The agronomic value of precision planting technologies with winter grain crops

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Key findings

- Precision planting improved the uniformity of crop stands and often allowed reductions in plant density without loss of yield.
- Potential benefits will be greatest in crops with high seed input costs.
- Grain yield responses to precision planting have been variable in project trials to date and suggests adoption of the technology may not be warranted based on crop yield response alone.
- Precise and smart seeding technology is evolving rapidly with air-seeder based transitional options becoming available, which may allow a more practical and cost-effective pathway to greater planting precision.

Background

Precision planting technologies are designed to place seed at a consistent depth and interplant distance within a row to promote uniform emergence and to minimise interplant competition. The ability to precisely locate a single seed in the seeding row is referred to as singulation. Precision planters first appeared in the post-war era as a technology to improve yield in maize and they have been used extensively since then in a wide range of summer crops where expensive and high vigour hybrid seeds are planted at relatively low plant populations.

The recent interest in using precision planting technology with winter crops, especially in hybrid canola, has been prompted by a desire to reduce the costs of using hybrid seeds and has been reported that even placement of seeds improves yields at low plant densities, which would allow significant reductions in seeding rates. For example, field trials in Canada (Yang *et al.* 2014) reported yields with equally spaced canola plants were up to 20% and 32% higher compared to uneven spacing at low and high yielding sites, respectively. More recent work in WA in canola and lupin have indicated that even spacing, minimising interplant competition, may allow a reduction of sowing rates below current recommended rates, with predicted savings of $24/ha in seed of hybrid canola (Harries *et al.* 2019).

While these results are encouraging, there has been no systematic assessment of the value of precision planting technology in winter crop production for small grain crops in Australia. The aim of the current project is to assess the value of precision planting in canola and a number of pulse crops in the southern and western regions. The project has three main components:

(i) a paddock survey of establishment in a number of crops in 2018 and 2019 in the southern and western regions to assess the variation in seedling emergence and seedling depth and to examine what factors may contribute to this variation.

(ii) a series of small-scale and large-scale trials comparing conventional sowing (either a cone seeder or an air-seeder) with precision planting and,

(iii) a qualitative survey of current users of precision planters for winter grain crops.

This paper focusses on the results of the field trials and the experiences of growers using precision planters. The results of the crop survey have been reported previously (McDonald *et al.* 2020).

Method

A series of small plot trials was conducted between 2018 and 2020 using a purpose-built 6-row seeder that could sow seeds as a conventional cone seeder or as a precision planter. The precision planting units used in Victoria and South Australia were commercial row units supplied by Spot-on-Ag, in Boort Victoria (see Table 4). The trial at Merredin in 2019 used a small plot seeder operated by WA DPIRD with the capacity for singulation as well as conventional sowing. Both plot seeders used disc seeding systems, except in 2018 when cone seeding could only be done with a tyned seeding system. Details of the trials are given in Table 1.

Table 1. Details of the small plot trials conducted between 2018 and 2020.

Year	Site	Crop	
2018, 2019	Birchip Hart	Canola Lentil	Seeding method (Conventional, Precision) Plant density (6) Row spacing (23 cm, 30 cm)
2019	Roseworthy	Canola	Seeding method (Conventional, Precision) Plant density (5)
		Faba bean	Seeding method (Conventional, Precision) Seed treatment (Graded, Ungraded) Plant density
2019	Merredin	Lupin Canola	Seeding method (Conventional, Precision) Plant density (4)
2020	Horsham	Canola	Seeding method (Conventional, Precision) Plant density (4)
		Faba bean	Seeding method (Conventional, Precision) Row spacing (23 cm, 46 cm) Plant density (4)
2020	Hart	Canola Chickpea Wheat	Seeder type (Conventional, Precision) Plant density (4)

Large scale trials were also conducted with canola and faba bean near Skipton in western Victoria using a Väderstad airseeder (Seedhawk model in 2018; Rapid model in 2019) and a Väderstad precision planter (Tempo). Each trial compared the responses to row spacing (25 cm *vs* 50 cm) and sowing rate (recommended *vs* half-recommended) and were sown in plots 150 m long.

In all trials, seedling emergence at 5 weeks after seeding, interplant distance at seedling emergence, NDVI, biomass production at flowering or peak biomass, grain yield and yield components were measured. All trials were replicated and randomised and were designed either as split plot or as complete factorial trials with between 4 and 6 replicates. The uniformity of seed placement within the rows was assessed by the coefficient of variation (CV) of the interplant distance.

Results and discussion

Plot trials

The emergence rate of the trials varied considerably (Tables 2, 3). In the canola trials there were both increases and reductions in seedling establishment with precision planting (Table 2). However there was a consistent improvement in the uniformity of the interplant spacing with a 20-40% reduction in the CV for interplant distance.

In most trials there was no significant difference in the yields between the two seeders, with significant differences being measured in two of the nine trials; in both cases precision planting improved yields.

*Table 2. Summary of the effects of conventional and precision seeding on crop establishment, the uniformity of plant spacing and grain yield in canola. The trial at Skipton used commercial seeding and planting equipment in large plots and the remaining experiment used a small plot seeder. The significance of the difference between the precision planter and the conventional seeder is indicated: *** - P≤0.001; ** - P≤0.001; * - P≤0.05; NS = not significant.*

Site and year	Conventional sowing			Precision planter		
	Crop establish-ment (%)	*Interplant distance CV (%)*	*Grain yield (t/ha)*	*Crop establish-ment (%)*	*Interplant distance CV (%)*	*Grain yield (t/ha)*
Hart 2018	90	101	1.38	65***	77***	1.39 NS
Birchip 2018	64	103	0.35	59 NS	80***	0.37 NS
Hart 2019	67	99	0.54	64NS	72***	0.61*
Birchip 2019	105	103	2.15	82**	66***	2.21 NS
Roseworthy 2019	51	89	0.98	68***	61***	0.98 NS
Merredin, 2019	88	-	0.34	69***	-	0.39 NS
Skipton 2019	102	85	2.64	76***	78NS	2.68 NS
Hart 2020	48	94	1.01	52NS	59*	1.06 NS
Rupanyap, 2020	100	99	3.40	83NS	73***	3.62*

Crop establishment in the pulses were generally higher than in canola, but as with canola, there was no consistent effect of precision planting on establishment and crop uniformity was improved substantially (Table 3).

Precision planting improved grain yield by 18% or 22% in faba bean and significant increases of 10% (lupin) and 14% (lentil) were also measured. The results for canola and pulses indicated that despite variable effects on establishment, precision planting resulted in yields equivalent to or higher than those achieved with conventional sowing.

*Table 3. Summary of the effects of conventional and precision seeding on crop establishment, the uniformity of plant spacing and grain yield in pulse crops. The trials at Skipton used commercial seeding equipment in large plots and the remaining experiment used a small plot seeder. The significance of the difference between the precision planter and the conventional seeder is indicated: *** - P≤0.001; ** - P≤0.001; * - P≤0.05; NS = not significant.*

Crop	Site and year	Conventional sowing			Precision planter		
		Crop establish-ment (%)	*Interplant distance CV (%)*	*Grain yield (t/ha)*	*Crop establish-ment (%)*	*Interplant distance CV (%)*	*Grain yield (t/ha)*
Faba bean	Skipton, 2018	125	84	1.33	115*	34***	1.57*
	Skipton, 2019	129	86	3.95	124NS	41***	3.91NS
	Roseworthy, 2019	86	81	2.23	72**	39***	2.25NS
	Rupanyap, 2020	69	104	4.56	89**	66***	5.57**
Lentil	Hart, 2018	101	-	1.21	77*	-	1.38*
	Birchip, 2018	97	102	0.91	106NS	63***	0.88NS
	Hart, 2019	59	95	2.55	50**	70***	2.43NS
	Birchip, 2019	114	99	0.69	81***	73***	0.64NS
Lupin	Merredin 2019	105		0.70	94NS		0.77*
Chickpea	Hart, 2020	64	89	0.99	60NS	58***	1.10**

The relationships between grain yield and established plant number were examined because of the variable effects of precision planting on both plant number and yield. Among all the trials, three types of responses were evident (Figure 1, 2): no difference in the response to plant density between the conventional and precision planting, a consistent yield advantage of precision planting over a range of plant densities and a greater ability to maintain yields at low density by precision planting.

A consequence of the latter two responses is that precision planting would allow a reduction in plant density with little or no yield penalty. Similar relationships were reported by Harries *et al.* (2019) in comparisons between unevenly spaced and evenly spaced plantings (Figure 3), suggesting the responses observed in the current trials were associated with differences in the uniformity in plant spacing within the crop. The potential economic benefit of this is the saving on seed costs from producing the same yield with fewer plants/m^2 and little yield penalty. However, the responses to precision planting varied among experiments and it is still unclear what the main factors that influence the response are.

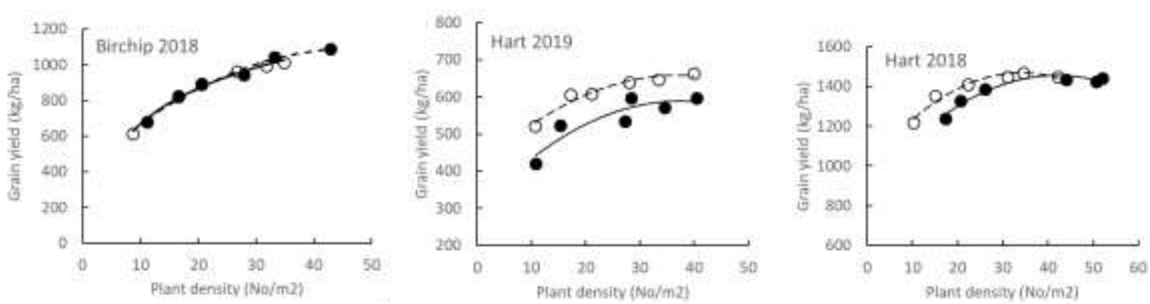

Figure 1. The relationships between the established number of plants/m^2 and the yield of canola sown either with a conventional cone seeder (●) or a precision planter (○) at three sites.

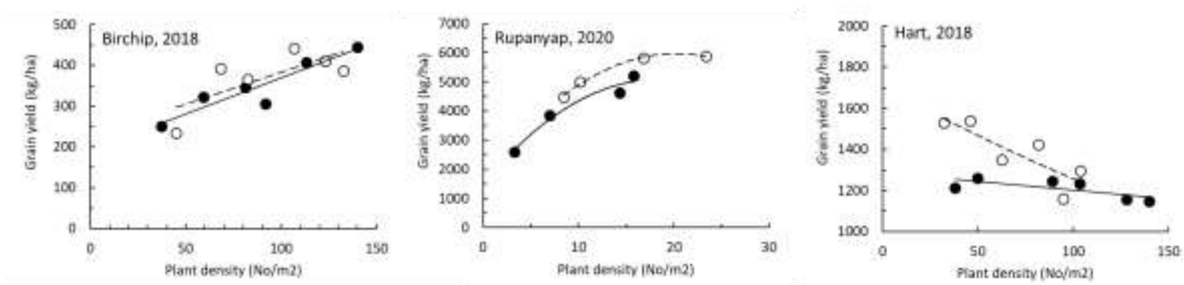

Figure 2. The relationships between the established number of plants/m^2 and the yield of pulse crops sown either with a conventional cone seeder (●) or a precision planter (○). The crops were lentil (Birchip 2018, Hart 2018) and faba bean (Rupanyap 2020).

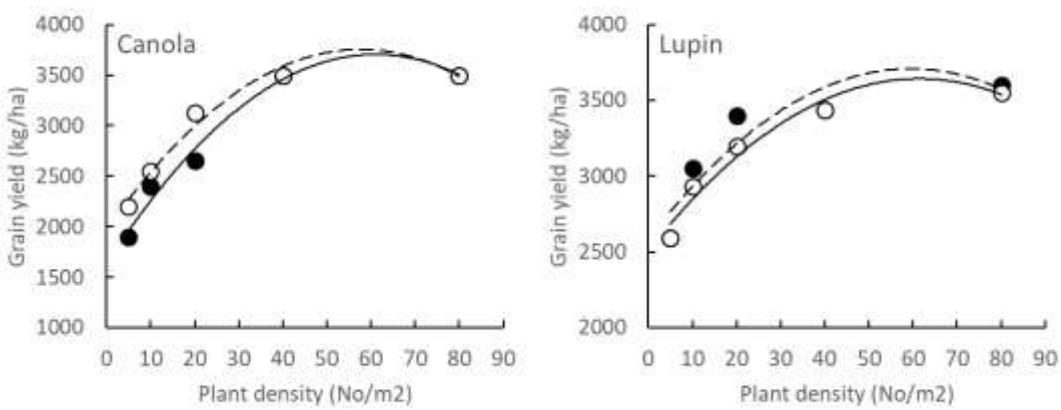

Figure 3. The response to plant density in canola and lupin by plants that were unevenly spaced (●) or evenly spaced (○) in trials in Western Australia (after Harries et al. 2019).

Field survey: precision planters vs air seeders

The paddock survey on crop establishment included four paddocks of two growers currently using precision planters, which allowed a limited comparison of commercial performance relative to conventional air-seeders. One grower was from the southern region and one from the western region. There was no consistent difference in crop establishment between paddocks sown with precision planters and conventional seeders (data not shown). In comparison with canola crops sown using conventional seeders, three of the four paddocks sown with a precision planter had lower-than-average variation in plant numbers and seedling depth, but there were also several paddocks sown with airseeders that showed similar or greater uniformity in plant number and seedling depth. These results suggest that while precision planters increase the ability to improve the uniformity of crops stands, there are still substantial gains that can be achieved using conventional air-seeder equipment and good results can also be achieved through careful settings and operations, and with adoption of 'precision seeding systems'.

The project also evaluated the impact of precision planter settings on performance, highlighting in particular the rapid negative impacts of high planting speed and sub-optimal vacuum levels on seed singulation quality. Figure 4 shows an example of a calibration with field peas on the coefficient of variation output by the sensor-based monitoring system. The data, which correlated very well with weight-based seed rate calibration, show good to excellent singulation quality (%CV≤15) at 3 km/h and very satisfactory quality (15≤%CV≤30) at 6 km/h with sufficient vacuum level (> 18 " H_2O). Performance at 9 km/h was sub-optimal with the 21-slot disc used, while a 35-slot disc could slow down the disc rotation by 40% and align the 9km/h performance between that of the original 3 and 6 km/h.

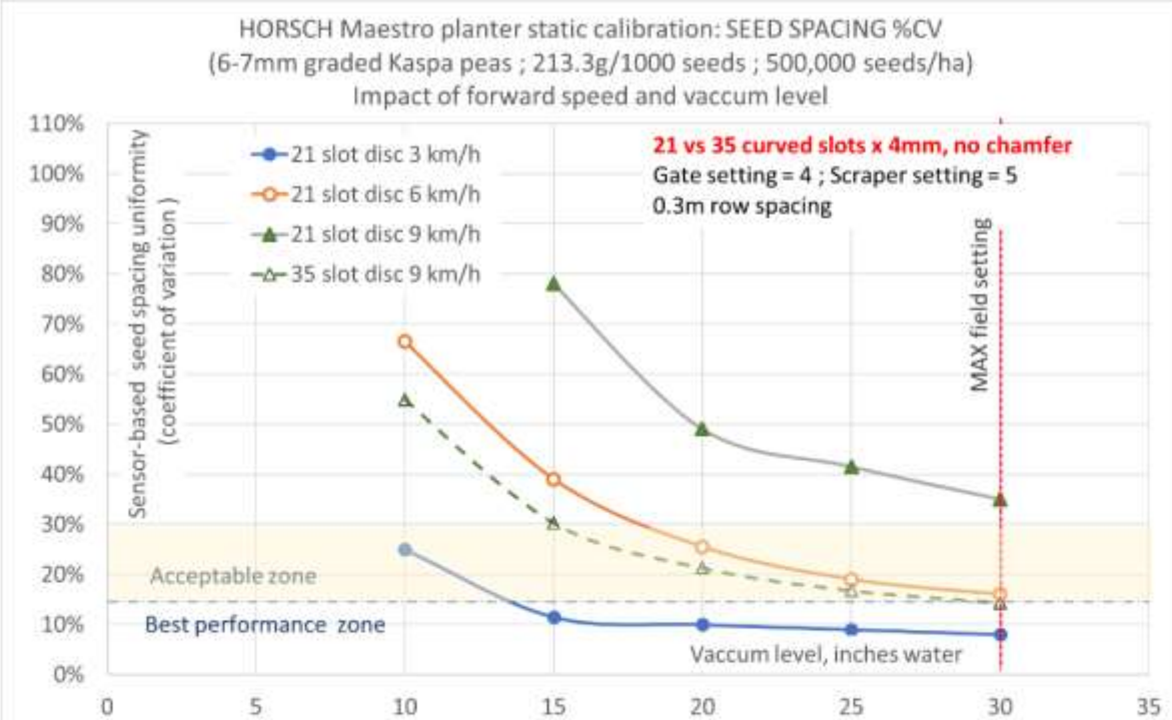

Figure 4. The impact of singulation vacuum setting and planting speed on the coefficient of variation (CV) of inter-seed spacing, with two disc plate designs.

Current developments in precision planting technology

There is a wide range of precision planter technologies commercially available, increasingly trending towards 'Intelligent Planting', using hi-tech sensor-based real-time monitoring and automation. Precision planter technology is increasingly catering for winter grain crops, including:

- improved singulation with winter grain dedicated plates and meter accessories,
- control systems suited to linear seed rate of winter grain crops,
- narrower row spacings within the 190-380 mm range,
- central commodity (bulk fill) system for broadacre applications, and
- liquid and/or granular fertiliser banding options.

To improve the versatility of singulation planters, downgrading to 'bulk metering' disc plates can be done selectively with crops where singulation may be unreliable, to ensure accurate bulk seed rate is still achieved (e.g. Great Plains Ag. *Yield-Pro HDP planters*).

Intermediate technologies also exist to improve the uniformity of seed distribution across seeding rows, such as single-row metering rollers where row-to-row variation can be 50% less than with centralised air-seeding (PAMI, 2019). Seed singulation row-kits are also emerging as optional features on broadacre disc seeding machines – which can be selected on a paddock-by-paddock basis. This integration of singulation kits onto air-seeders combines the flexibility of fertiliser placement and separation options available with air-seeding systems. Their integration with tyne-based seeding systems presents specific challenges and to date has been limited to prototypes, while limited tyne-disc hybrid systems are now commercially available. 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, but their mainstream adoption will rely on them being practical, cost-effective, and not affecting the timeliness of sowing within a cropping program.

Conclusions

Precision planting trials conducted over the last 3 years demonstrated an improved uniformity of crops stand and resulted in grain yields equivalent to or better than those achieved with conventional sowing. In a number of cases, plant density could be reduced with precision planting without a yield penalty, allowing a reduction in seed costs. However, the magnitude of the effect varied considerably, and further work is required to understand the main environmental and management factors that determine the agronomic benefits of precision planting. In dedicated calibration evaluation, planter performance was shown to be easily affected by suboptimal planter settings and operation.

A small number of growers using precision planting technology for winter grain crops in the southern and western regions have struggled with lack of technical support and information and with trying to adapt old technology to winter cropping. Nevertheless, some have experienced sizeable benefits with specific crops and are optimistic that gains in productivity and profitability can be achieved by more uniform seed placement along the row. Commercial precision planters increasingly cater for winter grain crops planting, use smart technology to monitor and automate adjustments on-the-go, while singulation kits are now slowly appearing as an additional feature of air-seeders for use on selected crops. The mainstream adoption of precision planters will require their use to not only be cost-effective but also practical, versatile and not significantly reduce seeding timeliness.

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