "We are also finding that hair-pinning on sandy soils is no longer a problem. Our aim has been to maintain a good amount of stubble without reducing crop germination."

Air cart performance

Behind the Flexi-Coil ST820 system is a 13,390 litre Flexi-Coil 3850 tow-behind air cart with a FlexControl in-cab monitor. Andrew believes the air cart metering system, which is a roller type system, performs quite well. "The suitability for coarse seeds is good, but it has been very susceptible to minor changes when using small seeds like canola," Andrew says. "The distribution of canola seed has been average and although some improvement has been seen since having the Flexi-Coil, variation in the

Andrew Sargent says the key advantages of their Flexi-Coil seeder bar are better stubble handling and improved crop establishment. Photo: Hart Field Site Group

distribution across rows has been observed. We normally check our calibration every 10 to 15 hectares when sowing canola as it's a relatively expensive crop to invest in."

Andrew believes the sensitivity of small seeds comes back to fan speed. "Getting fan speed right has been an issue in the past and it is critical to get it right as small variations in fan speed affect distribution and rate."

Maximising establishment

To Andrew, successful crop establishment is defined by the early and uniform germination of crops. "Good crop establishment is being able to reach your target plant density," he says. "You are already on the back foot if you're not achieving desired plant density for maximum yield."

Andrew believes timeliness of sowing is one of the most important factors in good crop establishment and the Sargents sow as quickly and as early as they can. "I also believe selecting a good, clean seed source is important. We don't tend to hold onto seed for more than one year to ensure quality," he says.

Machine set-up is important at 'Brook Park'. Come seeding, ample time is spent ensuring calibrations and seeding depth are correct. Andrew says seed depth is set for each crop type and is adjusted in the paddock as necessary. "Good early rain is also key for successful and early crop establishment," Andrew says. "The key to good establishment is getting the basics right, don't over complicate. In dry years, we rely on seeding depth and chase deep moisture if we need to."

Although their seeder bar is not a low soil disturbance system, Andrew believes minimal disturbance is an important factor in improving establishment in drier times. The Sargents have been able to maximise plant establishment through better seed placement with their current equipment. They have done this by reducing hair-pinning across sandy soils, which became a common issue in wet conditions during seeding.

One benefit of the Flexi-Coil machine has been the ability to better incorporate pre-emergent herbicides at seeding time, allowing for better crop competition. "Annual ryegrass and brome have been our two biggest weeds on-farm. Since we have been using the knife-point press wheel system, we have increased control through better incorporation of herbicides," Andrew says. "Pre-emergent herbicides such as trifluralin and Tri-allate® (Avadex Xtra®) still work well and remain a good weed control tool within our program."

Looking forward

The seeder bar has some limitations. The Sargents have had implement steer technology now for two years; however, technology compatibility issues continue to interrupt their operations. "The machine doesn't track very well without implement steering, so we are looking at ways to improve so we can better inter-row sow."

Considering singulation planters

Andrew believes singulation planters could fit within their system if they could be adapted to tyne technology. With the increasing costs of seed such as genetically modified canola, Andrew believes precision planter technology could work better to reduce input costs and also address the variability of canola germination and establishment.

Andrew's top tips to improve crop establishment

1. Select the right seeder for your system.
2. Seed in a timely manner.
3. Take the time to set up your machine correctly.

MORE INFORMATION:
Andrew Sargent, 0400 179 956, andrew@brookparkag.com.au

The seeder bar with paired-row ribbon points and root boots has improved seed and fertiliser placement. Photo: Hart Field Site Group

Tim Rethus believes that when it comes to selecting a seeder, you need clear objectives about what you want to achieve on-farm plus an understanding of the implications for your existing cropping system. Photo: GRDC

TIM RETHUS

Crop establishment learnings from the Wimmera

Tim Rethus operates a farming business in the Wimmera with his wife Michelle, brother Luke and sister-in-law Charlene, and his parents Chris and Geoff. For the Rethus family, good crop establishment is critical for success. "If you have poor establishment, you end up with reduced yield and yield is what we get paid for," Tim says.

"Dad has a saying: 'Your maximum yield potential is the day you sowed it.' After that the most important thing is controlling what you can to minimise losses," Tim says.

SNAPSHOT

GROWER: Tim Rethus

LOCATION: Horsham, Victoria

FARM SIZE: 5000ha over three properties

ANNUAL RAINFALL: 400mm

AVERAGE GROWING SEASON RAINFALL: 300mm

SOIL TYPE/S: Self-mulching cracking clay and clay-loam soils

ENTERPRISES: 2000ha wheat, barley, canola, beans, durum, lentils and hay crops

SEEDING EQUIPMENT: Zero-till disc seeding, controlled traffic. 24.38m (80ft) side-shifting NDF frame fitted with 38.1cm (15in) spaced double disc openers, all individually downforce-controlled with hydraulic DeltaForce system, using Keeton seed firmers and twin cast closing wheels. Row-by-row seed counting, blockage sensing on each fertiliser tube, and furrow quality monitoring with Smart Firmers. John Deere 1910 tow-behind air cart with section control and Liquid System on tracks. Also fitted with PJ Green mouse baiting system for baiting at sowing.

Embracing technology

Staying up-to-date with technology is important to the Rethuses and they also enjoy it. Prior to coming back to the family farming business, both Tim and his brother Luke worked in the corporate world for more than 10 years as chemical and telecommunications engineers, respectively. "As a former engineer, I like to know how things work. It's about solving the problem by understanding the source of it," Tim says.

"What I love about farming is there's always a challenge and the possibility of creating something new to solve the problem." His family's ability to modify and adapt their seeding equipment and technology is testament to this ethos. "We moved to a disc seeder around 2000 to maintain a nice soil structure around the seed while still having good infiltration of water," Tim says. "We wanted the accuracy of depth and control over how the furrow is forming. These two elements make a big difference to plant establishment. The disc system also fitted with where we were going in terms of moisture conservation by retaining stubble."

He also believes discs work more effectively than a tyne in tall stubble. "Tall stubble minimises chaff on the ground that can cause pinning and standing stubble disrupts the wind, which helps retain moisture over summer. Sowing wheat into tall canola stubble is a great mix," Tim says. "The stubble acts as a nice, warm blanket for the wheat, protecting it from wind, but letting light through, which helps with establishment and growth."

Machinery choice and modifications

The Rethus family has made decisions about machinery designed to improve plant establishment, including purchasing a precision planter in 2016. "We had a single disc Daybreak, but we were having trouble with the discs stalling in our increasingly soft soils and it wasn't doing a clean job placing the seed," Tim says. "We had the option to purchase a John Deere DB60 precision planter. The twin disc opener delivered fantastic seed placement and also further minimised soil disturbance over the single disc. We decided however to dis-adopt, due to the complexity involved in getting the singulation right and its cost. It couldn't do all our crop types like barley and oats, which foul the seed singulation discs. It was also doubtful that singulation was offering an advantage on our 15in row spacing. For canola it did, and seeds were about 8cm apart, but in lentils it was 2.5cm and in wheat less again."

This meant they had to use the Daybreak seeder and the precision planter at the same time, leading to a faster sowing program but a more logistically complicated seeding process. The family now has a high technology seeder, which is essentially a precision planter without singulation. They had their seeder custom built: a NDF Ag Design 24.38m (80ft) frame on tracks with Harvest International double discs openers. "Essentially it is a precision planter with the singulation equipment removed and matched to our standard airseeder system," Tim says.

"Due to the technology commercially available for precision planters, we could install an auto-adjusting downforce system (DeltaForce), retain the seed sensing at delivery, install Agtron blocked row sensors for the separate granular fertiliser outlets, achieve section control, and furrow property monitoring (Smart Firmer) with liquid delivery of specialty fertilisers, fungicides or insecticides."

Tim believes this approach provides his family with maximum flexibility to customise seeding operations to each paddock with minimal effort. "We like having the ability to tune it. Bits just bolt on. It has lots of aftermarket options to fix problems due to its precision seeder heritage, different discs or closing wheels, for example – parts that are easy to obtain to fix problems quickly," he says. "We wanted something that would bridge the problems of both systems; we loved twin discs but liked the robustness of airseeding."

Geoff Rethus with his previous John Deere DB60 precision planter. The family stopped using the planter in 2019 despite its great benefits, due to the complexity and cost involved in getting singulation right for all crops in their system. Photo: supplied

The family used a 1910 John Deere air cart with rotary valve with cyclone set-up to feed the DB60 precision planter. "This has allowed us to feed a high positive pressure air cart into a vacuum pressure precision planter CCS tank," Tim says. "It tops itself up meaning we save time as we don't have to fill up as often. We tow the air cart for granular fertiliser anyway so we can utilise its seed carrying ability and liquid system."

However, he says one downside of precision seeders is they are not suited to the high seeding rates generally used in his region. They also lack the seed-holding capacity of an airseeder and an airseeder's ability to easily apply granular fertiliser. Modifications to the new seeder also mean there are a number of monitors in the tractor cab.

"At one point I think we had up to 13 monitors in the cab, but as the technology improves, we've been able to scale back," Tim says. "All data is now automatically synced to the cloud, saving us a job and enabling information to be used when needed. You need to be able to access data reliably for it to have any value."

Challenges with the seeder

The Rethus family's seeder still has problems with hair-pinning in wet conditions, when the soil and chaff become difficult to penetrate. "It's not so much the stubble because we inter-row, it is the really fine fluffy chaff, especially if it has chemical residue present and is jammed down the seed slot," Tim says. "It's a compromise between sowing shallow for rapid emergence and sowing deep enough to ensure you have cut through the residue, but not too deep."

They also have trouble with their seeder in sticky soils. "Wimmera soil is renowned for its stickiness and this can lead to build-up on the discs." Tim says it is important to analyse issues such as this. "It does become a mindset change to understand the strengths and weaknesses of your system," he says. "A disc seeder runs at a higher ground speed whilst sowing, but you may start later and finish earlier if there is surface moisture causing stickiness compared to a tyne. In wet conditions, the disc can often start earlier, as soon as the surface starts to dry, compared to a tyne that is lifting wet soil to the surface that can build up on press wheels."

Some of these challenges have meant the uptake of disc seeders has been slow and steady, particularly in the Mallee, but Tim believes they could fit a broader range of farming systems. "The key is having a good idea where you want your farming system to go. There is no silver bullet. You've got to be prepared to modify and to pick a machine that suits you." For this reason, he advocates having a whole-of-farming system approach to business. "You can't use a disc seeder, especially a high-technology seeder, in isolation. It is like a piece of Lego. It needs to fit into what you are trying to achieve on your farm."

He also supports having a few options for different on-farm conditions. "The beauty of a system like ours is that you can easily modify one row unit as a trial. We have tried changing rubber gauge wheels with nylon, then back to rubber with metal tipping which acts as a scraper when we need it," he says. "We have serrated discs, thicker discs – stronger with less flex. With these we can get closer with the gauge wheel. When it's really wet and you're trying to get the wheel close to the furrow, we have played with the RFM spring coil type, which we have found to work well."

For growers thinking about changing their seeding system to improve crop establishment, Tim has some recommendations:

1. Have a plan. Do your research. Check out other growers' machines and share experiences and learnings. Do not complicate things early: there is a lot to learn and you are better off doing a few things really well first before looking for the next improvement.
2. Know what your objectives are and understand the implications of any changes for your existing cropping system.
3. Continuously monitor threats such as pests and disease to maintain the maximum yield potential targeted as part of your strategy.

Preparations for sowing

The Rethus family is committed to ensuring an even spread of residue at harvest to avoid accumulation, which can be a problem in a controlled traffic system. They also manage summer weeds and this helps reduce insects and conserve moisture.

Timing and frost management

The family plants by calendar starting on 1 April. "We start with crops that aren't critical for flowering time: vetch hay, oaten hay, beans. [Then we move to] canola as data is showing canola really needs to be germinated by Anzac Day, so by mid-April hopefully we are putting that in the ground," Tim says. "We then follow with wheat in the southern part of the farm, which benefits from a longer season. I believe frost damage isn't just about one cold day, it's about how we maximise the health of those plants more than just sowing date, and of course, sowing date doesn't matter if it doesn't rain."

Tim believes heat stress could actually be more of a problem than frost, which is why he prioritises getting seeds in the ground early. "It's easy to quantify a frost because it causes a patchy yield map, but with heat stress, it's even – yield is down uniformly."

Dealing with pests

The family also regularly monitors pests on the farm. They do a snail survey at the start of March and then again closer to seeding to assess whether baiting is needed. Mice are also monitored, particularly after big seasons. "We will probably bait these twice; once before seeding and then once with the seeder. It's part of our strategy to protect the crops when seedlings are small and susceptible," Tim says.

Tim is committed to reducing the use of insecticides on-farm and believes seed dressings could prove a better long-term strategy. "Russian wheat aphids have not been a problem because we have been applying seed dressings, which are more environmentally friendly than a broad-spectrum insecticide that can impact both pests and the beneficials," he says.

Weed control strategy

The Wimmera grower believes good crop establishment is an excellent weed control strategy. "If you have poor crop establishment, that's where the weeds grow and in our system, with minimal disturbance, it can take years to get rid of them," Tim says. "As growers, we can underestimate the competitive ability of the crops. The seeds we plant are plump and vigorous compared with weed seeds. They produce instant competition, so weeds are under pressure early when plant establishment is done well."

The family believes its zero-till system is helping reduce weed pressure. Pre-emergent herbicides are used post-sowing, which have also worked well. "Our double disc system doesn't form a furrow, which prevents bigger rainfall events from washing and concentrating chemicals into the furrow."

The Rethus family's custom-built seeding system is flexible. Photo: supplied

Using seed dressings to minimise disease

Tim also believes disease pressure has been eased through the use of seed dressings, which he says can take a crop "deep into the season when the seasonal outlook is clearer, making subsequent management decisions easier".

Fine-tuning nutrition with the seeder

Using a seeder that can apply two different fertilisers (a liquid and granular) to the seed furrow allows the family to fine-tune individual crop nutrition requirements. "We can put on a standard granular phosphorus (P) then top it up with a liquid brew that suits that field and crop. Often that involves zinc to get that early vigour, maybe some nitrogen, fungicide or insecticides down there too as it's sometimes easier than on the seed," Tim says. "If we are worried about fertiliser toxicity in canola, the flexibility of the liquid system allows us to put on liquid P, which means we can get our unit of P out without causing problems with establishment."

Tim's top tips to improve crop establishment

1. Sow early, using the right variety, to take advantage of the opening rains and warm soils. This generally requires dry sowing.
2. Take care in selecting and preparing seed for seeding. Use plump grains that are more vigorous and more likely to germinate. Pay attention to seed dressing and early nutrition (starter fertiliser and trace elements).
3. Know the target plant density (measured as plants per square metre) suitable for your system. This may mean conducting your own in-paddock trial strips to work out the optimum established density.
4. Ensure correct and uniform seed placement. This means clean, residue-free furrows and good soil–seed contact.

MORE INFORMATION:

Tim Rethus, 0425 791 651, tim.rethus@gmail.com

Benefits and challenges of precision planting winter grain crops in the southern and western regions

Key points

- Precision planting technology meters seed singly and places seeds at a consistent interplant distance and uniform depth in the furrow.
- There are potential yield benefits from achieving a uniform crop stand with plants equally spaced along the seeding row.
- In about 50 per cent of recent trials, winter crop grain yields from precision planting have been shown to exceed yields from conventional sowing.
- In recent trials, yield increases in canola and a range of pulses averaged about six per cent.
- With precision planting, there were significantly higher gross margins at lower sowing rates in canola but not in pulses.
- These results are consistent with experiences of growers who have adopted precision planting technology.
- There are several factors limiting the adoption of precision planting technology in winter cropping systems, including: reliance on double disc systems; wide row spacing; limitations with fertiliser delivery and hopper seed capacity; and the sensitivity of singulation to conditions at sowing.
- Precision planting should be viewed as the final component of an overall management system that aims to maximise crop establishment.
- Intermediate technologies are becoming more common and may provide an easier entry point for growers wanting to transition to more precise seeding.

What is precision planting?

Precision planting was initially developed after World War II to improve the yield of maize using an innovative method of metering seed delivery to the sowing boot. This technology has since been adopted widely in other summer crops such as soybean and cotton, which rely on expensive hybrid seeds sown at relatively low plant densities. Precision planting mostly relies on disc seeding systems (Figure 11) and uses a seed metering system that selects individual seeds for placement at a consistent spacing along the row. This is referred to as 'singulation'. Precision planting results in uniform plant emergence at even spacing along the seeding row, which minimises interplant competition and has the potential to improve competition against weeds.

The uniformity of crop stands depends on two factors: crop establishment rate and the evenness of seed placement along the seeding row. Low crop establishment rate will reduce uniformity as it creates gaps in the plant stand where a seedling fails to establish. Although precision planting improves the uniformity of seed delivery along the row and placement at depth within the furrow, its benefits will be greatest when conditions favour high rates of establishment. Therefore, precision planting should be viewed as the final component of a management system that aims to maximise high levels of crop establishment. That is, its benefit relies on first optimising all other aspects underpinning the success of the crop seeding operation.

Benefits of uniformly spaced plants

Improving crop stand spatial uniformity has the potential to improve yields. Field trials in Australia and Canada with canola in which plants were evenly spaced to create uniform stands have shown grain yield improvements of between five and 34 per cent compared with crops with unevenly spaced plants. Often the greatest benefit is observed at low plant densities. Smaller improvements have been measured in lupin crops from data acquired across fewer experiments.

Assessing interplant spacing uniformity

Uniformity of crop stands can be assessed by measuring the variation in interplant distance along the seed rows. These data can be used to derive several different indices of variability (Box 5). The most common approach is to estimate the coefficient of variation (CV) for the interplant distance, which is the ratio of the standard deviation and the mean of interplant distances within a crop. A low CV for interplant distance indicates more evenly spaced plants and a more uniform crop stand (Figure 12).

Figure 11: Different precision disc planter technologies, each offering the additional dimension of seed singulation in precision seeding and providing the basis for consistent interplant spacing along the seed row.

Source: Jack Desbiolles

Figure 12: Faba bean crop three weeks after sowing: a) sown with conventional disc seeder (20 plants/m^2; CV = 80%); and b) sown with a precision planter (18 plants/m^2; CV = 39%).

a) Conventional disc seeder

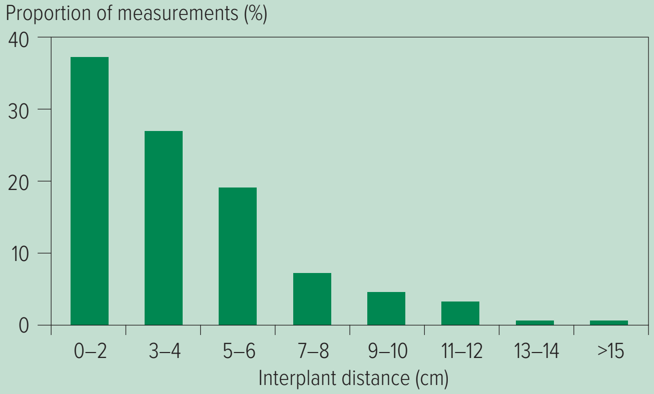
b) Precision planter

Source: Glenn McDonald

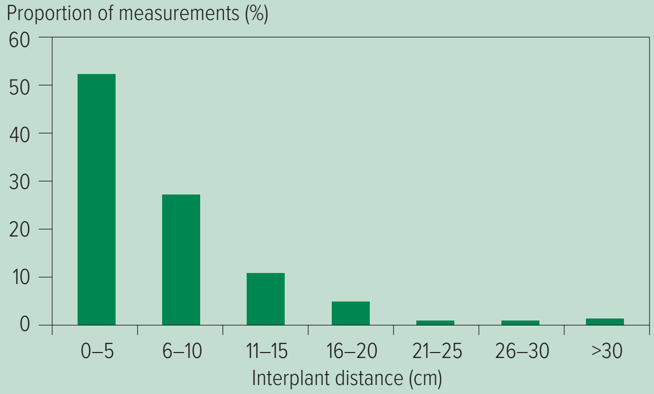
BOX 5: MEASURING CROP STAND UNIFORMITY

The distribution of seedlings along rows within crops of a) wheat and b) canola. The interplant distance is the distance between adjacent plants in the row.

a) Wheat. Mean: 4.1cm. CV: 71%



b) Canola. Mean: 7.4cm. CV: 102%



When seeds are planted without using any precision planting technology, the distribution of seedlings within a crop is generally not uniform and the variation in the interplant distance can be high. The distribution is generally highly skewed and the high variability is often associated with the proportion of gaps and clusters in the stand, as shown above for crops of wheat and canola.

There are several indices that can be used to assess the uniformity of a crop stand, based on the variation in the interplant distance within the crop. These indices also enable seeder and planter performances to be compared across different crops and sowing rates.

COEFFICIENT OF VARIATION (CV)

This index has a single variable. It is the ratio of the standard deviation in interplant distance and the average distance, generally expressed as a percentage. CV is defined as:

CV (%) = (Standard deviation / mean interplant distance) x 100

The higher the CV, the greater the variability. The CV measures the spatial uniformity of the seedlings in the row but it does not indicate why there is a lack of uniformity. A perfectly uniformly spaced crop has a CV of 0 per cent.

QUALITY OF FEED INDEX (QFI)

This index also has a single variable and was developed for precision planters. It considers the number of missing plants (skips) and the number of multiple seed drops in the row. The QFI measures the proportion of the interplant distances that are within an acceptable range, defined as ±50 per cent of the theoretical interplant distance. The theoretical interplant distance is calculated from the target plant density and the row spacing. For example, if the target density is 40 plants/m^2, the theoretical interplant distance will be 10cm for a 25cm row spacing and the acceptable range will be 5 to 15cm. QFI is defined as:

$$QFI = n / N$$

In this equation, n = number of measurements falling within the acceptable range and N = the total number of measurements made. When QFI = 1, all the interplant distances are within the acceptable range but seedling establishment may not be completely uniform, whereas when QFI = 0.3, only 30% of the measurements are within the acceptable range.

INTERQUARTILE VARIATION (IQV)

This index has two variables and measures the difference between the third and first quartile values relative to the mean interplant value. IQV is defined as:

$$IQV = (Q_3 - Q_1) / \text{mean}$$

In this equation, Q1 and Q3 are the first and third quartile values within the set of interplant spacing measurements, respectively. The higher the IQV, the greater the variability in spacing and the less uniform the crop. A perfectly uniform crop has an IQV = 0.

INTERPLANT SPACE INDEX (I_{su})

This index has three variables and considers the number of values that are in the tails of the distribution relative to the number of values that are in a preferred range of interplant distance. The values of the tails and preferred range can be varied to suit the thresholds of acceptability. I_{SU} is defined as:

$$I_{su} = (n_1 + n_2) / n_3$$

In this equation:

- n_1 is the number of measurements in the lower tail – for example, measurements that are less than a quarter of the target interplant distance (representing the number of relative clusters);
- n_2 is the number of measurements in the upper tail – for example, measurements that are more than twice the target interplant distance (representing the number of relative gaps); and
- n_3 is the number within the preferred range – for example within 20 per cent of the target interplant distance.

By definition, this index is better at expressing differences between seeder performances. The I_{SU} value decreases rapidly with improved crop stand uniformity and approaches zero in a perfectly spaced crop.

Delivery of seeds to the sowing boot by airseeding systems is variable, causing uneven distribution of seeds along the row and a high CV for interplant distance. Crops sown with airseeders typically have crop stands with CVs for interplant distance of 90 to 100 per cent (Figure 12), whereas precision planters can achieve CVs of 60 to 70 per cent or less. In a perfectly uniform crop, the CV would tend towards zero.

The Quality of Feed Index (QFI) has been used in research to quantify the proportion of interplant distances that are in an acceptable range, often equal to ±50 per cent of the target interplant distance, for the given plant density at a set row spacing (Box 5). A recent survey of crops sown with airseeders found the most common QFI for crops of canola and lentil was 30 to 40 per cent; in other words, only 30 to 40 per cent of seedlings were within the acceptable interplant distance range (Figure 13) whereas in a perfectly uniform crop, this would be 100 per cent.

In precision planting, the variation in the quality of seed singulation is assessed by the proportion of missing plants (skips) or multiple plants (doubles or clusters). More advanced spacing uniformity index parameters (for example, interplant space index; I_{SU} – see Box 5) can take these into account.

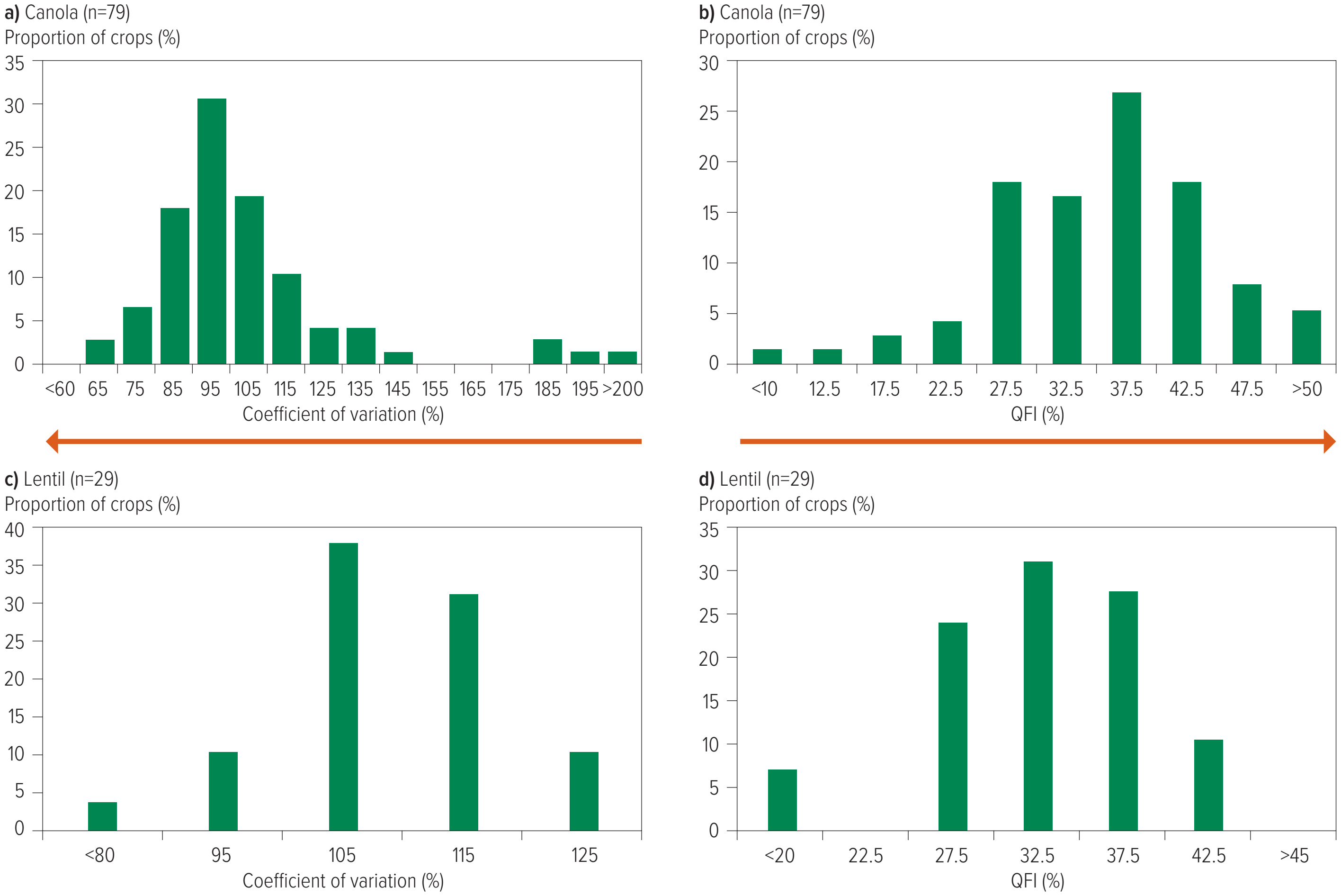
Row-to-row variability

As noted above, the variability in establishment between seeding rows also contributes to the poor uniformity within a crop (see Figure 3 in Section 1). Sowing rates can vary from row to row, resulting in a high CV between rows; this should be checked, and corrected if necessary, during seeder calibration (see Box 3). Seed drills generally have a lower sowing rate CV across seed rows than airseeders, which are subject to splitting inaccuracies of seed flow within primary and secondary distributor heads. Comparatively, precision planting results in the lowest CV across seed rows due to its better controlled seed rate input, which is monitored seed by seed and row by row.

Seed singulation

Seed singulation is used by precision planters to achieve constant plant densities across seed rows as well as consistent interplant spacing along the seed row (Figure 12). Seeds are selected from a bulk quantity via a disc plate with holes that trap seeds under either a positive pressure (on the seed side of the plate) or a vacuum (on the opposite side of the plate). As the disc rotates, the seeds trapped on the plate holes are thinned to a single seed per hole before crossing over a vented zone and being released. Seeds drop uniformly into the delivery tube and are guided on a smooth trajectory towards the furrow, to land at a consistent spacing along the seed row (Figure 14).

Figure 13: Uniformity indices for commercial airseeders: a) CV for interplant distance in canola; b) QFI in canola; c) CV in lentil; and d) QFI in lentil. Paddocks across Victoria, SA and WA were surveyed, with 'n' representing the number of crops sampled. More uniform interplant distance is indicated by a low CV or a high QFI. For comparison, CV and QFI values measured in trials with precision planters were less than 70% and more than 40%, respectively. The orange arrows indicate increasing uniformity.



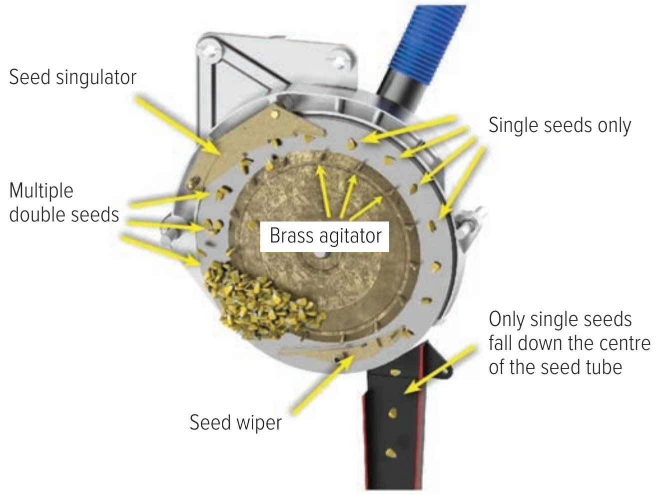
Source: McDonald (2022)

The number of holes on the disc plate and disc rotation speed ensure the sowing rate is matched precisely row by row, and individual electric drives coupled with GPS input allow the control system to apply row-by-row rate control. This includes speed compensation to maintain a constant interplant spacing when planting on a curved pathway. Optical or radio-wave sensors within the seed tubes monitor the seed spacing and the control system displays the plant density sowing rate and singulation quality (percentage skips or doubles) in real-time, eliminating the need for gravimetric calibration and allowing the operator to adjust settings on the go to correct the planter's performance.

Evaluation of precision planting in winter grain crops

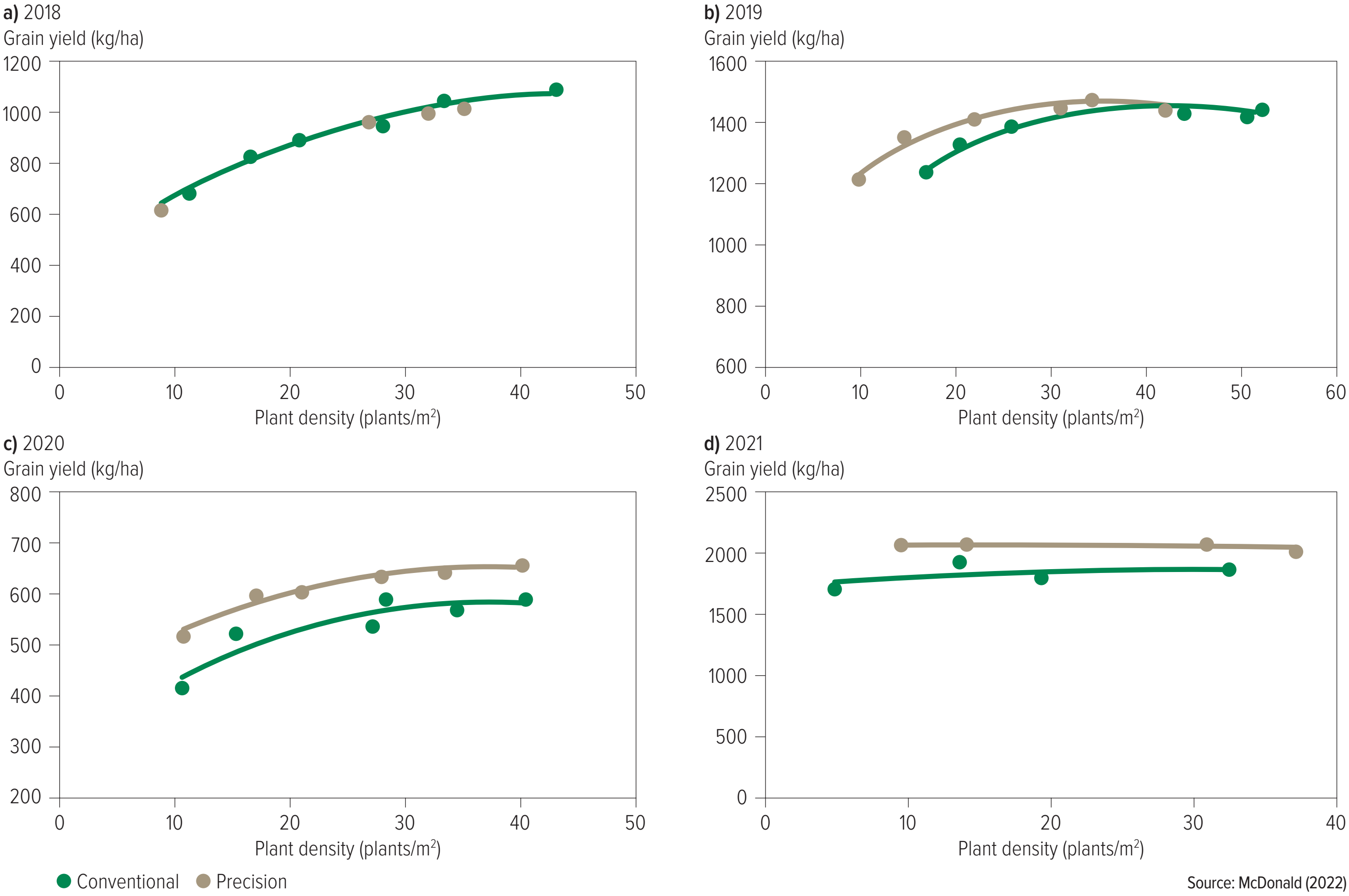
Although the benefits of precision planting in summer crops are well documented, experiments conducted in SA, Victoria and WA between 2018 and 2021 indicated precision planting may have similar benefits for winter grain crops. These experiments compared precision planting with conventional sowing over a range of plant densities to reach this conclusion, which is consistent with results from North America.

Figure 14: How seed singulation works in a Monosem precision vacuum planter.



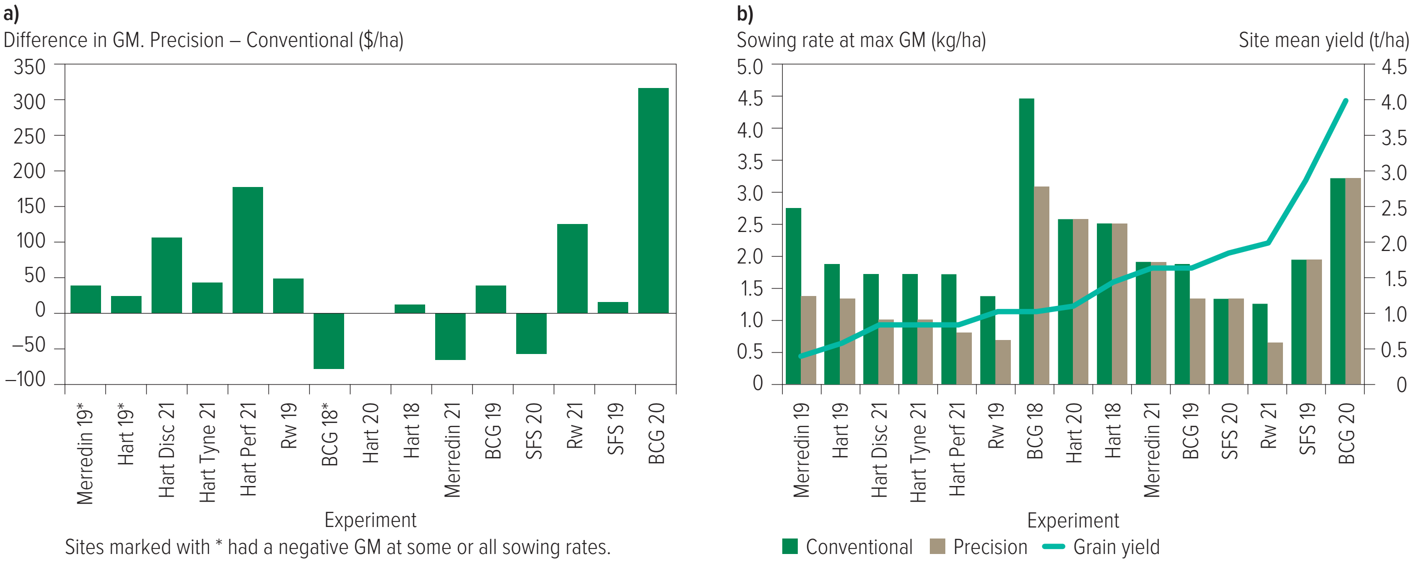
Source: The Farmer Magazine

Figure 15: Examples of the different effects of precision planting and plant density on the grain yield of canola observed in field trials: a) no difference in the response between seeding method; b) an increase in yield with precision planting at low plant densities; c) and d) an increase in yield from precision planting over all plant densities.



Source: McDonald (2022)

Figure 16: Results from canola experiments at various sites between 2018 and 2021, showing: a) the difference in the maximum gross margin (GM) between precision planting and conventional sowing; and b) the sowing rate at which the maximum GM was achieved. Sites marked with * had a negative GM at some or all sowing rates.



Source: McDonald (2022)

Table 7: The mean yield benefits from precision planting in canola and pulse crops relative to conventional sowing. The benefits were based on the predicted values from the response curves (Figure 15) either at all sites or only at sites where a significant difference due to sowing method was observed. Values are the mean benefits over all sowing rates at each site and are shown as the mean ± standard error of the mean. N = number of sites.

	All sites			Responsive sites		
Crop	N	% increase	kg/ha increase	N	% increase	kg/ha increase
Canola	10	7 ± 1.4	71 ± 12.1	8	9 ± 1.5	96 ± 12.3
All pulses	8	6 ± 1.7	97 ± 35.2	4	7 ± 2.3	144 ± 60.9
Lentil	4	5 ± 2.4	35 ± 29.3	2	4 ± 2.7	48 ± 485
Faba bean	2	8 ± 2.4	334 ± 119.3	1	14 ± 2.0	614 ± 158.8

Source: McDonald (2022)

Yield improvements

Precision planting consistently improved the evenness of crop stands with greater uniformity in interplant distance. Four types of yield response were observed among the experiments (Figure 15) with yield improvements from precision planting (Figure 15b to 15d) being found in about half of the experiments. When yield increases occurred, precision planting improved yields at the lower plant densities only (Figure 15b) or over all densities (Figure 15c, 15d). The latter response was more common.

The average grain yield benefit from precision planting in canola over 10 trial sites was seven per cent, and across the eight sites where responses to precision planting were significant, the average yield increase was nine per cent (Table 7). A yield response to precision planting was observed in four of the eight trials conducted with pulses, generating similar average responses as canola (six per cent).

In several experiments, precision planting enabled yields to be maintained at low planting densities compared with conventional sowing, offering an opportunity for savings in seed cost (Figure 15).

Gross margin benefits

Estimated gross margins from precision planting canola were equivalent to or greater than those achieved with conventional sowing (Figure 16a). The average improvement in the gross margin with precision planting was $49.50/ha but with a high variability.

At about half the sites, the highest gross margins were obtained at a sowing rate about 0.5kg/ha lower than that for conventional sowing (Figure 16b). With hybrid canola, it was estimated that seed savings of about $24/ha may be possible. In pulses, the gross margins of conventional and precision planting were similar and achieved at comparable plant densities.

Precision planting and weed competition

Planting arrangement and plant density affect the competitive ability of crops against weeds. Although one of the potential advantages of precision planting is that it may allow a reduction in the sowing rate of canola, this could reduce the crop's ability to compete against weeds. However, experiments conducted at Merredin in 2021 suggested the evenly spaced planting that precision technology can achieve may improve a crop's competitiveness against annual ryegrass (Figure 17). It was found that precision planting suppressed tillering in ryegrass at all canola densities (Figure 17a) and at different ryegrass densities (Figure 17b). Precision planting reduced:

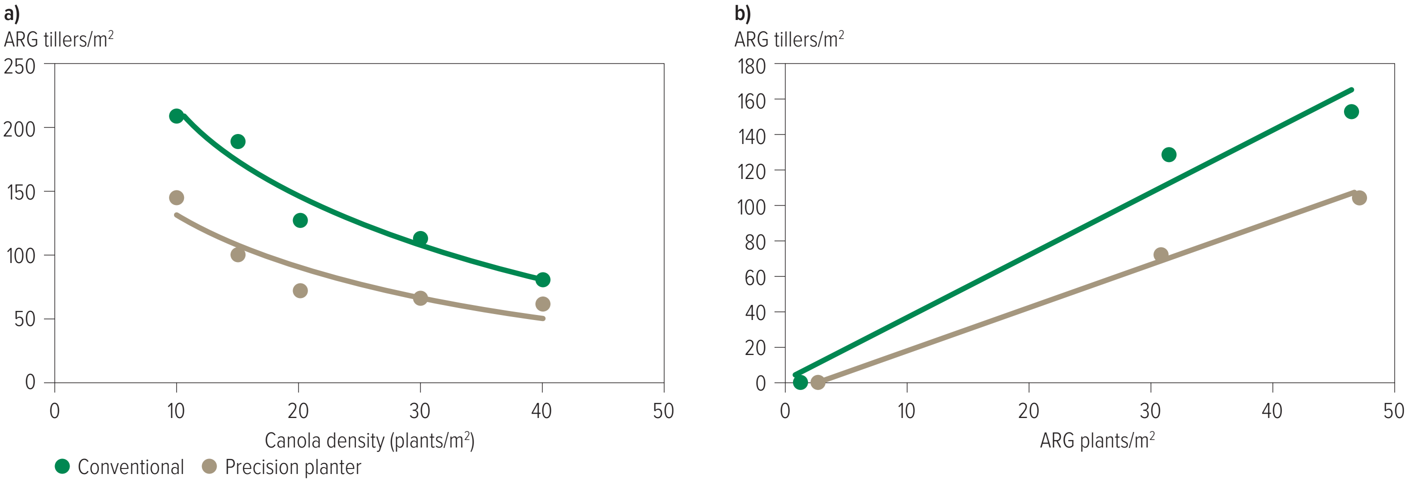
- the number of large gaps in the canopy that allow weeds to grow; and
- the level of interplant competition among canola plants (Figure 18).

Local grower experience with precision planting

Local experience using precision planters in winter grain crops is recent and inspired by successful adoption overseas (for example, Dietz 2021; Barker 2022). However, it is limited to a small number of growers operating mainly across the southern region. Precision planters have been adopted mainly to sow canola and a range of pulse crops (faba bean, lentil and chickpea), sometimes in rotation with irrigated summer crops.

Box 6 provides some tips for adopting precision planting in winter grain crops from precision planter owners in the southern region.

Figure 17: The effect of precision planting on the growth of annual ryegrass (ARG) at Merredin: a) the effect of canola density on tiller number; and b) the relationship between ARG density and ryegrass tiller number.



Source: McDonald (2022)

Figure 18: Canola sown at 10 plants/m² with a conventional cone seeder (left) and a precision planter (right) with 30 annual ryegrass plants/m². The canola plants sown with the precision planter are more evenly spaced with fewer gaps in the canopy and were better able to compete against ryegrass.

a)

b)

Source: Glen Riethmuller

BOX 6: TIPS FOR ADOPTING PRECISION PLANTING IN WINTER GRAIN CROPS FROM PRECISION PLANTER OWNERS IN THE SOUTHERN REGION

1. Optimise other parts of the farming system and seeding operation first. The benefits of seed singulation are not realised unless good establishment and accurate seed placement can be delivered through a combination of technology design features, field settings and operation, as well as improved paddock management.
2. Plan the shift to precision planting and address: soil constraints; paddock preparation; seed grading, cleaning and quality; residue; weed management; and logistics.
3. Do some homework: research, talk to users and manufacturers, and look internationally for up-to-date information.
4. Ensure technical support is available for your choice of technology or be ready to struggle.
5. Be confident in your choice of planter or delay selection until you are.
6. It may not be necessary to use high-tech equipment initially: high-tech planters do not imply higher cost-effectiveness.
7. Use clean, graded, high-quality seeds.
8. Keep an eye on performance, monitor regularly and be conscious of speed.
9. Start with precision planting of larger seeds, which are less challenging than small seeds.

The benefits these growers have reported relative to baseline seeder technologies have included:

- improved accuracy of seed placement resulting in better and more even crop emergence;
- an even distribution of seeds in the furrow;
- an improvement in early crop vigour; and
- reduced seed costs per hectare, especially with hybrid canola.

Improved yields were not always reported, but those improvements cited occurred mainly in canola and faba bean.

The common problems experienced when using precision planting equipment for winter grain crops include:

- planter row spacings that are too wide for winter crops, requiring multiple passes;
- limited or no capacity to apply or split-band fertiliser in the furrow;
- limited seed hopper capacity on row units;
- seed discs being unsuitable for many winter crops;
- limited ability of control systems to achieve desired winter crop planting densities;
- sensitivity of planting performance to operating speed and paddock surface roughness; and
- limitations associated with the ground-engaging disc seeding system component in some conditions, such as in sticky soils.

Figure 19: Precision planter technology has evolved to better suit the sowing context of winter grain crops, with features such as fertiliser banding, centralised bulk fill and narrower row spacing.

Source: Väderstad International

Recent improvements in technology have increased precision planter efficiency and their suitability for winter crops (Figure 19), with the availability of improved design features such as:

- improved singulation of winter grains with optimised plates and control systems;
- centralised bulk fill systems;
- liquid and/or granular fertiliser banding options;
- narrower row units for spacings down to 250 to 380mm (and as narrow as 190mm with simplified row units);
- self-adjusting downforce for controlled penetration across soil conditions;
- pressurised or belt-guided seed delivery to furrow for high-speed planting;
- row-by-row shut-off control to achieve zero overlap on angled headlands;
- serrated disc blade technology for improved residue cutting; and
- twin row synchronised checkerboard planting patterns (staggered seed drop).

Other precision metering technologies

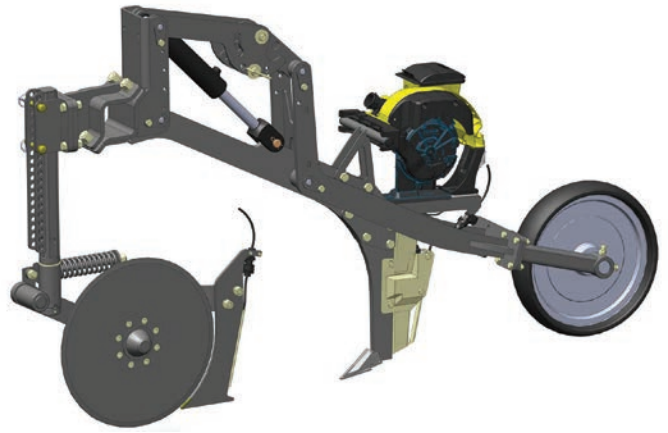
Intermediate seeder technologies that are able to improve the uniformity of seed distribution across seeding rows also exist. These include single-row metering rollers (for example, SeedMaster Ultra Pro II) that can achieve row-to-row variation that is 50 per cent lower than with centralised airseeding (PAMI, 2018).

Seed singulation row kits are also emerging as optional features on broadacre disc seeding machines and can be selected on a paddock-by-paddock basis (for example, Horsch Funck metering SingularSystem, and the upcoming Bourgault Air Planter™ eXact Placement Meters™).

When these singulation kits are integrated onto airseeders, the flexibility of fertiliser placement and the separation options available with airseeding systems are combined. However, integrating singulation kits with tyne-based seeding systems presents specific challenges and to date such integrations have been limited to prototypes (Figure 20). There is a limited range of tyne–disc hybrid systems now commercially available (Figure 21).

Developments of these intermediate technologies in the future could increase the versatility of precision planting in winter cropping systems in a range of soil conditions. However, to be adopted widely they will need to be practical, cost-effective and have no negative impact on the timeliness of sowing.

Figure 20: The commercial development of precision planting with tyne systems has been limited to date.



Source: GROUND BREAKER Precision Agriculture

Figure 21: Example hybrid tyne–disc seeding system with seed singulation capability.

Source: Equalizer

Useful resources

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Specific recommendation on sowing of various crops can be found in GRDC GrowNotes: grdc.com.au/resources-and-publications/grownotes

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P Level 4, 4 National Circuit, Barton ACT 2600 | PO Box 5367, Kingston ACT 2604
T 02 6166 4500 **F** 02 6166 4599 **E** grdc@grdc.com.au