Hort Innovation

Final Report

Precision seeding benefits for processing pea production

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Project code:

VG15039

Project:

Precision seeding benefits for processing pea production VG15039

Disclaimer:

Funding statement:

This project has been funded by Hort Innovation, using the Vegetable research and development levy and contributions from the Australian Government. Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture.

Publishing details:

ISBN 978 0 7341 4555 0

Published and distributed by: Hort Innovation

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www.horticulture.com.au

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Summary

The processing green-pea industry in Tasmania is focused on increasing its economic competitiveness in a global market through increasing production efficiencies. Crop establishment practices have been identified as key areas for improvement, and this study aimed to evaluate the effect of spacing arrangement and stand density on pea yield. It also sought to better understand how individual plant structure within crops influences yield, and how water availability at key stages of crop development interacted with the plant spatial arrangements and density to affect overall crop performance.

Field trials were undertaken across three production seasons (2016/7, 2017/8 and 2018/9) in commercial crops in Northern Tasmania and at TIA Vegetable Research Facility (TVRF), Forth, Tasmania. Over 430 large trial plots were implemented in addition to extensive surveys of commercial sites, and glasshouse trials.

From the benchmarking of industry practices, stand densities in commercial crops (n=40) mostly fell between 80 to 120 plants/m^2 but ranged from ~60 to 140 plants/m^2. Detailed trials across three production seasons indicated that a stand density of approximately 110 plants per m^2 is an optimal target. Although slightly higher gross returns can be achieved at higher stand densities there is a trade-off between the marginal increase in yield and the cost of seed for sowing, which accounts for about one-third of the cost to pea growers.

Field trials investigating the interaction between irrigation pre- and post-flowering and stand density (80, 100, and 120 plants/m^2) demonstrated that appropriate soil water availability to crops both before and after flowering is required to maximise crop performance. While gross returns (and thus yield) generally increased with increasing stand density (from 80 to 120 plants/m^2), this was not the case when irrigation was insufficient during flowering, pod set and pod fill. In this situation, the returns decreased with increasing stand density. This highlights the importance for higher inputs to higher stand density crops throughout the crop lifecycle to realise the benefits.

Planters used to establish crops are usually based on either 125mm or 200mm inter-row spacings. Field trial comparisons showed that pea returns ($/ha) were on average 7% higher in 125mm than 200mm row spacing at the same stand density. This 7% increase associated with reducing the inter-row spacing represents a net benefit with no additional costs. Perfect spatial arrangements at equal distances within and between rows demonstrated benefits of up to ~20% compared with current practice. Significant investment in precision technology would be required to capture this benefit.

Surveys of commercial seeders used in industry identified significant variability in achieving the target stand density and plant spacing within and between rows, with target intra-row spacing achieved less than 50% of the time in most crops. The survey outcomes highlighted the importance of maintaining drills, calibrating equipment and soil preparation to achieve consistent planting.

Plant size and health at the time of flowering is a key determinant of yield. This was identified in a survey across commercial crops and from field trials investigating the effect of timing of irrigation. Severe water deficit pre-harvest led to shorter plants and low yield that could not be overcome by high levels of irrigation post-flowering.

The majority of peas that contribute to harvested yield arise from the first two nodes to flower on plants. Attempts to modify plant structure and thus harvested yield potential was explored using sub-lethal doses of herbicide or the physical removal of the apical meristems at key stages. While multiple reproductive branches could be stimulated the plants appears to adjust resource partitioning and thus the number of peas produced.

This project has produced new knowledge on the establishment factors of plant spacing and density and how these interact with irrigation scheduling in commercial settings to inform agronomic practices.

Keywords

Spatial arrangement, stand density, green peas, processing, irrigation, seeders, flowering, pod fill.

Introduction

Green peas are an important crop within the intensive vegetable cropping system in Tasmania. Each year Tasmanian vegetable growers produce approximately 24,000 tonnes of green peas from about 4000 ha for processing worth an estimated $10m at the farm gate. The Australian Bureau of Statistics reported that the volume of green peas produced in Tasmania accounted for around 95% of total production of green peas for processing in Australia. The vast majority of the peas are packaged as frozen produce and retailed in domestic markets, and the last Australian grown products remaining in this market sector, representing a clear point of difference.

The importance of the green peas to Tasmania's vegetable industry exceeds its direct value. Although they are a relatively low return crop they represent about 40% to 45% of Simplot Australia's vegetable processing factory throughput. This volume aids in covering factory overheads and capital utilisation, and therefore underpins the entire frozen vegetable industry in Australia. In addition to its economic benefits, pea crops play a valuable role in vegetable crop rotations and environmental sustainability. This leguminous crop contributes nitrogen to the cropping system, and the trash (vine material left after harvesting) is often used as stock fodder or ploughed back into the ground to improve soil properties.

The viability of frozen pea production in Australia is currently under threat, as frozen produce continues to face increased competition from the import of processed vegetables. In 2016/17 Australia produced nearly 33,000 tonnes of green peas and imported nearly 23,000 tonnes, placing considerable pressure on the industry. In the previous year, imports exceeded domestic production (Rolley 2018). Green peas are imported from several countries, but the majority originates from New Zealand. As the last frozen food processor left in Australia, Simplot is continually faced with the challenge of increasing production efficiencies in order to maintain a viable processing pea industry.

The Pea and Bean Productivity Group was established by Simplot Australia Pty Ltd and comprises growers, industry and government representatives, research academics from TIA/UTAS, and Simplot Australia field staff. In recognition of the challenge for the industry to lower production costs, increase the yields, and extend the practices of growers (McGee and Yost 2010, unpublished report), Simplot and the Productivity Group set a yield target of 8t/ha by the year 2020. This group identified plant establishment as one of the focus areas for general crop improvements.

Currently, the average yield is 6t/ha (at target maturity index), although some growers regularly achieve 8 to 9t/ha on soils that are not regarded as the best pea-growing soils. Previous research has demonstrated that in the southern Tasmanian pea growing area, the critical times that determine final yield are at establishment, flowering and pod fill, with 92% of the harvested yield derived from the first two nodes that flower on each plant (Gracie 2012, unpublished data). At establishment, plant stand density, spatial arrangement, uniformity of seedling development, weed control and seedling vigour all influence potential crop yield. During vegetative and reproductive growth, irrigation has been demonstrated to significantly increase the number of filled pods per plant, peas per pod and green pea weight (White *et al*. 1982). For this reason, the project was extended to include an investigation of irrigation pre- and post-flowering and how it interacts with stand density to affect overall yield.

Improvements in return may be offset by influences on the costs of production: the most significant cost is seed (28%), followed by contract work (20%), sprays for weeds, pests and diseases (15%), and fertiliser (14%). Irrigation comprises 6% of the variable costs (DPIPWE 2019). Sowing at higher densities, controlling weeds, fertilising and irrigation all add to production costs, so optimising return depends on the relative cost and return of each of these actions.

Current commercial practice is to sow peas to achieve a plant stand density of 110 seeds/m^2 using air seeders and conventional drills with disc or tine openers. Although the importance of spatial arrangements for pea crops is well understood, current practices and machinery configurations do not satisfactorily achieve target stand densities or the desired spatial arrangement. Due to the positive influence of establishment on pea return, a review of commercial practice may identify opportunities to increase efficiency and optimise seed use. Additionally, as plant spatial arrangement is related to inter- and intra-plant competition, and hence influenced by plant structure, previous work on spatial arrangements require realignment with the architecture and physiology of newer varieties.

Considering this, and focusing on crop establishment and irrigation, the aim of this research is to support the productivity and profitability goals of the processing peas industry in Australia. This project sought to:

- Evaluate plant spatial arrangements and stand density on crop development, uniformity and yield,
- Assess current commercial seeders and establishment practices in achieving target spacing,
- Explore approaches to modify plant structure to increase the overall number of pods that contribute to harvested yield, and
- Demonstrate the benefits of reliably achieving optimal stand density and plant spatial arrangement to contract growers.

Figure 1: Pea field trial at Forthside Tasmania, 8 December 2018 (supplied by Elliana Hope).

Methodology

The research program comprised several objectives that incorporated establishment conditions, commercial seeding outcomes, plant modification and resultant potential economic benefits. A summary of methods is provided below, with the detailed methodology available in appendices.

Gross returns ($) per hectare (ha) is used to report the outcomes of the field trials for several reasons: 1) it is easy to understand and meets a core objective of demonstrating economic benefits to growers; and 2) pea yield per unit area is adjusted by a green pea maturity index (e.g. tonnes of product present at the time of ideal maturity) and thus the amount growers receive per tonne depends on the average crop "green pea" maturity at the point of harvest. Pea maturity is measured using machines that measure "firmness" and this parameter can increase substantially over a 24-hour period. Gross returns (or $ value) therefore accounts for the relationship between gross yield and pea maturity by utilizing the commercial sliding scale of payment and is therefore the fairest unit of measurement to compare treatments.

1. What are the optimal stand density, plant spatial arrangement and irrigation settings to maximise pea return?

Field trials were conducted to assess the effect of stand density, spatial arrangement and irrigation on crop return. Trials conducted in 2016/17 and 2017/18 were randomised complete block designs comprising three or four blocks (usually four) of replicates in each trial. Irrigation trials conducted in 2018/19 were split-plot trials, with main plots allocated to irrigation treatments. At the TIA Vegetable Research Facility ("Forthside"), plots generally comprised a 10m length of a bed (1.6m wide). The specific details on the field layout and designs are incorporated in the appendices.

In 2016/17, two trials were conducted, one at Forthside and one at a commercial crop site near Longford, Tasmania. The interaction of density and spatial arrangement was assessed using five target densities (60, 90, 110, 130, 160 plants/m^2) by three spatial arrangements (125mm and 200mm rows, and a square arrangement). One hundred plants/m^2 is the commercial density targeted by Simplot Australia. These trials incorporated both hand and machine planting using the pea cultivars *Ashton*, *Reliance*, and *Resal* (design in Appendix 1).

In 2017/18, a trial was conducted at Forthside using the *Resal* cultivar. The interaction of density and spatial arrangement was assessed using five target densities (80, 90, 100, 110, 120 plants/m^2) by two spatial arrangements (125mm and 200mm rows). Additionally, stand density was manipulated at ten commercial crop sites that were representative of the range of commercially practiced row spacing.

In 2018/19, two trials of stand density, spatial arrangement and interaction with irrigation were conducted across two separate sowing dates (four trials in total) and cultivars (August/*Reliance* and December/*Resal*).

- August: Trial 1 incorporated three target densities (80, 100 and 120 plants/m^2), one spatial arrangement (125mm rows), and three irrigation treatments (100%, 50%, and 0% irrigation). The irrigation treatments were applied from the fourth node stage to flowering, followed by resumption of full irrigation of all plots to maturity. Trial 2 incorporated three target densities (80, 100 and 120 plants/m^2), two spatial arrangements (125mm and 200mm rows), and three irrigation treatments (100%, 50%, and 0% irrigation). The irrigation treatments were applied from flowering to maturity.
- December: Trial 1 incorporated three target densities (80, 100 and 120 plants/m^2), one spatial arrangement (125mm rows), and three irrigation treatments. The treatments were 100% irrigation, 0% irrigation from fourth node stage to flowering, and 0% irrigation from fourth node stage to maturity. Trial 2 included three target densities (80, 100 and 120 plants/m^2), two spatial arrangements (125mm and 200mm rows), and three irrigation treatments. The treatments were 100% irrigation, 0% irrigation from flowering to maturity,

and 0% irrigation from fourth node stage to maturity.

In each of these field trials, plots were established and within each a 1 x 2m sample area defined. Emergence and actual stand density were recorded and, where required, thinning was conducted to achieve the target density. Agronomic management for all trials were consistent with commercial practices, and regular observations were made of each trial including growth stage, plant vigour and presence of disease. Plots were harvested at commercial maturity with the assessment of plant characteristics and yield conducted at Forthside.

2. What is the degree of variability observed in density and spacing using commercial seeders?

Benchmarking surveys of plant density and spatial arrangement were conducted in a selection of forty commercial crops in 2016/17, targeting a range of drill types, grower practices, soil types, and cultivars. Stand density, row spacing, within-row spacing and crop yield were assessed. Average stand density was also recorded for commercial crop sites containing trials in the 2017/18 and 2018/19 seasons.

Assessment of planter performance was based on stand establishment with distances between plants along a row (usually 5 meters) recorded when the crop was at approximately four true leaves. The intra-row distances between plants where then used to assess variability. In short, where plants were within ± 50% of average spacing they were recorded as “on-target”; e.g. 6cm average then on-target would be between 3 and 9 cm. Less than 50% of “target” (e.g. <3cm) was represented as “doubles” and greater an 150% of average (e.g. > 9cm) were recorded as “misses”. This approach is commonly used to evaluate planter performance.

3. What is the relationship between plant structure and pea yield?

As more than 92% of pea yield is produced on the first two reproductive nodes of the main plant stem, experiments were conducted to determine if increased branching during development could increase gross yield. Glasshouse experiments were conducted in 2016/17 to investigate induced stem branching. Two experiments utilised the physical removal of the apical meristem at specific growth stages; Experiment 1 included removal at five stages (3, 4, 5, 6, and 8 nodes), and Experiment 2 included three stages (6, 8, and 12 nodes). A separate experiment was conducted using the application of herbicides at the five-node growth stage to damage the apical meristem and promote an altered growth response. Four pea cultivars were used in the herbicide treatment, *Ashton*, *Reliance*, *Resal* and *Columbus*.

Further, a selection of representative plants were collected from a range of 2017-19 trial sites, including the 2017/18 Forthside trial and ten commercial survey sites from that season (refer to Objective 1). Collections were also taken from the 2018/19 Forthside trials and from an additional nine commercial crop sites. Characteristics and yield of the selected plants were recorded and paired with experimental treatment to assess the impact on pea yield and plant architecture. The data collection protocol is available in Appendix 1.

Outputs

This project has delivered a range of experimental and survey data in addition to extension events and products. Experimental data on plant spacing, stand density, and irrigation interaction were collected from over 430 trial plots in addition to extensive surveys of commercial sites, and two glasshouse trials of plant structure modification.

Key findings are summarized and provided below:

1. What are the optimal stand density, plant spatial arrangement and irrigation settings to maximise pea return?

To determine the optimal establishment conditions for pea crops to support the industry productivity goals, research was required to understand the interaction of resource availability and plant competition. This section presents the results of three years of field trials investigating density and plant spacing, the interaction with irrigation, and the impact on gross returns. The data are presented as gross returns ($/ha), which are based on a commercial sliding scale of payment that accounts for pea maturity. As the sliding scale of payment accounts for the relationship between pea maturity and yield, gross return is therefore the most objective unit of comparison to assess productivity.

a) Optimal stand density

Investigations of stand density showed that optimal returns were achieved at densities between 100 and 120 plants/m^2, returning nearly $4800 per hectare in some trials. The field trials of three commercial cultivars *Ashton*, *Reliance* and *Resal* showed that gross returns ($/ha) increased with stand density until 120 plants/m^2. Above this density there was no additional benefit to return, indicating that increased plant competition for resources was limiting the value of the crop (Figure 2).

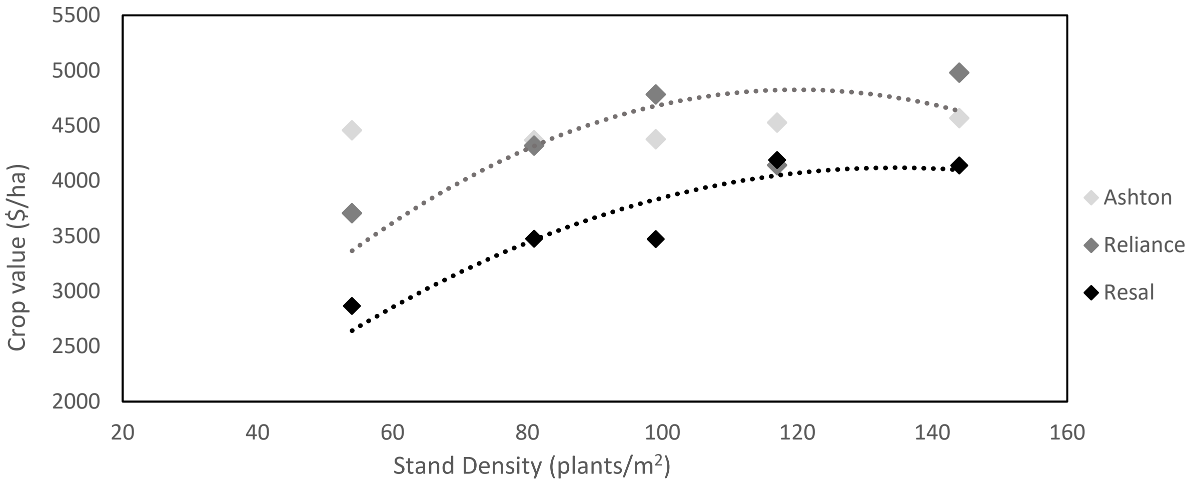


Figure 2: Relationship between actual stand density (plants/m^2) and crop value ($/ha) in each *Ashton*, *Reliance* and *Resal* cultivar trial, averaged across both 125mm and 200mm row widths (2016/17). Data are mean values (n=6), line of best fit (trend line) for *Reliance* and *Resal* cultivars displayed.

b) Ideal plant spatial arrangement

Trials of plant spatial arrangement found that an additional 7% return can be achieved by using a narrower row width for planting. This is a significant increase in return with no additional costs and is an achievable change in practice. On average, at the same density, gross return was 7% higher ($348/ha) and total plant biomass was 10% higher (0.5kg/m^2) in plots using 125mm rows than the wider 200mm rows, indicating that plants were more vigorous in plots under the narrower row width (Figure 3).

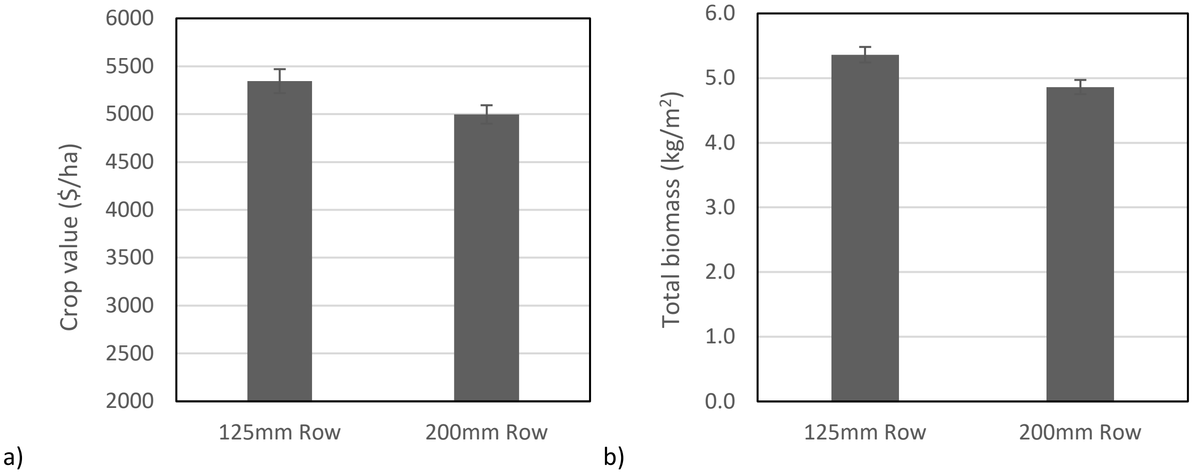


Figure 3: a) Crop value ($/ha) and b) Total biomass (kg/m^2) for 125mm and 200mm row widths averaged across all densities (2017/18), error bars represent ±1 SEM, n=15.

Plants in 125mm rows also out-performed those planted in 200mm rows whether planted by hand or machine (Figure 4), suggesting that there is a distinct advantage by planting in narrower rows, even in the absence of precision intra-row spacing as was achieved by hand planting. Narrow rows would reduce the onset of competition among plants, leading to earlier canopy closure and improving sunlight capture. This in turn enhances access to resources and produces healthier, more vigorous plants.

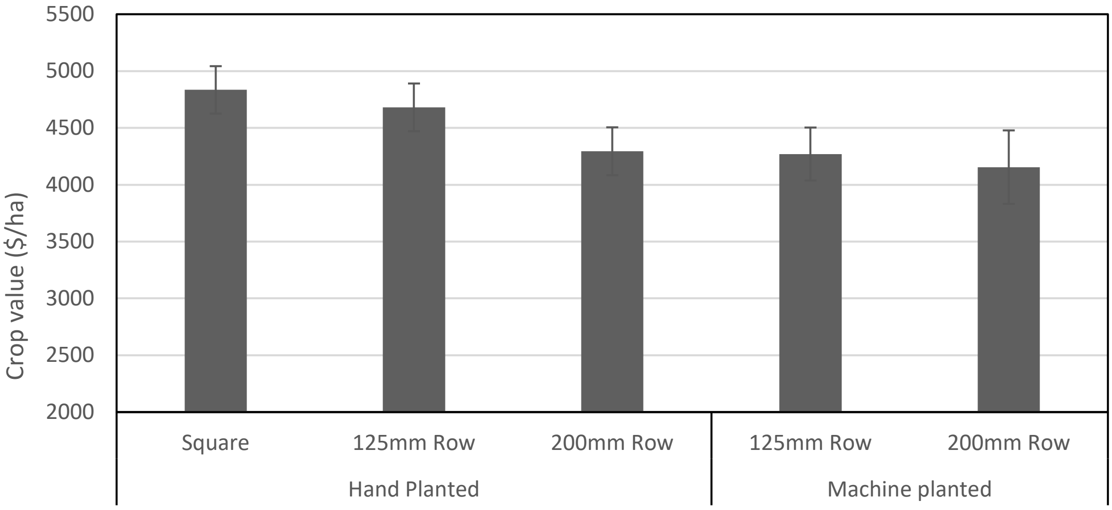


Figure 4: Comparison of planting methods averaged across *Ashton*, *Reliance* and *Resal* cultivars at consistent plant density of 110 plants/m^2 (2016/17). Hand planted square arrangement (n=7), hand planted 125mm and 200mm inch rows (n=17), and machine planted 125mm and 200mm rows (n=9), error bars represent ± 1 SEM.

All hand planted plots had greater returns than the respective machine planted plots, and planting at equal distances (on the square) within and between rows produced the highest return (Figure 4). Planting on the square returned $4,835 per hectare (on average). This was 16% higher than the machine planted 200mm row, and 3% higher than the hand planted 125mm row. The advantage of hand planting was that it provided precise control of spacing within and between rows and reduced plant competition. Planting on the square provided plants with optimal access to resources and the upper efficiency limits associated with perfect spacing arrangements.

Even of the square, gains in return can also be achieved by controlling spacing within rows, this demonstrated through hand planting a selection of plots in the 2016/17 trials. Data from 35 plots showed a remarkable 20% increase in return when peas were planted with even intra-row spacing in 125mm rows compared with random drill spacing at the same row width (Figure 5). The wider row, 200mm, resulted in an increased return of 11% with even intra-row planting. The advantage of consistent and even spacing in crops is that it reduces unnecessary competition and increases access to available resources.

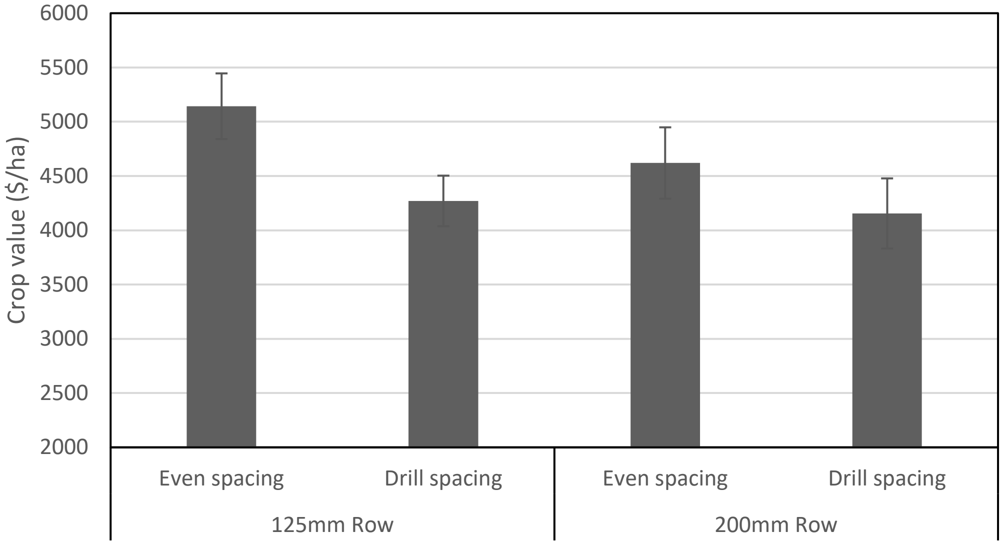


Figure 5: Comparison of inter- and intra-row plant spacing arrangements averaged across *Ashton*, *Reliance* and *Resal* cultivars at consistent plant density of 110 plants/m^2 (2016/17). Arrangements include 125mm rows with plants evenly spaced (n=8) and randomly spaced (n=9), and 200mm rows with even and random spacing (both n= 9). All plots located within the machine planted trial section, error bars represent ± 1 SEM.

c) Irrigation and stand density interactions

In 2018/19 two separate field trials were conducted to assess stand density, spatial arrangement and irrigation interactions. The two trials represented separate sowing dates (spring and summer) and the associated commercial cultivars (*Reliance* and *Resal*).

Spring sowing:

Gross returns increased with stand density when irrigation was applied post-flowering, even with irrigation deficits during the pre-flowering stage. The opposite occurred when irrigation deficits were applied during post-flowering, with returns declining as stand density increased (80-120 plants/m^2). The highest return was from plots planted at 120 plants/m^2 and which were fully (pre-and post-flowering) irrigated (Figure 6).

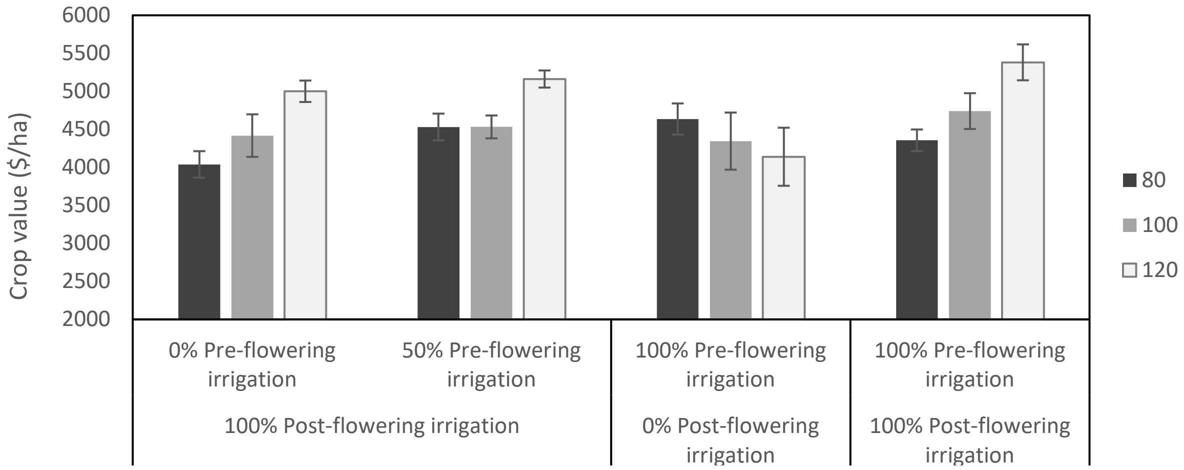


Figure 6: Influence of stand density (plants/m^2) and irrigation treatment during crop development on value ($/ha) (2018/19, Sowing 1). All plots sown in 125mm rows, each column represents mean values, error bars represent ± 1 SEM. In 0% pre-flowering deficit of 80 and 100 plants/m^2 n=4, n=3 for 120 plants/m^2 in this irrigation treatment. For 50% pre-flowering deficit and 0% post-flowering deficit, n=4 for all plot densities shown. In the full irrigation treatment n=8 for 80 plants/m^2 column, and n=7 for 100 and 120 plants/m^2.

Plants that were water stressed during vegetative growth (pre-flowering) were limited in biomass, whereas plants that were irrigated during this phase grew quickly and developed more biomass (Figure 7).

Crop plants that were water stressed during the reproductive phase (post-flowering) responded poorly to the lack of water, as reflected in the lower returns. Good growth during vegetative growth (Figure 7) and higher density exacerbated the effect of resource limitation post-flowering; that is, returns were lowest at 120 plants/m^2 when irrigation was not supplied post-flowering (Figure 6). This was possibly because the cost of plant maintenance was much higher than for plants with less vegetative mass.

Water availability during flowering/pod fill was key to capitalising on the plant growth that occurred during pre-flowering (even if this was under deficit) as demonstrated by all plots that received irrigation after flowering (Figure 6).

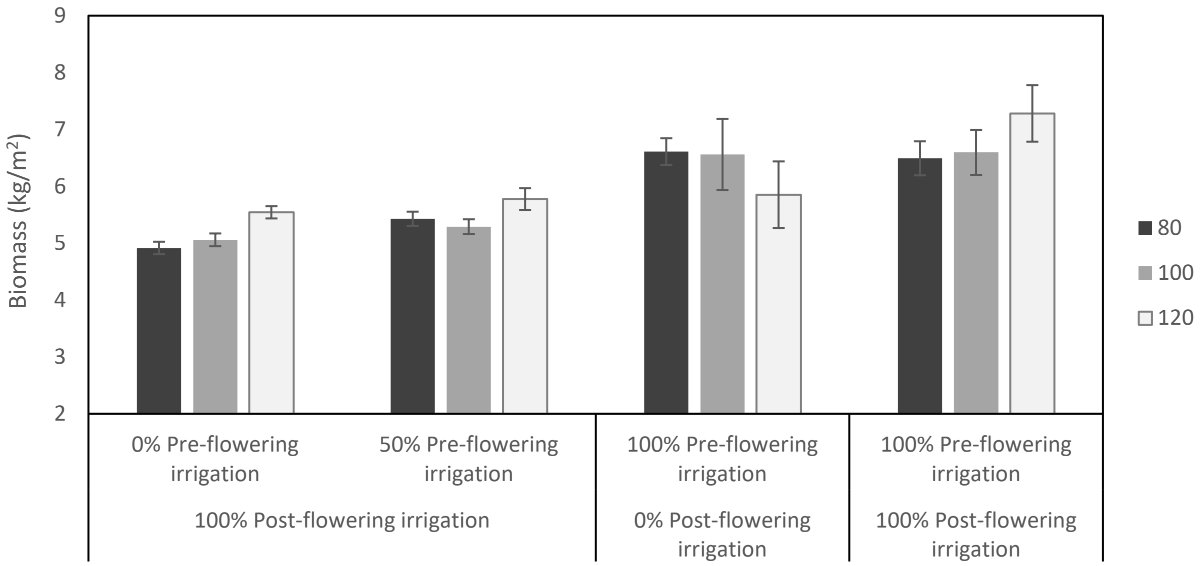


Figure 7: Influence of stand density (plants/m^2) and irrigation treatment during crop development on biomass produced per plot (kg/m^2) (2018/19, Sowing 1). All plots sown in 125mm rows, each column represents mean values, error bars represent ± 1 SEM. In 0% pre-flowering deficit of 80 and 100 plants/m^2 n=4, n=3 for 120 plants/m^2 in this irrigation treatment. For 50% pre-flowering deficit and 0% post-flowering deficit, n=4 for all plot densities shown. In the full irrigation treatment n=8 for 80 plants/m^2 column, and n=7 for 100 and 120 plants/m^2.

There were two significant rainfall events early in plant development which may have increased water availability to pre-flowering deficit plots, and one significant rainfall event during the reproductive stage which may have influenced post-flowering deficit plots (Figure 8), however this rainfall does not appear to have affected the overall trends apparent in the data, including soil moisture (data not shown).

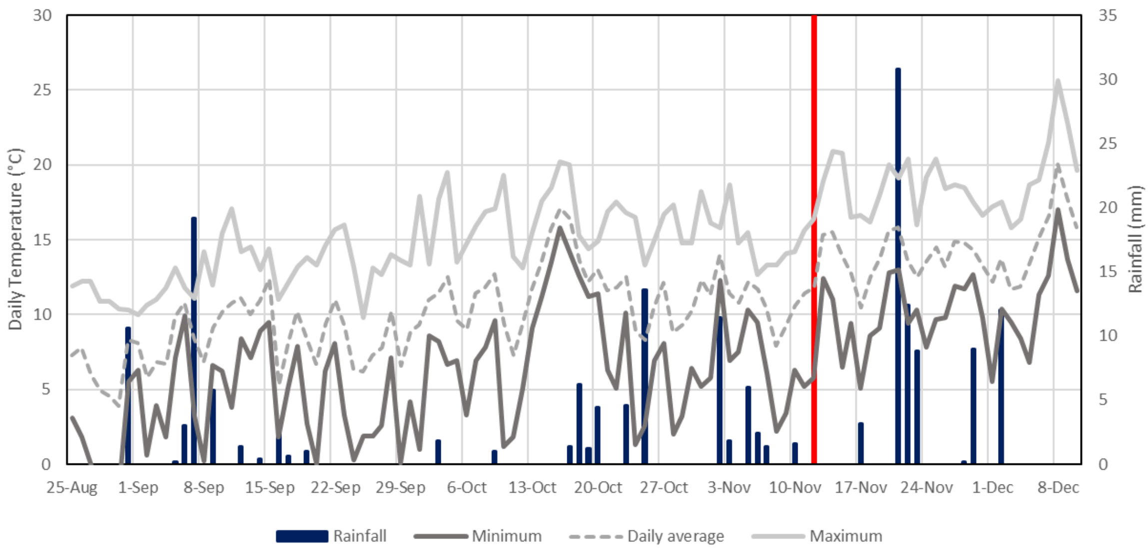


Figure 8: Rainfall and temperature data for sowing 1 (2018/19). Data recorded at the Forthside Research Facility weather station. Red line indicates 50% flowering at 12 November 2018.

Summer sowing

The total rain during the summer-sown trial (52mm) was substantially lower than the spring-sown trial (180mm), as were the moisture deficits achieved where the moderate and zero irrigation treatments volumetric soil moistures were mostly lower than the refill point (<0.25 mm/mm) prior to flowering. In sum this is reflected by the lower biomass in plots from the summer trial.

When compared to full irrigation gross returns were on average 47% lower for plots that experienced water deficits during vegetative growth (Figure 9). The negative impact on plant health during the pre-flowering stage was not recovered by resuming irrigation, i.e. there was a negligible difference in return between plots that received no irrigation at all and those that received irrigation after flowering (Figure 9).

Gross returns were 13% lower on average when plots experienced water deficits during pod fill (post-flowering) compared to full irrigation (Figure 9). Many legume crops are sensitive to water stress at the pod fill stage, as reflected in the lower returns when compared with full irrigation (Figure 9).

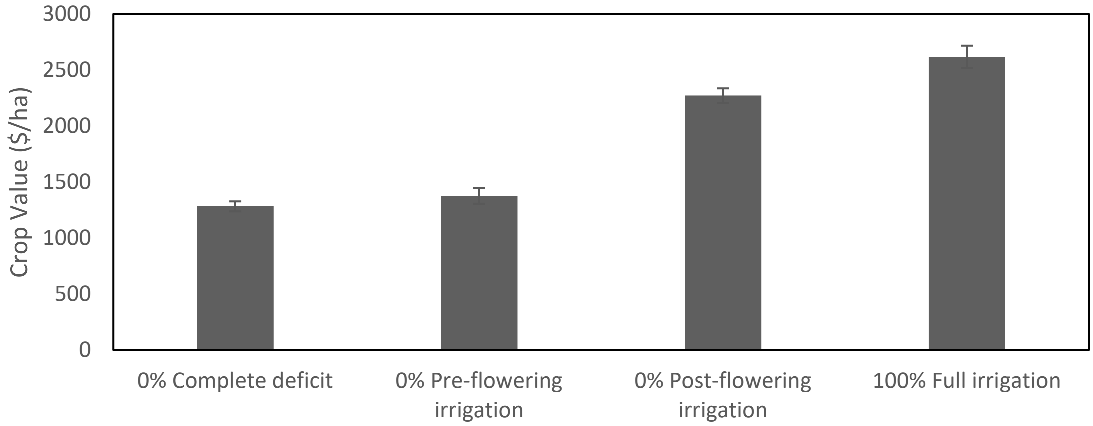


Figure 9: Influence of irrigation treatment on value ($/ha) (2018/19, Sowing 2). Columns are mean values across all plot densities, all planted in 125mm rows, error bars represent ± 1 SEM. For 0% complete deficit n=23, pre-flowering deficit n=12, post-flowering deficit n=12, and 100% full irrigation n=24.

There was also a significant effect of irrigation deficit on total plant growth. When compared to fully irrigated plants biomass was 69% lower if plants experienced water deficits during the pre-flowering stage. This negative impact on growth was not recoverable by resuming irrigation, i.e. there was little difference in weight between plots that received no irrigation at all (complete deficit) and the 0% pre-flowering treatment (Figure 10).

Biomass was 33% lower where plants experienced water deficits implemented during pod fill (post-flowering) compared to plants fully irrigated pre- and post-flowering. Water stress at this stage negatively impacted on return, however the effect on return was less significant than the effect on biomass. This suggests that establishing healthy plants early in development is fundamental to good returns.

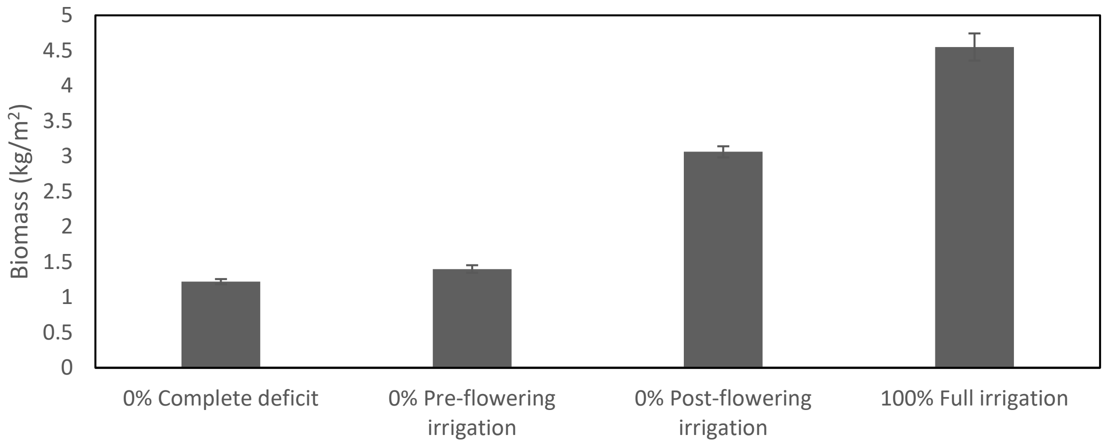


Figure 10: Influence of irrigation treatment on biomass produced per plot (kg/m^2) (2018/19, Sowing 2). Columns are mean values across all plot densities, all planted in 125mm rows, error bars represent ± 1 SEM. For 0% complete deficit n=23, pre-flowering deficit n=12, post-flowering deficit n=12, and 100% full irrigation n=24.

There were no significant rainfall events during the pod fill stage and the mid-December rain events do not appear to have affected the results of the pre-flowering water deficit treatments (Figure 11).

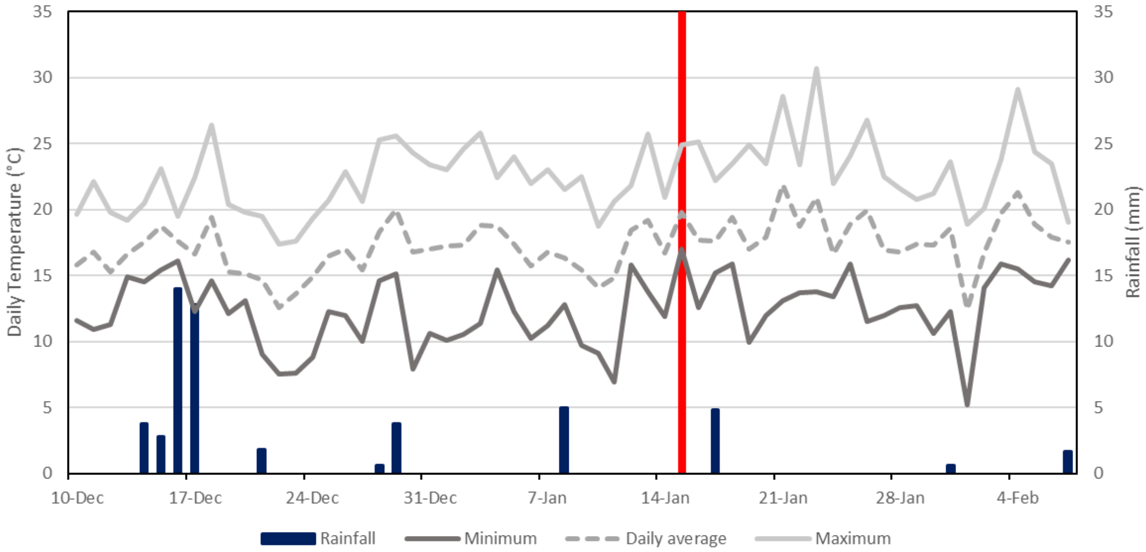


Figure 11: Rainfall and temperature data for sowing 2 (2018/19). Data recorded at the Forthside Research Facility weather station. Red line depicts 50% flowering, 15 January 2019.

The interaction of stand density and irrigation that was observed in the spring sowing was also apparent in the summer sowing. Gross returns increased with density but required high irrigation inputs to maximise productivity (Figure 12).

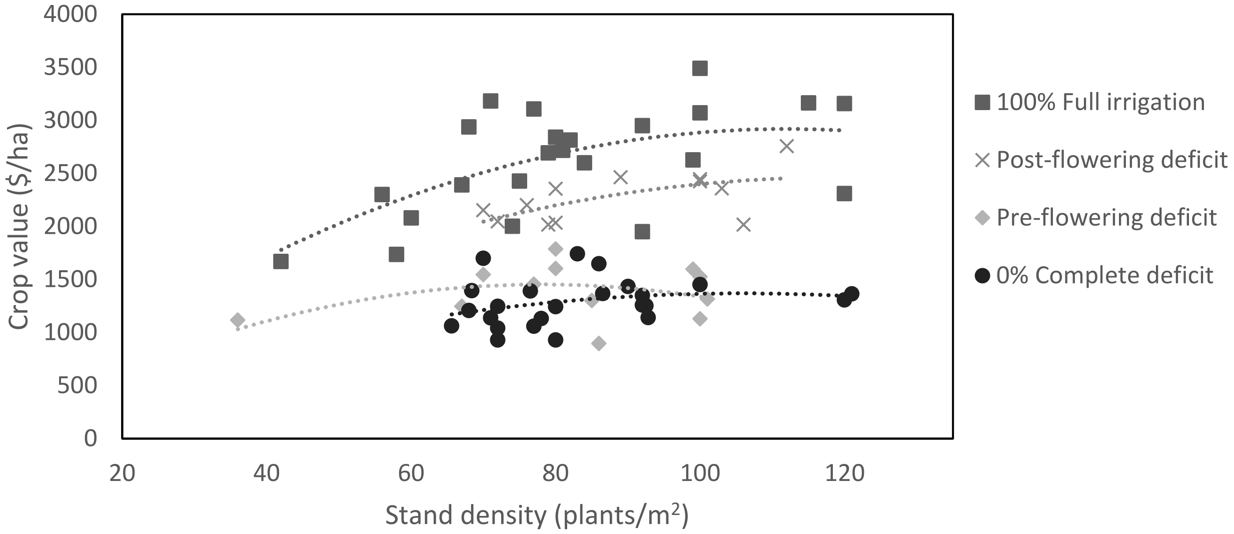


Figure 12: Influence of irrigation treatments on value ($/ha) across a range of stand densities (plants/m^2) (2018/19, Sowing 2). Each data point represents one plot, all sown in 125mm rows.

In summary, optimal planting density was between 100-120 plants/m2 and irrigation during both vegetative growth and after flowering were both necessary to maximise yield. Pre-flowering deficits for summer sown crops resulted in crops that did not flourish and returns were similar to crops that experienced a complete deficit (Figure 12). Irrigation prior to flowering was critical to establishing a healthy pea crop that was able to produce optimal returns (particularly for the summer planting), but a lack of irrigation during pod fill also compromised returns, indicating that water availability during pod fill was also important to maximise return. Crops that had high stand densities and received the highest irrigation inputs also produced higher returns (Figure 12).

Note: 2018/19 data for 200mm row widths has not been presented. The trials found no significant effects of row width on yield, however this outcome was heavily influenced by difficulties in achieving the target stand density in 200mm row width.

Key messages:

- *The highest returns were generated by planting in 125mm rows, using consistent intra-row spacing and with a stand density of 100 to 120 plants/m^2. These are the optimal establishment conditions, but irrigation at key stages is critical to maximizing the potential return.*
- *There was a strong interaction between stand density and irrigation timing on gross returns in spring sown crops. In the situation where there was healthy crop development until flowering, water deficit during flowering and pod-fill phase led to lower returns at higher densities. This contrasts with higher returns at higher densities when the crops were well watered during this phase.*
- *Gross returns were reduced by nearly a half (47%) when summer sown crops experienced water deficits during vegetative growth (pre-flowering). Irrigating after flowering did not compensate for the negative impact on early plant health.*

2. What is the degree of variability observed in density and spacing using commercial seeders?

Density and spacing are key factors in plant establishment and crop returns, and with seed the highest cost component, it is important that commercial planters maximise the use of seed to gain the greatest return. Understanding the achieved (versus target) stand density and the degree of variability within commercial crops can inform effective improvements to planting practice. This section presents the density and spacing outcomes of a survey of forty crops using eight different models of commercial drills. Specific models are not identified in the data as the intent of the survey was to examine planting precision under commercial conditions and was not intended as a comparison of planters.

A range of stand densities was recorded in the survey of commercial crops, with the average density ranging from a low of 60-69 plants/m^2 to a high of 130-139 plants/m^2, but most commonly at 80-110 plants/m^2 (Figure 13). The distribution of density was skewed towards stand densities below the commercial planting target of 100 plants/m^2.

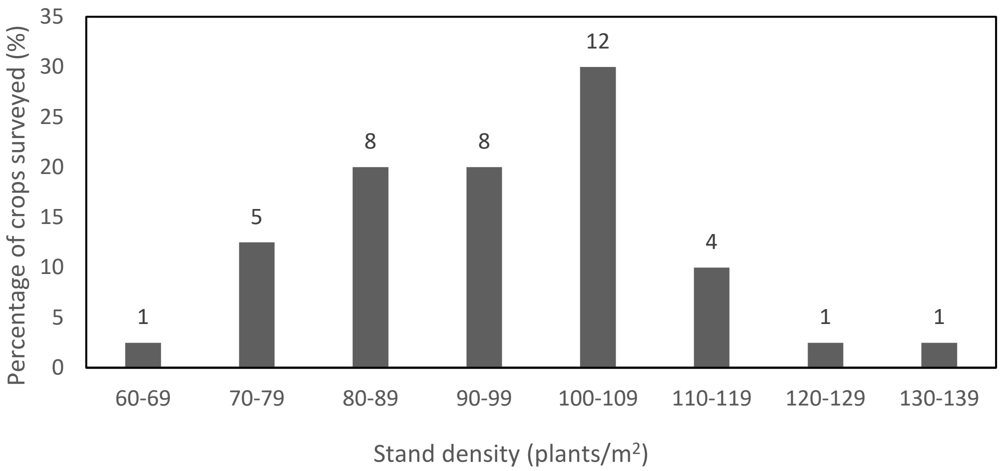


Figure 13: Average plant density in commercial crops surveyed across three years 2016-19 (combined). In 2016/17 this was calculated from four quadrat (1m^2) images per site, in 2017/18 and 18/19 density of three trial plots per crop recorded. n=40.

The drills surveyed represented the range currently used across industry, with row spacing from 12.5cm to 25cm and average distance between plants from 3.69cm to 7.44cm. The total count of plants also varied significantly, especially for data collected from five metre rows (drills 4 to 8) (Table 1).

Table 1: Spatial arrangement summary of pea plants within rows across eight crops and drill types. Data for drills 1, 2, and 3 were collected from eight 3m rows at two locations within the crop. Data for remaining sites were collected from eight 5m rows, at two locations within the crop.

	Drill 1	**Drill 2**	**Drill 3**	**Drill 4**	**Drill 5**	**Drill 6**	**Drill 7**	**Drill 8**
Row Spacing (mm)	125	143	125	200	125	167	167	250
Mean (mm)	67	58	73	74	71	59	72	37
Minimum (mm)	0	0	0	0	0	0	0	0
Median (mm)	50	40	50	50	50	40	40	20
Maximum (mm)	360	370	470	480	480	330	700	380
Total Count	346	405	315	534	527	613	567	1002

The surveyed drills only achieved intra-row target spacing 40 to 50% of the time, indicating that most seedlings were outside the desired spacing and either too close or too far apart (Figure 14). Given the importance of stand density and regular spacing for gross return, there is significant opportunity to increase returns simply by improving drill spacing in commercial practice.

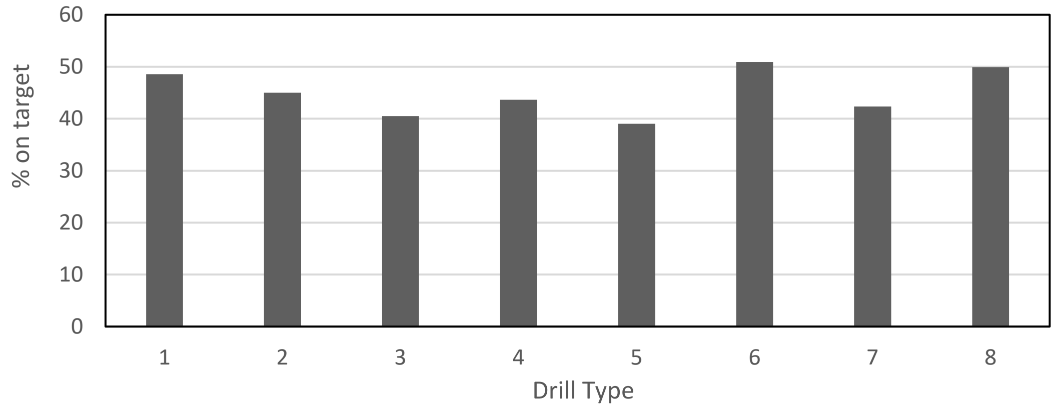


Figure 14: Percentage of seedlings that were spaced within the target range. Data were collected from eight rows across two locations within each crop, and represented approximately 1000 intra-row spaces per crop.

Seed placement was predominately doubled or on target, with the remainder (ca.20%) consisting of up to 3 misses. Double planting occurred in 29-40% of the surveyed spacing across drills, with all types of misses accounting for 18-23% of the surveyed spacing (Figure 15). Double planting and misses are an inefficient use of seed. Unnecessary competition is created between plants that are too close together, and the effect of other inputs such as sprays and irrigation is not optimised when applied to unplanted areas in the crop. A focus on improving singulation and soil preparation may help address the high proportion of doubles seen in this study.

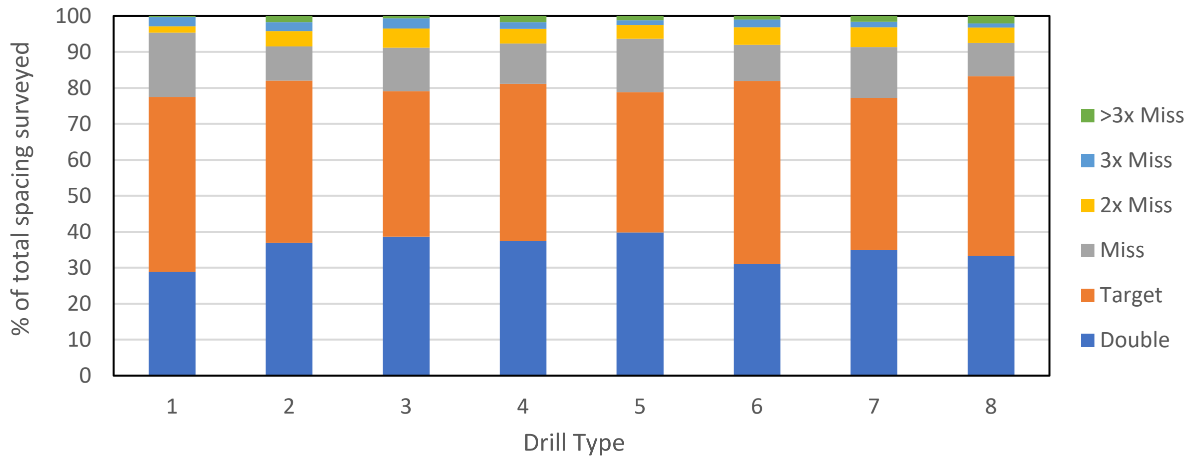


Figure 15: percentage of the surveyed spacing sown at double spacing, target spacing, or missed sowing. Misses were one (x1), two (x2), three (x3) or more than three (>x3) times the target spacing.

Three commercial drill operations were reviewed in detail. Drill 4 and Drill 8 planted wide rows, and Drill 5 planted narrow rows. The number of seedlings planted in each row highly variable within a crop. Per five metre row, Drill 4 ranged from 54 to 84 seedlings, Drill 5 ranged from 52 to 76 seedlings, and Drill 8 ranged from 82 to 150 seedlings (Figure 16).

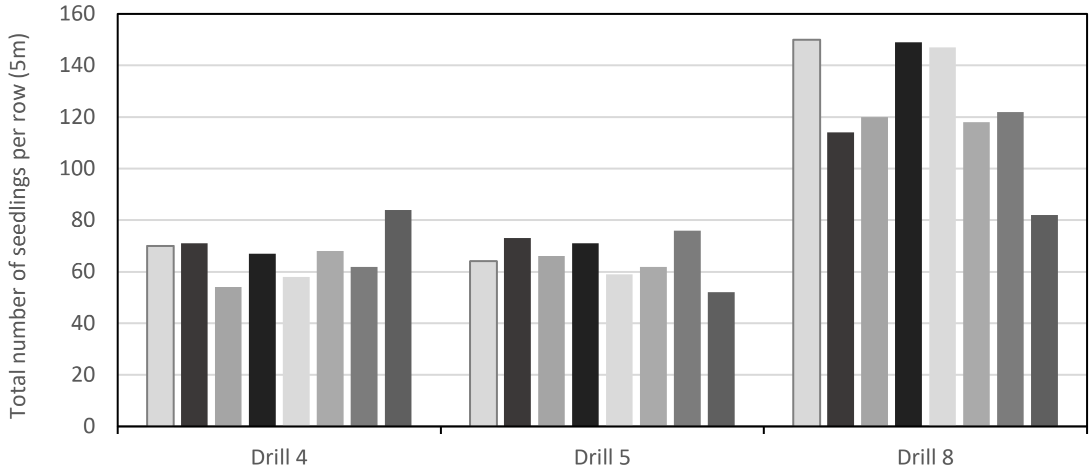
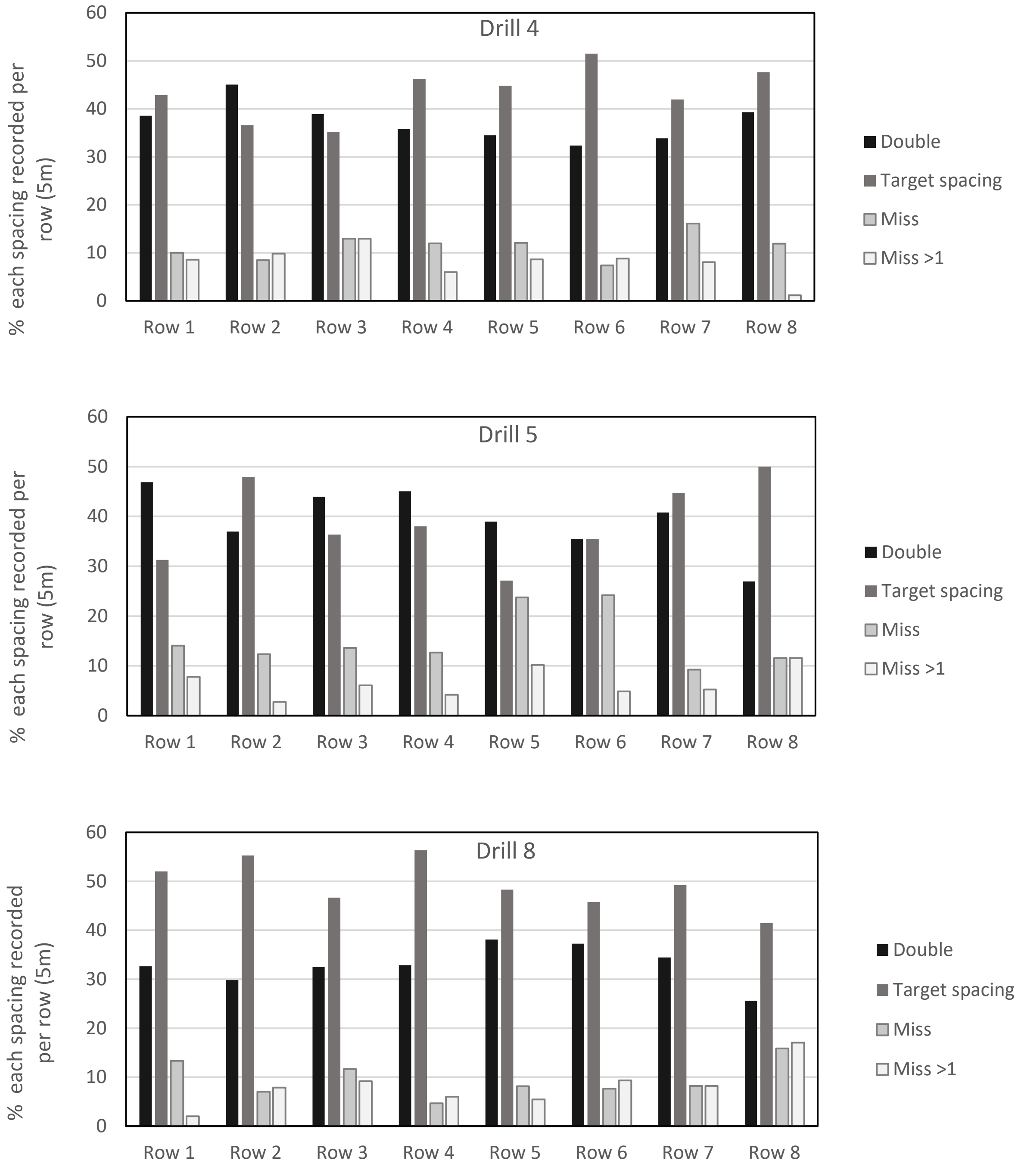


Figure 16: Total number of seedlings per five metre row for eight representative rows. Drill 4 (200mm row width), Drill 5 (125mm row width) and Drill 8 (250mm row width).

While total seed number per row was also influenced by row width of the planter, the wide variation in seedling number showed that within-row spacing was very inconsistent. Drill 4 mainly contained doubles and target spacing with consistent misses across the rows. Target spacing varied from 35% to 50% across the rows (Figure 17a). Drill 5 was highly variable in target spacing, ranging from 27% to 50% across the rows. This drill had a comparatively higher proportion of misses, and overall the placement faults varied in proportion from row to row, resulting in a highly inconsistent crop planting (Figure 17b). The increase in misses in rows 5 and 6 may have resulted from either a problem with the drill planting units or poor bed preparation. Drill 8 often achieved the target spacing with some variability across rows, however this drill produced one row with a higher proportion of misses and multiple misses (Figure 17c). This suggests that one planting unit on this drill was not operating efficiently (i.e. either a mechanical fault or not set at an appropriate depth).

The variability of planting within and between rows by each of these drills indicates that performance has not been optimised through bed preparation, and/or drill maintenance and set-up. The variation in seed placement suggests that in these crops there will be less return on expensive input's such as the seed and irrigation. Good bed preparation, optimal equipment set up and equipment maintenance will improve the consistency of spacing and is a low-cost way to maximise the return on inputs.



a)

b)

c)

Figure 17: Percentage of spacing sown at target spacing, double or missed planting. Data shown for a) Drill 4, b) Drill 5, c) Drill 8. Spacing measured along eight representative rows of five metres in length.

Key messages:

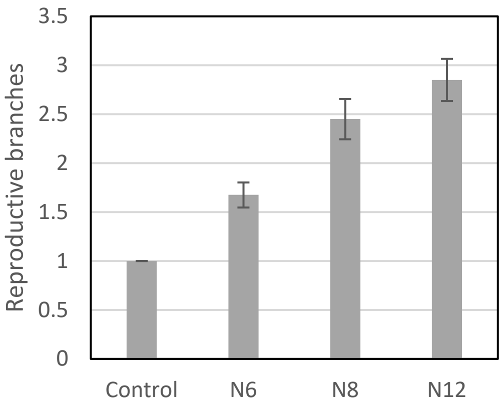
- *Between row variation (between drill units) was high amongst commercial plantings suggesting some improvements can be made through maintenance and uniform set up of the planting units.*
- *Improving the consistency of spacing within and between rows and achieving target densities is a low-cost way to increase returns.*
- *Seed is the most expensive component of pea crop production so equipment calibration, drill maintenance and soil preparation will help maximise the return on this input.*

3. What is the relationship between plant structure and pea yield?

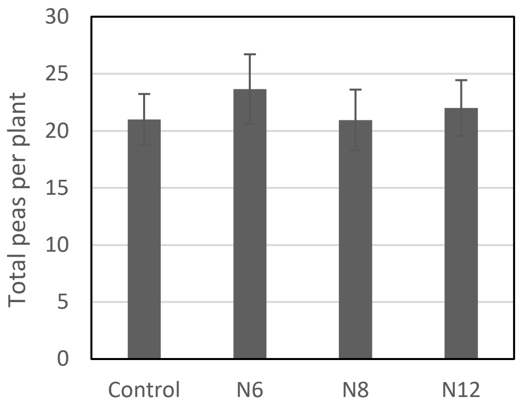
Previous research has identified the importance of the first two reproductive nodes in pea yield, with more than 92% of the harvested yield produced by the first two nodes that flower on each plant. This section describes the glasshouse trials that used physical and chemical methods to alter plant structure and potentially increase pea yield, with a focus on reproductive nodes 1 and 2. The topmost growing point (apical meristem) of pea plants was removed or chemically treated to simulate the effect of herbicide or mechanical damage, where the removal or damage to the meristem triggers hormonal cues to branch. Plant structure was also recorded in the field trials of spacing, density and irrigation to assess the effect of these parameters on structure and yield. *Ashton*, *Columbus* and *Resal* are indeterminate and leafy in growth habit, whereas *Reliance* is a semi-dwarf, semi-leafless variety.

Glasshouse branching trials

Branch numbers increased when the growing point was removed, and later tip removal at higher nodes (older plants) produced the highest branch numbers (Figure 18a). This was possibly because there were more available nodes for branching to occur in older plants once apical dominance was lost. While all cultivars produced more reproductive branches when the growing tip was removed (Figure 19a) there were potential differences in response, in particular for *Columbus* which produced approximately half as many additional branches compared to the other cultivars. Pooled across cultivars there was no net increase in number of peas produced per plant even though branching increased (Figure 18b). This yield compensation indicated that as a rule of thumb there may be no benefit to gross return in attempting to alter pea plant structure using agronomic techniques. There was however some evidence that this may not hold true for all cultivars. While the number of peas on a plant did not increase with branching for *Reliance* and *Columbus*, and the results for *Resal* were unclear (Figure 19b), total peas per plant did appear to increase with branching in the *Ashton* cultivar following tip removal. For this cultivar total peas per plant increased linearly from an average of 12 per plant to 21 per plant (control versus N12) (Figure 19b).

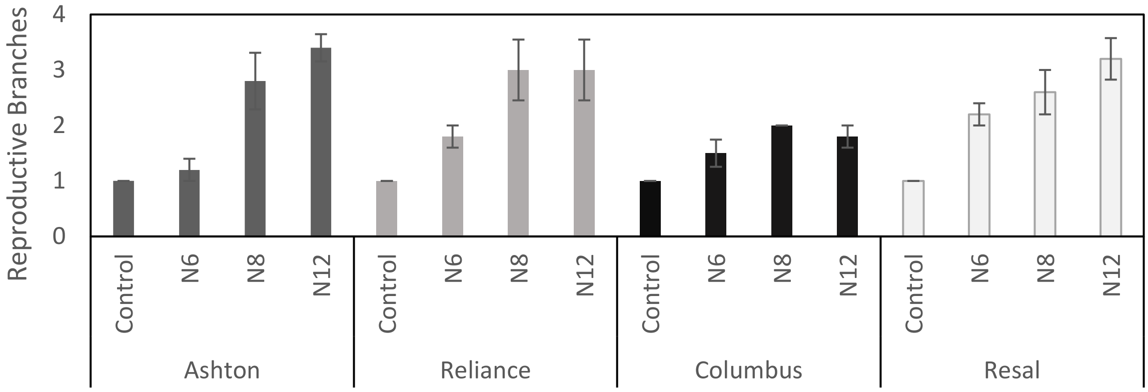


a)

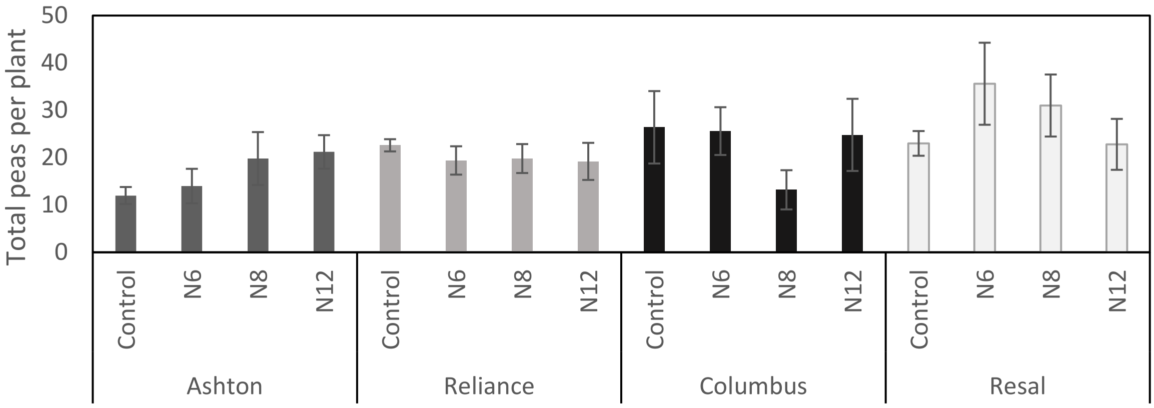


b)

Figure 18: a) average number of reproductive branches and b) average total peas per plant produced by plants across all cultivars treated with physical apical meristem removal at various growth stages (nodes 6, 8, and 12), error bars represent ± 1 SEM.



a)



b)

Figure 19: a) average number of reproductive branches and b) average total peas per plant produced by plants for all cultivars treated with physical apical meristem removal at various growth stages (nodes 6, 8, and 12), n=5, error bars represent ± 1 SEM.

The use of sub-lethal herbicide application on the growing tip had a minor effect on branching, and pea yield was reduced or unaffected. Managing the sub-lethal dose was challenging with death of seedlings occurring with Goal®, Tryquat® and Basta®. Plants treated with Fusilade® and Bladex® survived with damage to foliage, but had limited or no effect on pea yield when compared with control plants. Fusilade® application stimulated new growth at the base of the stem just prior to flowering of the primary stem of plants. This was observed across all cultivars (Figure 34, Appendix 1).

Stand density, plant structure and yield

Plants had fewer branches as stand density increased in the *Resal* trial at Longford in 2016/17. Generally, there were more single stem plants at higher densities. There were also more single stem plants in the 125mm row plots than in the 200mm row plots (Figure 20). Plants in the narrow rows in this trial out-performed those in wider rows, producing the highest returns ($/ha, Figure 3, Section 1). Narrow rows would reduce the onset of competition among plants, leading to earlier canopy closure and optimising access to sunlight. Healthy, vigorous plants with fewer branches can allocate maximal resources to the developing flowers and pods.

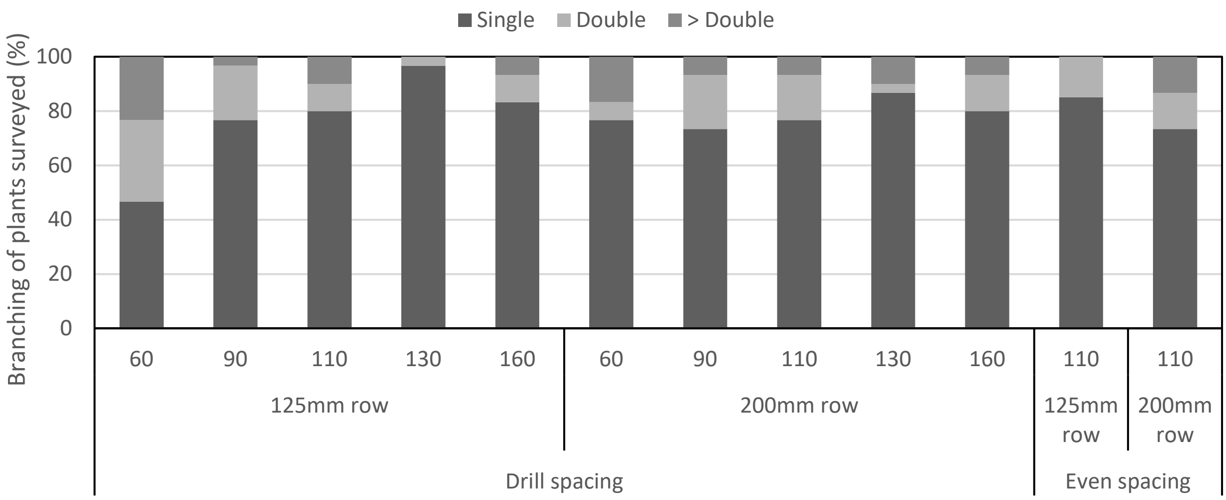


Figure 20: Degree of branching observed in a sample of plants randomly selected from each row width and plant density combination from *Resal* trial at Longford 2016/17, n=10. Branching refers to single stem "single", two main stems "double" and greater than 2 main branches ">double")

Even hand spacing resulted in higher returns ($/ha) than drill spacing (Figure 4, Section 1) and there were also differences in plant branching. Even spacing in the 125mm row produced 5% more single stem plants than using drill spacing, and only produced plants with single or double stems. Drill spacing was less consistent and often did not achieve target stand density (Figure 17, section 2), with larger spacing resulting in more highly branched plants. Thus inconsistent stand density affected plant structure.

Stand density also affected the number of peas in pod 1, the first pod on the first reproductive node. There were more peas in pod 1 as density increased, up to 110 plants/m^2. Plants in narrow row plots had more peas in pod 1 than in those plants in wider rows, except at the highest planting density (Figure 21).

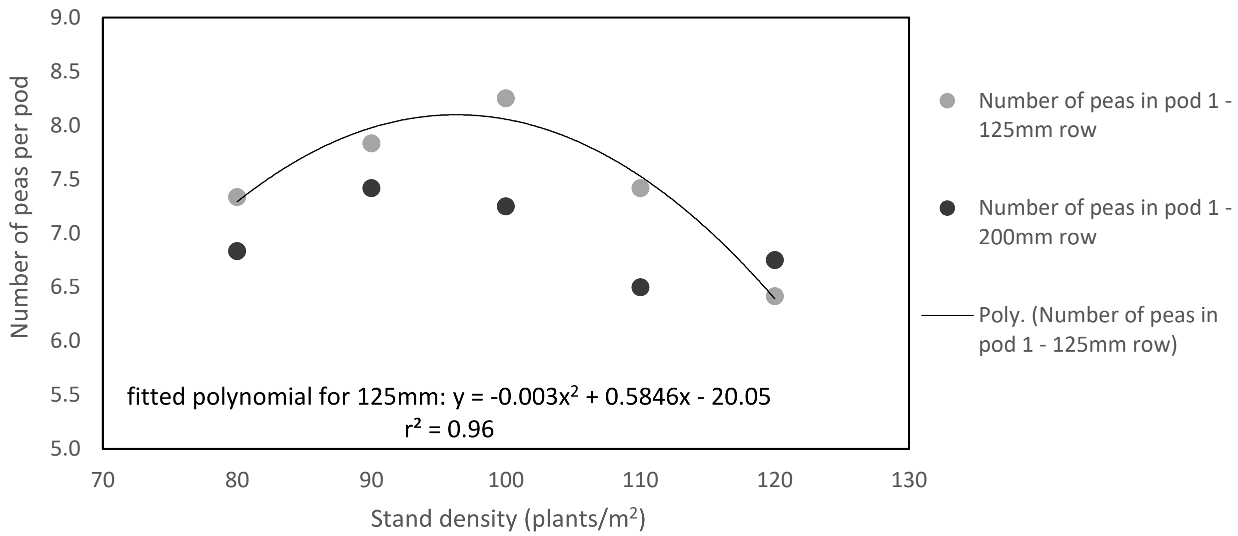


Figure 21: Characteristics of the first pod produced per plant (pod 1) across increasing stand density (plants/m^2), *Resal* trial at Forthside 2017/18, n=12.

Row spacing, plant attributes and yield

Row spacing was also associated with other key plant characteristics that influence pea yield. As an example, in the *Resal* trial at Forthside 2017/18, while pod numbers were equal, plants sampled from narrow row plots had more filled pods and longer pods than the plants sampled from wider rows, but there was no difference in the number of pods on reproductive nodes 1 or 2 (Figure 22). Also, the first two pods on the plant were longer and contained more peas in plants sampled from narrow rows than the wider rows (Figure 23). Although the differences appear marginal, the cumulative impact across a whole 'crop' would contribute to higher returns, as calculated in the experiment (Figure 3, section 1). As >92% of pods are produced by the first two reproductive nodes, it is likely that reduced early competition and the benefits of early plant vigour, allowed plants at the narrower spacing to allocate maximal resources to these reproductive nodes.

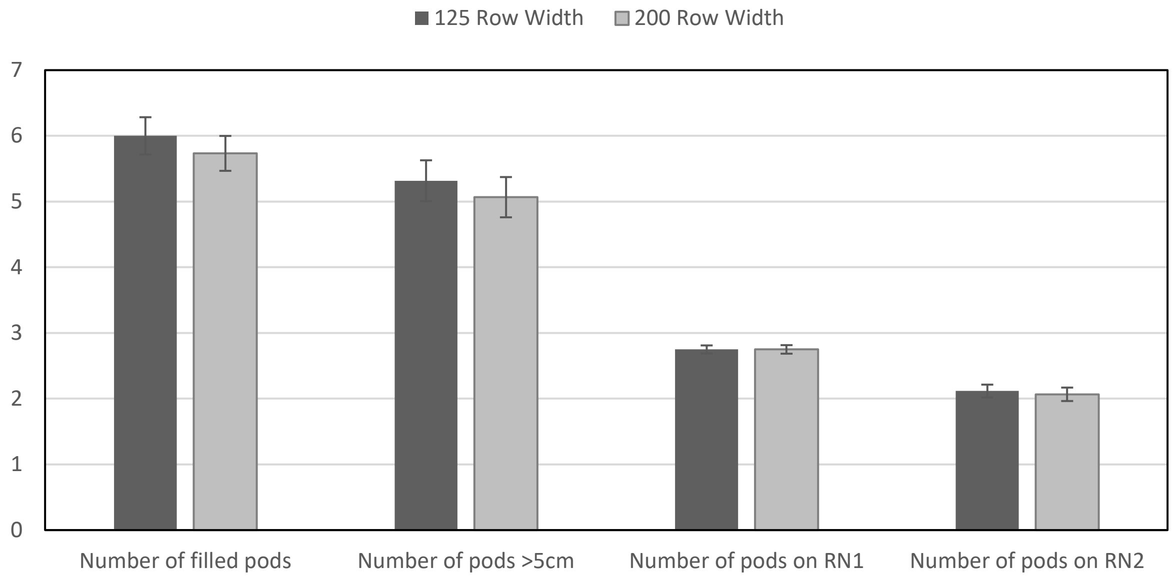


Figure 22: The effect of two row spacing arrangements (125mm and 200mm) on plant structure characteristics (the total number of filled pods, pods greater than 5cm length, and number of pods on reproductive node 1 and 2) across a range of plant densities (all combined), n=60 and error bars represent ±1 SEM. *Resal* trial at Forthside 2017/18.

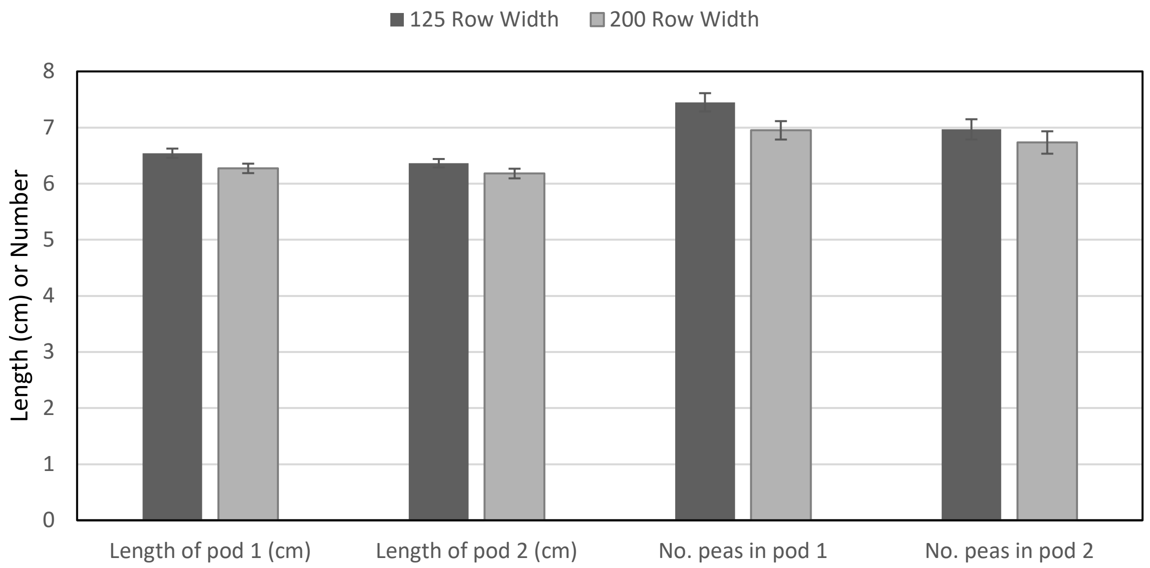


Figure 23: The effect of two row spacing arrangements 125mm (dark) and 200mm (light) on pod length and the number of peas in each, across a range of plant densities (all combined), n=60 and error bars represent ±1 SEM. *Resal* trial at Forthside 2017/18.

Irrigation, plant attributes and yield

Water availability had a large impact on plant architecture through its effects on the following plant attributes; height to first reproductive node, total pea weight, number of filled and flat pods, pod length, number of peas in pods, and the average number of pods on each of the first five nodes.

Plants were 30% higher (+10cm) when irrigated during the vegetative growth phase than non-irrigated plants regardless if irrigation was applied post-flowering (Figure 24). Height to the first reproductive node was used as a measure of growth rate and plant vigour; hence plants that experienced water deficits in the pre-flowering phase were judged less vigorous than those that were irrigated.

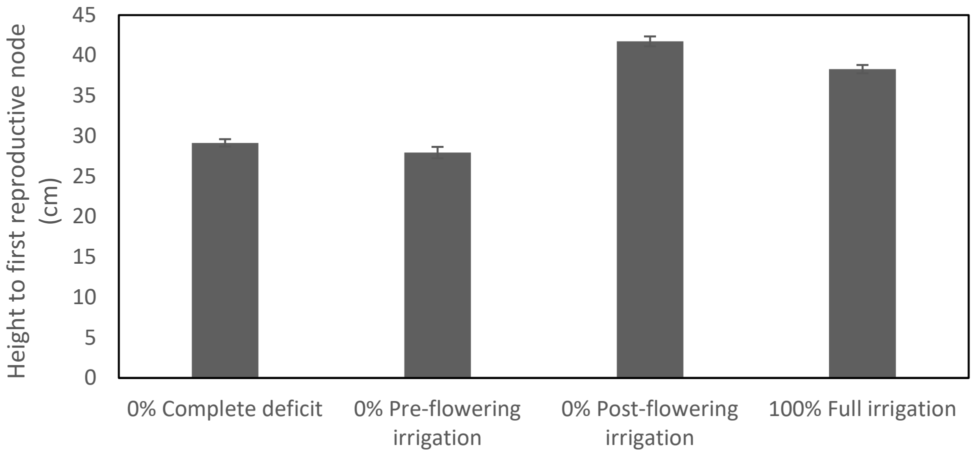


Figure 24: Influence of irrigation treatment (or periods of deficit during development) on height to first reproductive node (cm) (2018/19, Summer Sowing). Columns are mean values across all plot densities, all planted in 125mm rows, error bars represent ± 1 SEM. For 0% complete deficit n=60, pre-flowering deficit n=59, post-flowering deficit n=60, and full irrigation n=60.

Average total pea weight (g) was significantly reduced by deficits in irrigation, with the lowest total weights observed under complete and pre-flowering water deficits.

Plants that were not irrigated prior to flowering produced only 35% of the total pea weight (on average) yielded by plants that were 100% fully irrigated (Figure 25). Even when irrigation resumed after flowering, the average total pea weight at harvest did not improve. Plants in the pre-flowering treatment only slightly increased in the average total pea weight per plant when compared with complete deficits (Figure 25). This result reinforces the critical nature of irrigation during the vegetative growth phase. Without enough input, pea yield was irretrievably low, and returns were affected (Figure 9, section 1).

Plants that were not irrigated after flowering produced 60% of the total pea weight (on average) yielded by plants that were 100% fully irrigated (Figure 25). Although irrigation prior to flowering did improve pea yield, the post flowering deficit negatively affected the development of total pea weight. This indicates that irrigation is also crucial after flowering, when pods are developing and filling.

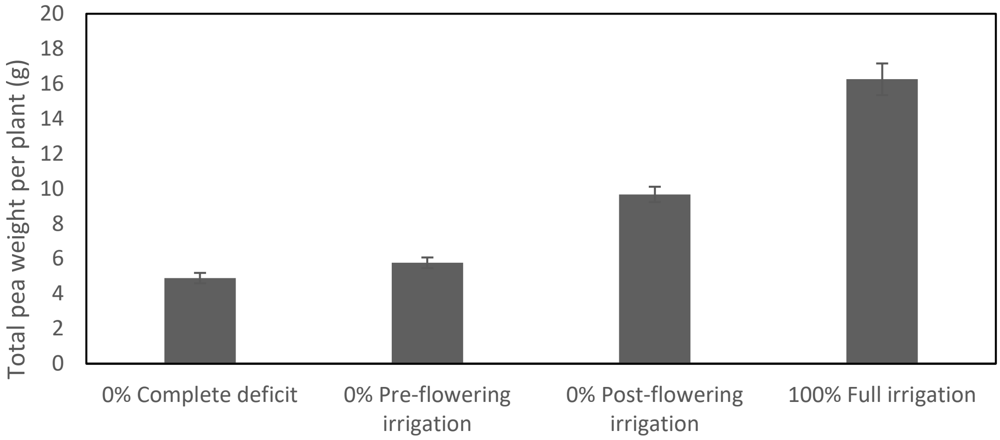


Figure 25: Influence of irrigation treatment (or periods of deficit during development) on total weight per plant (g) (2018/19, Summer Sowing). Columns are mean values across all plot densities, all planted in 125mm rows, error bars represent ± 1 SEM. For 0% complete deficit n=60, pre-flowering deficit n=59, post-flowering deficit n=60, and 100% full irrigation n=60.

Similar results were observed in the average number of filled and flat pods per plant. Plants with irrigation deficit prior to flowering produced only 55% of the filled pods that plants produced when 100% fully irrigated. There was no difference between the complete deficit and pre-flowering deficit treatments. Resuming irrigation for plants under the pre-flowering deficit did not result in any additional filled pods (Figure 26). Plants that were irrigated prior to flowering had a significantly higher number of filled pods. This shows that irrigation during vegetative growth is vital to the number of filled pods that are produced by a plant.

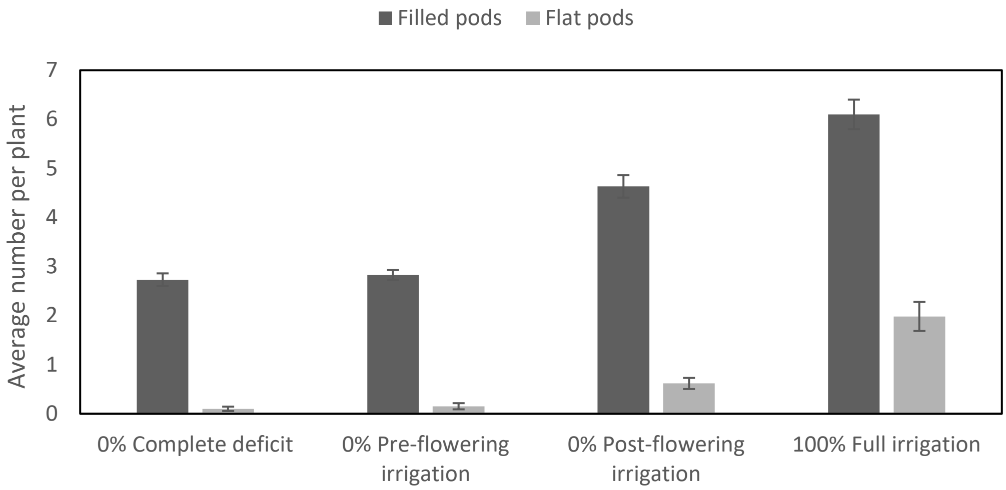


Figure 26: Influence of irrigation treatment (or periods of deficit during development) on average number of filled and flat pods per plant (2018/19, Summer Sowing). Columns are mean values across all plot densities, all planted in

125mm rows, error bars represent ± 1 SEM. For 0% complete deficit n=60, pre-flowering deficit n=59, post-flowering deficit n=60, and 100% full irrigation n=60.

With 92% of the pea yield sourced from the first two reproductive nodes (RN), it is important to understand where the additional yield was located on plants that received irrigation.

The first reproductive node produced the most pods, consistent with the pea plant prioritising earliest pod development by position through the preferential allocation of assimilates. Fewer pods were produced on successive nodes, especially for plants that experienced irrigation deficit prior to flowering (Figure 27). Water availability is important for the development of the total number of reproductive nodes in peas, and there was a clear difference between plants that had deficits prior to flowering and those that did not.

The complete deficit and pre-flowering deficit plants produced a similar average number of pods on RN1 and RN2, and usually did not produce any pods on other nodes. Plant that were irrigated through vegetative growth produced a similar average number of pods on RN1 and RN2 when compared to full irrigation and produced some pods across all five reproductive nodes measured. The main difference between the post flowering deficit treatment and full irrigation, was that fully irrigated plants produced more pods on RN3-5 (Figure 27). The full irrigation treatment also had more flat pods (Figure 26) however pea weight was not compromised (Figure 25).

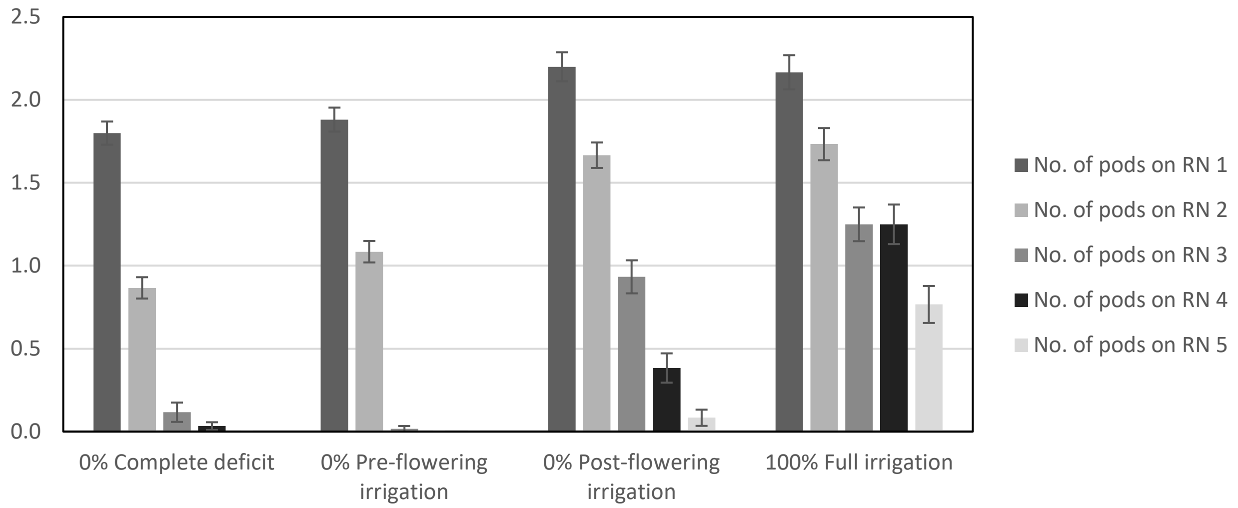
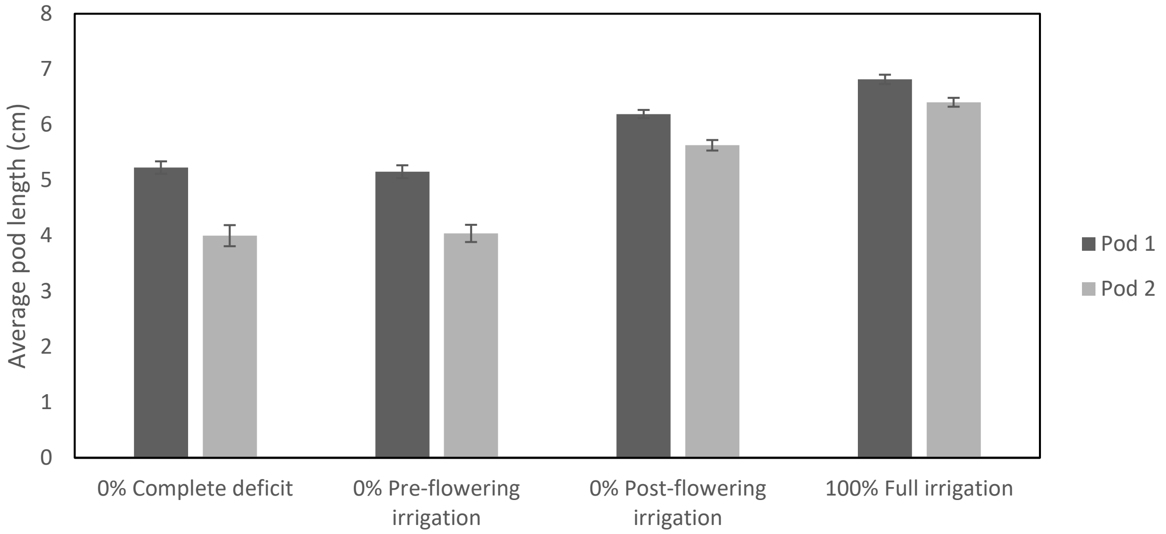


Figure 27: Influence of irrigation (or periods of deficit during development) on the average number of pods on each reproductive node for nodes 1 to 5 (2018/19, Sowing 2). Columns are mean values across all plot densities, all planted in 125mm rows, error bars represent ± 1 SEM. For 0% complete deficit n=60, pre-flowering deficit n=59, post-flowering deficit n=60, and 100% full irrigation n=60.

Although the number of pods on RN1 and RN2 was similar for the post-flowering deficit and fully irrigated plants, there were differences in pod characteristics.

Post-flowering deficits resulted in shorter pods (Figure 28a) with fewer peas (Figure 28b), especially for the second pod. Plants with irrigation deficits prior to flowering had the shortest pods altogether with fewest peas and again with this effect more significant for the second pod. This outcome demonstrated the impact of water stress had on pod development and highlights the importance of irrigation at key developmental stages to ensure that yields are optimised at the first two nodes.



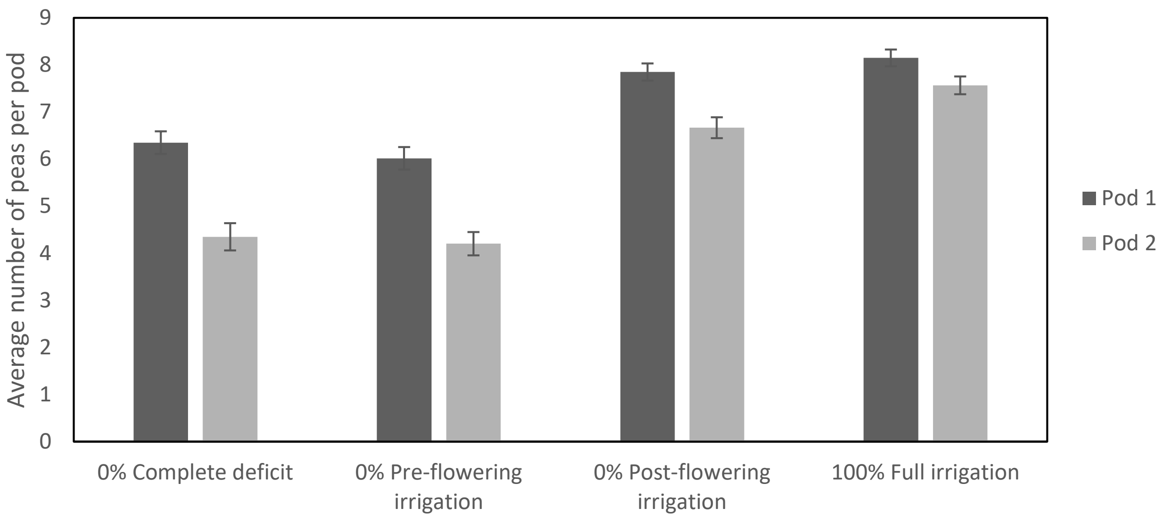


Figure 28: Influence of irrigation treatment (or periods of deficit during development) on a) average pod length (cm) and b) average number of peas per pod for pod 1 and pod 2 (2018/19, Sowing 2). Columns are mean values across all plot densities, all planted in 125mm rows, error bars represent ± 1 SEM. For 0% complete deficit n=60, pre-flowering deficit n=59, post-flowering deficit n=60, and 100% full irrigation n=60.

Key messages:

- *Physical removal of the growing tip stimulated the production of more reproductive branches but did not significantly increase plant yield for most cultivars, with Ashton as a possible exception to this.*
- *Herbicide application/damage did not stimulate reproductive branching.*
- *Narrow rows (125mm) produced more filled pods, longer pods, and more peas in a pod.*
- *Deficits in irrigation before flowering were detrimental to plant vigor, pod production and the pod characteristics that are important for yield. Negative effects on plant characteristics that determine yield could not be recovered with a resumption of watering after flowering. Irrigation was critical prior to flowering to ensure optimal pea yield.*
- *Deficits in irrigation after flowering were detrimental to average pea weight per plant and the number of filled pods. There was no negative effect on the number of pods at RN1 or RN2.*
- *For plants that were irrigated during vegetative development, continued irrigation after flowering did not produce more pods at RN1 and RN2, but did produce longer pods with more peas. Irrigation after flowering maximised pea yield.*
- *The highest average total pea weight was observed under conditions of full irrigation.*
- *As >92% of pods are produced by the first two reproductive nodes, it is likely that reduced early competition and the benefits of early plant vigour, allowed plants at the narrower spacing to allocate maximal resources to these reproductive nodes.*

Outcomes

The desired outcome for this project was to contribute to the competitiveness of the industry through the discovery of new knowledge and practice that could contribute to an increase in average returns per hectare of 20% to growers within 2 years of the completion of this project. This project has delivered against the overarching criteria of developing recommendations and protocols to improve the probability of high crop performances by understanding: optimal stand density and spatial arrangements; relationship between canopy structure and yield; interaction between stand density and inputs such as irrigation; and key information to inform planter setup and potential investment in crop planting equipment.

- *Improving the consistency of spacing within and between rows and achieving target densities is a low-cost way to increase returns.*
    - *We were able show that the use of 125 mm row spacing compared with 200 mm alone leads to a 7% increase improvement in yield (at a set pea Maturity Index) and thus returns. Narrow rows (125mm) produced more filled pods, longer pods, and more peas in a pod*
    - *The highest returns were generated by planting with a stand density of 100 to 120 plants/m^2. We recommend a target of approximately 110 plants per m^2.*
    - *Collectively, across all trials, between 9 to 20% increase in value can be realized by improved intra-row spacing at 125 mm inter-rows. Realizing the full benefit will require significant investment in precision planter technology.*
- *The commercial planters surveyed reflected the range used in industry. Generally, they were highly variable and most achieved target spacing on less than 50% of occasions.*
- *Seed is the most expensive component of pea crop production so equipment calibration, drill maintenance and good soil preparation will help maximise the return on this input.*
- *Crops that are well watered during both vegetative and reproductive growth perform the best.*
    - *The highest average total pea weight was observed under conditions of full irrigation.*
    - *Deficits in irrigation before flowering were detrimental to plant vigor, pod production and the pod characteristics that are important for yield. Negative effects could not be recovered with a resumption of watering after flowering. Irrigation was critical prior to flowering to ensure optimal pea yield.*
    - *There is strong interaction between stand density and key inputs such as irrigation. High stand densities (e.g. 120 plants per m^2) require higher inputs throughout the crop life cycle. Deficits after flowering lead to higher yields at 80 compared to 120 plants per m^2. But this is reversed with adequate irrigation is applied with 120 per m^2 yielding high than 80 plants per m^2. Inputs need to match the stand density to realise the yield potential.*
    - *Deficits in irrigation after flowering were detrimental to average pea weight per plant and the number of filled pods. There was no negative effect on the number of pods at RN1 or RN2.*
    - *For plants that were irrigated during vegetative development, continued irrigation after flowering did not produce more pods at RN1 and RN2, but it did produce longer pods with more peas.*

Irrigation after flowering maximised pea yield.

- *Physical removal of the growing tip stimulated the production of more reproductive branches but did not significantly increase plant yield in all cultivars.*
- *Herbicide application did not stimulate reproductive branching.*

Monitoring and evaluation

This final evaluation of the project's success is intended for consideration by the project team, Hort Innovation funds manager, the Vegetable SIAP, Simplot Australia staff and Tasmanian Institute of Agriculture management.

The desired outcome for this project was to contribute to the competitiveness of the industry through the discovery of new knowledge and practice that could contribute to an increase in average returns per hectare of 20% to growers within 2 years of the completion of this project. The contract criteria to assess this outcome were:

- the development of crop establishment protocols that lead to a higher probability of crops achieving the target stand density and spatial arrangement;
- increased understanding of the relationship between canopy structure and yield for the main cultivars;
- higher average returns to growers because of improved understanding of soil/plant/irrigation dynamics in relation to best practice pea establishment and growth management; and
- investment in crop planting equipment.

The following section addresses the Key Evaluation questions (KEQ's) developed as part of the project Monitoring and Evaluation Plan.

Effectiveness

From the perspective of applied science, this project fulfilled its desired outcomes as listed above, and the new information generated has increased both Simplot Australia and UTAS scientists understanding of the contribution density, spacing and plant health have on plant structure and yield. The outcomes of the research were shared directly with farmers involved in the project, field days, workshops, fact sheets and via comprehensive media coverage. One of the findings of the project was that drill performance was only partially linked to seed-drill type and largely linked to operator performance (bed preparation, drill maintenance and set-up). In this context we have not observed influence of this research on investment into planting equipment.

Table 2: Project outreach and extension activities

Year 1	**Topic**	**Date**	**Location**	**Target Audience**
Open field day	Forthside density trials	9-Nov-16	Forthside Tasmania	Growers
Industry presentation	Open precision agriculture forum, season results	30-Mar-17	Longford, Tasmania	Growers
Stakeholder meeting	Season 1 pea trial outcomes, season 2 planning	8-Jun-17	Devonport, Tasmania	Simplot Staff
Project group meeting	Season 1 pea trial outcomes, season 2 planning	23-Jun-17	Devonport, Tasmania	Pea & Bean Productivity Group
Industry presentation	Precision Pea Seeding project, fact sheet	27-Jul-17	Ulverstone, Tasmania	Simplot Growers Workshop
Year 2	**Topic**	**Date**	**Location**	**Target Audience**
Open field day	Forthside density trials	9-Nov-17	Forthside, Tasmania	Growers
Stakeholder meeting	Feedback to Hort Innovation	1-May-18	Devonport, Tasmania	Funding Body
Project group meeting	Season 2 pea trial outcomes, season 3 planning	20-Jun-18	Devonport, Tasmania	Pea & Bean Productivity Group
Industry presentation	Simplot Marketing & Roadshow event, fact sheet	25-Jul-18	Longford, Tasmania	Growers, Simplot field officers
Industry presentation	Simplot Marketing & Roadshow event, fact sheet	26-Jul-18	Devonport, Tasmania	Growers, Simplot field officers
Year 3	**Topic**	**Date**	**Location**	**Target Audience**
Open field day	Forthside density x spacing x irrigation trials	30-Jan-19	Forthside Tasmania	Growers

Table 3: Project media coverage

Year 1	Title of article	Outlet	Link
30-Aug-16	TIA and Simplot join forces in project to increase yields in Tasmanian peas	The Advocate, NW Tasmania	http://www.theadvocate.com.au/story/4130337/pea-research-project-to-increase-yield/
30-Aug-16	Increasing pea profits and production	UTAS Research website	http://www.utas.edu.au/research-admin/research-news/increasing-pea-profits-and-production
09-Nov-16	TIA opens gate to top class research	The Advocate, NW Tasmania	https://www.theadvocate.com.au/story/4282602/tia-opens-gate-on-top-class-farm-research/
Year 2	**Title of article**	**Outlet**	**Link**
04-Aug-17	Precision peas yield results	Tasmanian Country	In print
04-Aug-17	Precision peas yield results	UTAS TIA website	http://www.utas.edu.au/tia/news-events/news-items/precision-peas-yield-results
08-Aug-17	Green pea project targets increased yields for growers	The Examiner, N Tasmania	https://www.examiner.com.au/story/4841030/pea-project-yields-insight/
08-Aug-17	Green pea project targets increased yields for growers	The Advocate, NW Tasmania	http://www.theadvocate.com.au/story/4841030/pea-project-yields-insight/?cs=130
06-Sep-17	Precisely planted peas prosper	Brand Tasmania website	https://www.brandtasmania.com/agriculture-stories/?item=1344
Year 3	**Title of article**	**Outlet**	**Link**
17-Aug-18	Peas profit from good establishment	UTAS TIA website	http://www.utas.edu.au/tia/news-events/news-items/peas-profit-from-good-establishment

Process Appropriateness

The delivery of the project outcomes successfully utilised and traditional top down approach to extension, and to a lesser extent, Participatory Action Research. Participatory Action research works well in developing cultures although our experience with the process in an industrial context illustrated the difficulties growers have engaging with the experimental process due to a lack of time during the production season.

Through our experience of this project and others we note the importance of working closely with key stakeholders such as Simplot Australia staff and agronomy advisors to facilitate knowledge transfer in order to promote practice change by producers. No matter the effectiveness of the research and its communication the adoption of new technologies and practices can only be undertaken at the producer’s discretion, while scientists and extension practitioners can at best influence the decisions made by the business owners. Incorporation of new practice also includes a level of trust in the veracity of new information. We feel that the relevant, robust data provided in this project has aided in building trust and we will continue to work closely with the key stakeholders to transfer new knowledge.

Relevance of the project

The outputs of this project have direct relevance to grower profit margins, Simplot’s 2020 target of 8t/ha, Horticulture Innovations and the vegetable industry’s strategic investment plan (Outcome 3). Maximising seed germination and placement is shown in this study to captilise on the effectiveness of input costs and increases returns. The resultant increase in yield contributes to Simplot’s 2020 target whilst also increases gross margin (profit) per hectare.

Efficiency

No significant difficulties were experienced in maximising the efficiency of this project. The University of Tasmania utilises a sophisticated budgeting tool that allows for a relatively accurate estimate of the true project costs and expenditure. As such there were no budget shortfalls or restraints on the activities in the project. From a logistical perspective all trials ran to plan, apart from one field trial failure due to disease after heavy rainfall. The only significant challenges to the operation of the trial work occurred at harvest where large amounts of plant material and data were required to be gathered within a short harvest window of approximately 24-48h. This was mitigated through the employment of casual labour as necessary.

Recommendations

The outputs from the project have identified optimal conditions for plant establishment and irrigation. The following recommendations have been generated to assist the industry in achieving the yield target of 8t/ha:

- Narrow rows improve plant health and vigour: aim for planting in 125mm rows.
- Higher densities can improve gross returns: adopt a target density of 110 plants/m^2.
- Consistent intra-row spacing improves gross return and maximises the use of seed: equipment calibration, drill maintenance and soil preparation are low-cost ways to optimise establishment.
- Healthier crops prior to flowering were able to develop and retain more pods and had higher yields; reduce water stress by irrigating adequately during the vegetative growth stage.
- Irrigate after flowering to produce longer pods with more peas and increase crop pea yield.

Refereed scientific publications

None to report.

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Intellectual property, commercialisation and confidentiality

No project IP, project outputs, commercialisation or confidentiality issues to report.

Acknowledgements

We would like to acknowledge and thank Simplot Australia, the Pea and Bean Productivity Group, and the Tasmanian Institute of Agriculture (TIA) staff along with green pea growers for support, advice and assistance during the project. Working with industry is vital to the success of projects such as these, and we would like to acknowledge Leon Hingston, Jo Tubb and Peter Hardman from Simplot Australia and the numerous growers that provided access to their land, assistance and technical knowledge.

We would also like to acknowledge TIA staff Elliana Hope, Mark Boersma, Tammy Harvest, Sue Hinton, Tim Smallbon and Stephen Ives along with key staff based at the TIA Vegetable Research Facility; namely Ann-Maree Donoghue and Doug Clark and the many casual staff that thinned plots, collected, threshed and analysed samples to make this project possible.

Appendices

Appendix 1 - Detailed Methodology

1. Stand density and plant spatial arrangements

Field trials were conducted to assess the effect of stand density, spatial arrangement and irrigation on crop yield. Several trials were undertaken across three years at the Tasmanian Vegetable Research Facility (Forthside, Tasmania) and in local commercial crop sites.

All stand density and spatial arrangement field trials outlined below were consistently established with spray run and buffer areas sown at 100 plants/m^2 in 125mm wide rows. Machine planted beds were twelve metres long by two metres wide, and hand planted beds were three metres long by two metres wide. Trial plots of two metre length by one metre width were centrally positioned within these beds.

The harvest protocol and data collection were consistent across all trials outlined below. For each trial, plots were harvested at commercial maturity and samples were transported immediately to Forthside research facility for processing and data collection. All plant material within the designated plot area (2m^2) was harvested and total biomass (kg) was recorded. Samples were then processed through the viner to separate peas from vegetative material. The pea samples were washed and the total pea weight (g) from each plot was recorded. Maturity Index (MI) testing was then conducted (three measurements per sample) followed by size grading of a 500g sub-sample. Plant measurements were also recorded following harvest for the assessment of plant structure (refer to section 3).

2016/17:

In 2016/17 two trials were conducted, one at Forthside and one at a commercial crop site in Longford, Tasmania. These trials incorporated both hand and machine planting using the pea cultivars *Ashton*, *Reliance*, and *Resal*. *Ashton* and *Reliance* trials were combined in one sowing date at Forthside, while the *Resal* trial was located within a commercial crop at Longford.

For hand planted plots, spacing and density treatments were organised in three blocks using a randomised complete block design (RCBD) with five target densities (60, 90, 110, 130, 160 plants/m^2) in square arrangement. An additional plot planted at 110 plants/m^2 target density for each row spacing (125mm and 200mm) was included to enable comparison between hand and machine planted areas.

Table 4: Treatments within hand planted plots at Forthside and Longford.

Label	Spatial Arrangement	Stand Density (plants/m^2)
1	Square	60
2	Square	90
3	Square	110
4	Square	130
5	Square	160
6	125mm	110
7	200mm	110

Machine planted plots were also organised in three blocks using an RCBD arrangement with two row widths (125mm and 200mm) by five target densities (60, 90, 110, 130, 160 plants/m^2). These included an additional hand planted plot at 110 plants/m^2 target density for each of 125mm and 200mm row widths. The experimental design for the Forthside trials is illustrated below and on the following page (Table 5).

Figure 29: 2016/17 Forthside density and arrangement trials using ***Ashton*** and ***Reliance*** cultivars (supplied by Elliana Hope).

Table 5: Experimental design of 2016/17 Forthside density and arrangement trials using *Ashton* and *Reliance* cultivars.

	Mechanical Planting – *Reliance*														Mechanical Planting – *Ashton*															Hand Planting – *Reliance* (R) and *Ashton* (A)								
12m	**125** / 110	**200** / 110	**125** / 160		**125** / 60	**200** / 90	**200** / 60	**200** / 130	**125** / 110	**200** / 110		**200** / 160	**125** / 130	**125** / 90	**125** / 60	**200** / 130	**125** / 110		**200** / 60	**200** / 110	**200** / 160	**125** / 160	**125** / 90	**125** / 110		**125** / 130	**200** / 90	**200** / 110		R 6 A 4	R 4 A 6		R 2 A 1	R 1 A 5	R 5 A 7	R 3 A 3	R 7 A 2	Rep 1
12m	**125** / 160	**125** / 110	**125** / 110	*spray run*	**200** / 110	**125** / 90	**200** / 110	**200** / 130	**200** / 60	**125** / 60	*spray run*	**200** / 160	**125** / 130	**200** / 90	**125** / 130	**200** / 110	**125** / 110	*spray run*	**200** / 60	**200** / 110	**200** / 90	**200** / 130	**125** / 60	**125** / 160	*spray run*	**200** / 160	**125** / 90	**125** / 110		R 4 A 4	R 3 A 3	*spray run*	R 7 A 1	R 2 A 5	R 6 A 7	R 1 A 2	R 5 A 6	Rep 2
12m	**200** / 160	**200** / 60	**125** / 60		**200** / 90	**200** / 130	**200** / 110	**125** / 110	**125** / 130	**200** / 110		**125** / 160	**125** / 90	**125** / 110	**200** / 60	**125** / 160	**125** / 90		**125** / 130	**200** / 130	**200** / 110	**125** / 110	**200** / 90	**200** / 160		**125** / 60	**125** / 110	**200** / 110		R 7 A 7	R 2 A 1		R 6 A 5	R 1 A 2	R 3 A 4	R 5 A 6	R 4 A 3	Rep 3

Row width (mm) shown in bold type, followed by stand density (plants/m^2) for each bed. Shaded cells indicate hand planted plots.

Table 6: Experimental design of 2016/17 Longford commercial crop trial site, *Resal* cultivar.

Machine Planting – *Resal*

12 m	**200** / 110	**200** / 90	**200** / 130	**125** / 90	**200** / 60	**125** / 110	**125** / 130	**125** / 110	**200** / 110	**200** / 160	**200** / 90	**125** / 110	**200** / 130	**125** / 110	**200** / 60	**200** / 160	**125** / 130	**125** / 90
12 m	**125** / 60	**200** / 110	**125** / 110	**200** / 160	**125** / 160	**125** / 130	**200** / 110	**125** / 90	**200** / 60	**125** / 60	**200** / 130	**125** / 160	**200** / 110	**125** / 60	**125** / 160	**125** / 110	**200** / 110	**200** / 90
	Rep 1						Rep 2						Rep 3					

Hand Planting – *Resal*

1	3	6	5	2	4	7	Rep 1
4	3	6	7	1	5	2	Rep 2
6	5	2	4	7	1	3	Rep 3

Row width (mm) shown in bold type, followed by stand density (plants/m^2) for each bed. Shaded cells indicate hand planted plots.

In 2017/18 a trial was conducted at Forthside using the *Resal* cultivar. The interaction of density and spatial arrangement was assessed using five target densities (80, 90, 100, 110, 120 plants/m^2) by two spatial arrangements (125mm and 200mm rows, Table 7). Additionally, stand density was manipulated at ten commercial crop sites that were representative of the range of commercially practiced row spacing.

Table 7: Experimental design of 2017/18 Forthside trial, *Resal* cultivar.

12m	*buffer **	120	80	110	80	90	110	100	90	100	120	*buffer **	Rep 3
12m		80	100	120	90	90	100	80	110	120	110		Rep 2
12m		100	120	110	80	90	80	90	100	120	110		Rep 1

Plant density (plants/m^2) noted for each plot. Shaded cells indicate 125mm row arrangement, non-shaded cells indicate 200mm row arrangement.

In 2018/19 two trials of density, arrangement and irrigation interaction were conducted across two separate sowing dates and cultivars (August/*Reliance* and December/*Resal*). Trial 1 of the August 2018 sowing of *Reliance* incorporated three target densities (80, 100 and 120 plants/m^2), one spatial arrangement (125mm rows), and three irrigation treatments (100%, 50%, and 0% irrigation). The irrigation treatments were applied from the fourth node stage to flowering, followed by resumption of full irrigation to maturity. The flowering stage was determined to be the stage where 50% of the plants in the trial plot had flowered.

Table 8: Experimental design of 2018/19 Forthside: Sowing 1 x Trial 1 (*Reliance*)

C	*buffer **	120 (C)	100	80	100	80	120	100	80	120	100	80	120	*buffer **
B		120 (B)	100	80	100	80	120	100	80	120	100	80	120	
A		120 (A)	100	80	100	80	120	100	80	120	100	80	120	
		Rep 1			Rep 2			Rep 3			Rep 4			

Plant density per m^2 shown above for each plot, all beds planted at 125mm row width. Treatments were **A** – 100% irrigation, **B** – 50% irrigation, **C** – 0% irrigation. Full irrigation across all treatments up to 4th node and following flowering.

Figure 30: 2018/19 Forthside density and arrangement trials using the *Reliance* cultivar, 23 November 2018, supplied by Elliana Hope.

Trial 2 of the August 2018 sowing of *Reliance* incorporated three target densities (80, 100 and 120 plants/m^2), two spatial arrangements (125mm and 200mm rows), and three irrigation treatments (-100%, 50%, and 0% irrigation). Full irrigation was applied to all plots up to the flowering stage, and irrigation treatments were then applied from flowering to maturity. The flowering stage was determined to be the stage where 50% of the plants in the trial plot had flowered.

Table 9: Experimental design of 2018/19 Forthside: Sowing 1 x Trial 2 (*Reliance*)

C		**200** / 100	**125** / 100	**200** / 80	**125** / 120	**125** / 80	**200** / 120	**125** / 120	**200** / 100	**125** / 100	**200** / 80	**125** / 80	**200** / 120	**125** / 120	**200** / 100	**125** / 100	**200** / 120	**125** / 80	**200** / 80	**125** / 120	**200** / 120	**125** / 80	**200** / 100	**125** / 100	**200** / 80	
B	*buffer **	**200** / 100	**125** / 100	**200** / 80	**125** / 120	**125** / 80	**200** / 120	**125** / 120	**200** / 100	**125** / 100	**200** / 80	**125** / 80	**200** / 120	**125** / 120	**200** / 100	**125** / 100	**200** / 120	**125** / 80	**200** / 80	**125** / 120	**200** / 120	**125** / 80	**200** / 100	**125** / 100	**200** / 80	*buffer **
A		**200** / 100	**125** / 100	**200** / 80	**125** / 120	**125** / 80	**200** / 120	**125** / 120	**200** / 100	**125** / 100	**200** / 80	**125** / 80	**200** / 120	**125** / 120	**200** / 100	**125** / 100	**200** / 120	**125** / 80	**200** / 80	**125** / 120	**200** / 120	**125** / 80	**200** / 100	**125** / 100	**200** / 80	
		Rep 1						Rep 2						Rep 3						Rep 4						

Row width and plant density per m^2 shown above for each plot. **A** – 100% irrigation from flowering to harvest, **B** – 50% irrigation from flowering to harvest, **C** – 0% irrigation from flowering to harvest. Full irrigation was applied to all plots up to the flowering stage.

The second sowing in the 2018/19 season occurred in December 2018 and used the *Resal* cultivar. Trial 1 incorporated three target densities (80, 100 and 120 plants/m^2), one spatial arrangement (125mm rows), and three irrigation treatments. The treatments were 100% irrigation, 0% irrigation from fourth node stage to flowering, and 0% irrigation from fourth node stage to maturity. The flowering stage was determined to be the stage where 50% of the plants in the trial plot had flowered.

Table 10: Experimental design of 2018/19 Forthside: Sowing 2 x Trial 1 (*Resal*)

C	*buffer **	120 (C)	100	80	100	80	120	100	80	120	100	80	120	*buffer **
B		120 (B)	100	80	100	80	120	100	80	120	100	80	120	
A		120 (A)	100	80	100	80	120	100	80	120	100	80	120	
			Rep 1			Rep 2			Rep 3			Rep 4		

Plant density per m^2 shown above for each plot. **A** – 100% irrigation from 4th node to harvest, **B** – 0% irrigation applied before start of flowering, **C** – 0% irrigation from 4th node to harvest. Full irrigation was applied to all plots up to 4th node.

Trial 2 of the December 2018 sowing of *Resal* included three target densities (80, 100 and 120 plants/m^2), two spatial arrangements (125mm and 200mm rows), and 3 irrigation treatments. The treatments were 100% irrigation, 0% irrigation from flowering to maturity, and 0% irrigation from fourth node stage to maturity. The flowering stage was determined to be the stage where 50% of the plants in the trial plot had flowered.

a) b)

Figure 31: 2018/19 Forthside density, arrangement, irrigation trials using the *Resal* cultivar a) Forthside *Resal*, sowing 2, Trial 1; taken 18 January 2019 and b) Forthside *Resal* sowing 2, Trial 2; taken 28 December 2018. Supplied by Elliana Hope.

Table 11: Experimental design of 2018/19 Forthside: Sowing 2 x Trial 2 (*Resal*)

C		**200** / 100	**125** / 100	**200** / 80	**125** / 120	**125** / 80	**200** / 120	**125** / 120	**200** / 100	**125** / 100	**200** / 80	**125** / 80	**200** / 120	**125** / 120	**200** / 100	**125** / 100	**200** / 120	**125** / 80	**200** / 80	**125** / 120	**200** / 120	**125** / 80	**200** / 100	**125** / 100	**200** / 80	
B	*buffer **	**200** / 100	**125** / 100	**200** / 80	**125** / 120	**125** / 80	**200** / 120	**125** / 120	**200** / 100	**125** / 100	**200** / 80	**125** / 80	**200** / 120	**125** / 120	**200** / 100	**125** / 100	**200** / 120	**125** / 80	**200** / 80	**125** / 120	**200** / 120	**125** / 80	**200** / 100	**125** / 100	**200** / 80	*buffer **
A		**200** / 100	**125** / 100	**200** / 80	**125** / 120	**125** / 80	**200** / 120	**125** / 120	**200** / 100	**125** / 100	**200** / 80	**125** / 80	**200** / 120	**125** / 120	**200** / 100	**125** / 100	**200** / 120	**125** / 80	**200** / 80	**125** / 120	**200** / 120	**125** / 80	**200** / 100	**125** / 100	**200** / 80	
		Rep 1						Rep 2						Rep 3						Rep 4						

Row width and plant density per m^2 shown above for each plot. **A** – 100% irrigation from flowering to harvest, **B** – 0% irrigation from flowering to harvest, **C** – 0% irrigation from 4th node to harvest. Full irrigation was applied to all plots up to 4th node stage.

2. Commercial seeders and establishment practices

Benchmarking surveys of plant density and spatial arrangement were conducted in a selection of commercial crops in 2016/17, targeting a range of drill types, grower practices, soil types, and cultivars. Surveys of stand density in commercial crops were conducted by photographing plants in a 1m^2 quadrat at four randomly selected locations across each crop. Images were taken when the crop was at approximately the three-node growth stage and the number of plants within each quadrat was recorded. Crop yield for each site surveyed was later compared with average stand density.

a)  b) 

Figure 32: Quadrats laid in a commercial crop demonstrating the variability in spacing consistency across one crop. Average density: 79 plants/m^2, crop yield: 4.86 t/ha, 6 rows/m. Supplied by Elliana Hope.

a)  b)  c) 

Figure 33: Three sample quadrats laid in three separate commercial crops demonstrating the variability in drills; a) average density: 75 plants/m^2, crop yield: 5.59 t/ha, 5 rows/m; b) average density: 89 plants/m^2, crop yield: 7.14 t/ha, 8 rows/m; c) average density: 100 plants/m^2, crop yield: 8.78 t/ha, 7 rows/m. Supplied by Elliana Hope.

The surveys of plant spacing included between row and within row distances. Within row measurements were conducted by placing 5m of measuring tape along each row and noting the position of plants along the tape. Plants in every second row were measured for four rows total, and this was conducted in two randomly selected locations in each crop. Average stand density was also recorded for commercial crop sites containing trials in the 2017/18 and 2018/19 seasons.

3. Plant structure

Glasshouse experiments were conducted in 2016/17 to investigate induced stem branching. Two experiments utilised the physical removal of the apical meristem at specific growth stages; experiment 1 included removal at five stages (3, 4, 5, 6, and 8 nodes), and experiment 2 included three stages (6, 8, and 12 nodes). Physical removal of the apical meristem occurred by taking the uppermost 15mm of the primary shoot tip above the specified node stage.

A separate experiment was conducted using the application of herbicides at the five-node growth stage to damage the apical meristem and promote an altered growth response. Four pea cultivars were used in the herbicide treatment, *Ashton*, *Reliance*, *Resal* and *Columbus*. The herbicides used were Basta, Fusilade, Bladex, Tryquat and Goal. These were applied individually at the recommended rate to four seedlings per cultivar at the fifth node growth stage and observations of plant health and vigour were then recorded every second day after application.

Plant architecture surveys were conducted from a range of commercial crop sites and within trial treatments over the 2017/18 and 2018/19 seasons. In 2017/18 these sites included ten plants from each commercial crop site in the spatial density and arrangement trials, and four plants from each plot in the spatial density and arrangement trial at Forthside (three per treatment). In 2018/19 plant samples were collected from a range of plots within the four spatial density and arrangement trials at Forthside. Additionally, at nine commercial crop sites, ten plants each were collected from three randomly positioned plots of known stand densities. Crop yield data was later used to compare the architecture measurements from commercial crops and plot yield data for trial plots. All plants collected were randomly selected and representative of the median plant structure for that population. After collection, plants were transported to the Forthside Research Facility and the following measurements recorded.

Architecture protocol:

The data collection protocol recorded information on stem morphology, node specific data, pod and pea data. The stem morphology measurements taken for each plant included the number of reproductive and non-reproductive branches, and height to the first reproductive node (cm). Node specific data included the position of the first reproductive node (node number), and the number of flowers and pods on each reproductive node from the first to sixth nodes inclusive. Pod and pea data recorded were: the total number of pods greater and less than 5cm per plant; the total number of filled and flat pods per plant; length (cm) of the first two pods produced and the number of peas in each. All data was recorded by the same person across samples to achieve consistency in measurements, and any observations of disease presence or other plant characteristics relating to structure and yield were recorded.

a) 

b) 

Figure 34: Low branching stimulated by the application of the herbicide Fusilade to the apical meristem. Supplied by Elliana Hope.

Figure 35: The effect of irrigation deficit demonstrated in the figures from Sowing 2 - 2018/19 (plant architecture section). Supplied by Elliana Hope.

Appendix 2 – Precision pea project fact sheets– examples:

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Simplot AUSTRALIA

Horticulture Innovation Australia

Importance of good establishment to maximise processing pea yield

Importance of pea processing to Tasmanian growers

Each year Tasmanian vegetable growers produce approximately 24,000 tonnes of green peas from about 4000 ha for processing. Peas represent about 40% to 45% of Simplot Australia's vegetable processing factory throughput, underpinning the frozen vegetable industry.

Project Objectives

The Pea and Bean Productivity Group alongside Simplot, have set an average yield target of 8 t/ha by the year 2020. The group identified plant establishment as a focus area, as this is the foundation for achieving maximum yield. This study seeks to evaluate the effect of stand density, drill variability, spacing arrangement and branching on yield.

Why plant density and spacing affects yield

Pea plants compete for light, water and nutrients; essentially for growing space. The optimal distance between and within rows spreads resources evenly between plants. We confirmed that peas produce a maximum processing yield at ~ 100 plants m^2 across all drill configurations. At this density, when the spacing between plants is equidistant between and within rows, yield can be increased further. While we can plant on the square by hand, how close can a drill get to this? This was explored using hand planting at a density of 100 plants m^2 and an equidistant spacing arrangement to provide a baseline for maximum yield. This was compared to 13cm and 20cm machine row configurations. Pea yield was increased when hand planted at 13cm, but a smaller gain was achieved by machine. This indicates that more work is required to understand the influence of ground preparation and drill set up on establishment.

Ground preparation and drill set up determines maximum yield potential

Even emergence and establishment is the key to a high yielding crop. To germinate and emerge evenly, seed needs good soil contact, a constant planting depth and uniform moisture. Rough finish and clods in paddocks compromise depth and seed soil contact. Late emerging seedlings are easily damaged by herbicide, outcompeted and won't be mature by harvest.

We compared drill performance and found a high level of variability both across the paddock and with individual drill units. **Improving ground preparation and drill performance can increase margins by up to $750 per hectare.**

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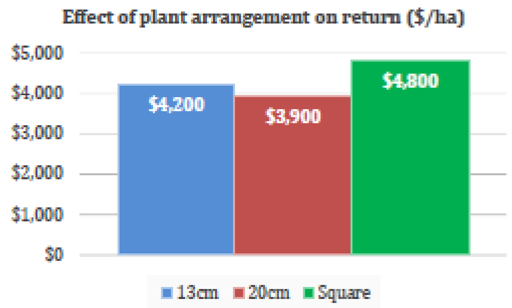
Building on the investment for maximum profit

Research by TIA has demonstrated 91% of the final pea yield is harvested from the first two reproductive nodes on the plant. This emphasises the importance of strong even plant development during this phase so that flowering and pod development occurs on all plants at the same time. Flowers and pods readily abort in response to competition, and irrigating during the flowering and pod fill phases plays a significant role in their retention to maximise yield. Applying preventative fungicides under high disease pressure can also increase returns by up to $350 per hectare.



Results from hand planted trial blocks adjusted for MI

Key message for growers

- ***Recent TIA research using Ashton, Reliance and Resal cultivars indicates when spacing between plants and within rows is equidistant at 100 plants m², gross income was maximized.***

- ***Simulating machine planting at 13cm and comparing to 20cm row spacing, demonstrated that closer row spacing (13cm) can also increase gross margins.***

- ***While still using existing commercial drills, with greater focus on distribution, uniformity of seed metering and soil preparation, achieving the 8 t/ha target is a realistic average.***

Funding recognition and project duration - Hort Innovation Australia & Simplot Australia - 2016 – 2019

Technology Transfer – Pea and Bean productivity group 06/17, and Precision Ag group 03/17

TIA is a joint venture between the University of Tasmania and the Tasmanian Government

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Plant density, spacing and health underpin green-pea returns

Key messages for growers

- Healthier crops prior to flowering were able to retain more pods and had higher yields.
- Flower and pod retention can significantly increase pea returns. Flowers and pods abort when plants are stressed.
- With a focus on establishment and prevention of crop stress, the 8 t/ha target industry average is achievable.

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Importance of pea processing to Tasmanian growers

Each year Tasmanian vegetable growers produce approximately 25,000 tonnes of green peas from about 3800 ha for processing.

Peas represent between 30-35% of Simplot Australia's vegetable processing factory throughput, and underpin the frozen vegetable industry. Australian consumers have a market preference for locally grown peas.

Project Objectives

The Pea and Bean Productivity Group alongside Simplot have set an average yield target of 8 t/ha by the year 2020.

The group identified plant establishment as a focus area, as this is the foundation for achieving maximum yield.

This study evaluates the effect of stand density, seed drill types, spacing arrangement and plant health on yield.

Row spacing affects yield

Better returns are achieved from 125mm versus 200mm row spacing at the same plant stand density.

At 125 mm the degree of competition among plants reduces as they are more evenly spaced.

Retention of flowers and pods during the reproductive phase is fundamental to realising crop yield potential.

Flowers and pods are readily aborted when the plants/crop become stressed by limited water, disease and high competition.

Crop management practices that limit crop stress are important to maximise yield.

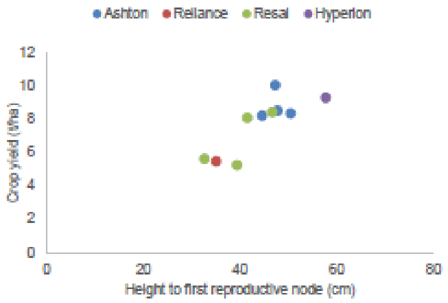

Figure 1. Relationship between the height to the first reproductive node and commercial crop yield of four pea cultivars

Higher yield from healthy plants

The length and number of pods on each of the first three reproductive nodes directly affect yield.

The structure of pea plants of the same cultivar can differ substantially both between and within crops.

Research conducted by TIA mapped key structural traits of the pea plants and compared these against harvested crop yield for commercial sites to assess how plant structure contributes to yield.

Data collected across commercial crop sites showed that increased height to first reproductive node (cm) was linked to higher crop yield (t/ha) (Figure 1).

Height to first reproductive node is determined prior to flowering and is an indicator of crop health.

The above information underlines the importance of crop health prior to flowering.

Limiting crop stress during flowering and pod-fill is also important for high yields.

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Funding recognition and project duration - Hort Innovation Australia & Simplot Australia - Precision seeding benefits for processing pea production 2016 – 2019
Technology Transfer – Pea and Bean productivity group 06/17, and Precision Ag group 08/17