Optimum density and optimum seed rate for canola in Western Australia: how important are they and what factors affect them?

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Abstract

24 canola cultivar × plant density trials were conducted in Western Australia between 2010 and 2014 and 112 individual yield-density response curves fitted. Economic optimum density was chosen as the point on the response curve where marginal return to increasing density equals the marginal cost. This depends on the following parameters: seed cost, seed size, germination percentage, field establishment (the proportion of viable seeds that become established plants), and grain price. Our best estimates of these give optimum densities ranging from 7 to 180 plants/m², with a median of 32.2. Mean optima of Roundup Ready® and hybrid triazine tolerant (TT) cultivars were 25-30 plants/m² in low and medium rainfall areas, and 25-40 plants/m² in high rainfall areas. Mean optimum density for TT open pollinated cultivars was higher, often outside the range of densities achieved in particular experiments, on account of the low cost of farm-retained seed of those cultivars. Among the parameters optimum calculations are based on grain price and field establishment can only be estimated, and the precise shape of the response curve is unknown when a crop is planted. The precise optimum cannot therefore be known. We show for a given response curve optimum density is most sensitive to seed cost and field establishment. Crop gross margin was quite insensitive to density around the optimum: when the deviation from the optimum was less than 10 plants/m² gross margin was generally reduced by less than $10/ha for hybrid cultivars, although more below the optimum than above. Density could often be reduced by up to 60 plants/m² with less than $10/ha change in gross margin for open-pollinated TT cultivars. We conclude that WA growers should aim to establish 25-30 plants/m² of hybrid canola in low and medium rainfall zones and ~35 plants/m² in high rainfall zones, aiming slightly above these targets if there is doubt about conditions for establishment. Growers planting farm-retained open-pollinated seed should aim for 50-60 plants/m² across all rainfall zones.

Keywords

Canola, optimum density, optimum seed rate, crop establishment, gross margin.

Introduction

Economic theory is ideally suited to the problem of choosing optimum densities for field crops (French et al. 1994; French et al. 2016; Roques and Berry 2016) and is easily extended to optimum seed rates. Yield-density response curves typically exhibit a diminishing returns pattern and are easily described mathematically (Bleasdale and Nelder 1960) so that economic return to increasing density is readily calculated, and the marginal cost of increasing density is also readily expressed as the extra seed required multiplied by the seed cost. However there are uncertainties associated with the response curve applying in different environments, especially in different seasons at the same location not always being the same, and with imperfect knowledge of how well seed will establish and of future prices. The contribution of these uncertainties to variation in optimum crop densities, and the economic consequences of achieving sub- or supra-optimal densities, has rarely been investigated. These issues are especially relevant to canola in Australia and elsewhere since there are large differences in seed cost between hybrid and open-pollinated (OP) cultivars and between different herbicide tolerance groups (French et al. 2016; Roques and Berry 2016), and canola establishment varies enormously under different environmental and management conditions (Brill et al. 2016; French et al. 2016; Harker et al. 2012; Harker et al. 2015). The differences in seed cost arise due to the need to purchase fresh seed of hybrid and genetically modified (GM) cultivars each season whereas non-GM OP seed can be retained by the grower from the previous season's crop. In this paper we use data from a recently published study of canola density response in Western Australia (French *et al.* 2016) to investigate how variation in these factors affect optimum density, and the economic cost of planting densities other than the optimum.

Methods

112 individual response curves were fitted to data from 24 canola density trials conducted in WA between 2010 and 2014 as described by French et al. (2016). Each trial was a factorial of cultivar and target density. Briefly, OP and hybrid cultivars from triazine tolerant (TT), Roundup Ready® (RR) herbicide tolerance groups were included in all trials, and Clearfield cultivars in some. Only TT and RR data are reported here. Cultivars representing each group were common across all trials in each year. 6 trials were conducted in low (<230 mm growing season (GS) rainfall), 12 in medium (>230 and <300 mm GS rainfall) and 6 in high (>300 mm GS rainfall) rainfall environments. Optimum density was calculated as the density where the slope of the response curve $s = (\text{seed cost (\$/kg)} \times \Delta) / \text{effective grain price}$. Δ is the seed in kg/ha required to raise density by 1 plant/m² given by $10^8 / (\text{seeds/kg} \times \text{FE} \times \text{germination})$. FE is field establishment, the proportion of germinable seed established, which along with germination is expressed as a percentage. Unless otherwise indicated we assumed 250000 seeds/kg, 90% germination, \$550 and \$505/tonne respectively for non-GM and GM canola, 70% and 58% FE respectively for hybrid and open-pollinated cultivars, and \$3, \$24, \$25, \$32/kg seed cost respectively for farm-retained OP TT, hybrid TT, OP Roundup Ready® (RR), and hybrid RR cultivars.

Results and Discussion

Optimum density was higher in high than medium or low rainfall environments and was higher for open-pollinated than hybrid cultivars (Figure 1) but varied within these categories. Mean optima of RR and hybrid TT cultivars were 25-30 plants/m² in low and medium rainfall areas, and 25-40 plants/m² in high rainfall areas. Mean optimum density for TT open pollinated cultivars ranged from 70 to 133 plants/m². Variation within a plant type is driven by response curve variation. The difference between hybrid and open-pollinated cultivars is due entirely to seed cost differences (French et al. 2016). Note predicted optimum densities for open-pollinated TT cultivars using farm retained seed were very high, often outside the range of densities observed in an individual experiment.

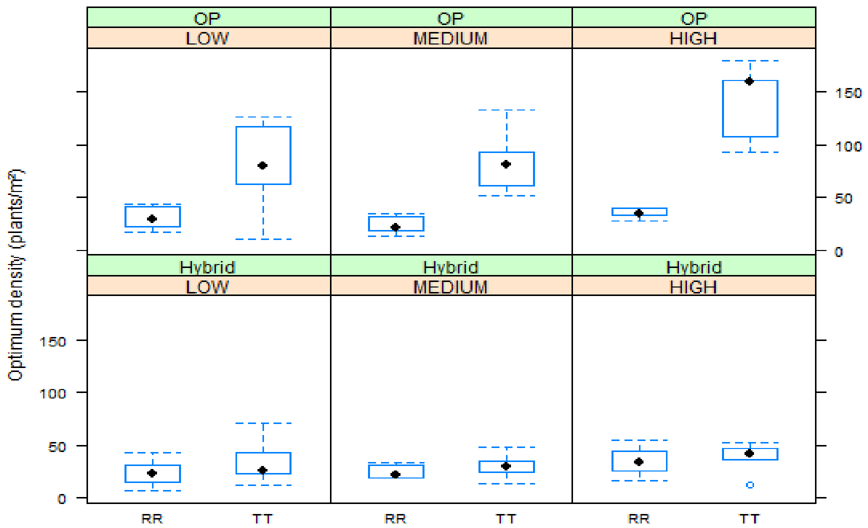

Figure 1. Box plot of canola optimum densities in low, medium, and high rainfall environments of Western Australia for hybrid and open-pollinated (OP) triazine tolerant and Roundup Ready® plant types. Centre dot represents median, margins of box 1st and 3rd quartile of the data and the extent of data outside this range up to 1.5 times the interquartile range. Open dots represent outliers. Boxplots derived from 6 values in low and high rainfall environments, and 12 in medium rainfall environments.

Other than the response curve itself, optimum density depends on seed cost, effective grain price (which includes transport costs and levies), seed size, FE, and germination %. These can all vary over a wide range: grain price has varied between about \$500 and \$600/tonne in recent years and seed cost can vary between \$3 and \$34/kg depending on whether it is farmer retained seed, open-pollinated or hybrid, and Roundup Ready® or not. The size of seed used in this series of trials ranged from 143000 to 344000 seeds/kg, with a mean of 260000, and observed FE ranged from 26 to 100%.

How seed cost and grain price affect optimum density is best shown as the effect of seed cost:grain price ratio which appears explicitly in the equation for the slope of the response curve at the optimum. At low ratios the optimum was usually high but it stabilised at ratios higher than 40 (Figure 2A). This is equivalent to $12.50/kg for seed when grain price is $0.5/kg ($500/tonne). Optimum densities fall in a much narrower range at high cost:price ratios. Thus the very high optimum densities for OP TT cultivars in Figure 1 depend on using farmer retained seed costing $3/kg and even a modest price increase, say to $6/kg which would double the seed cost:grain price ratio would reduce the optima considerably.

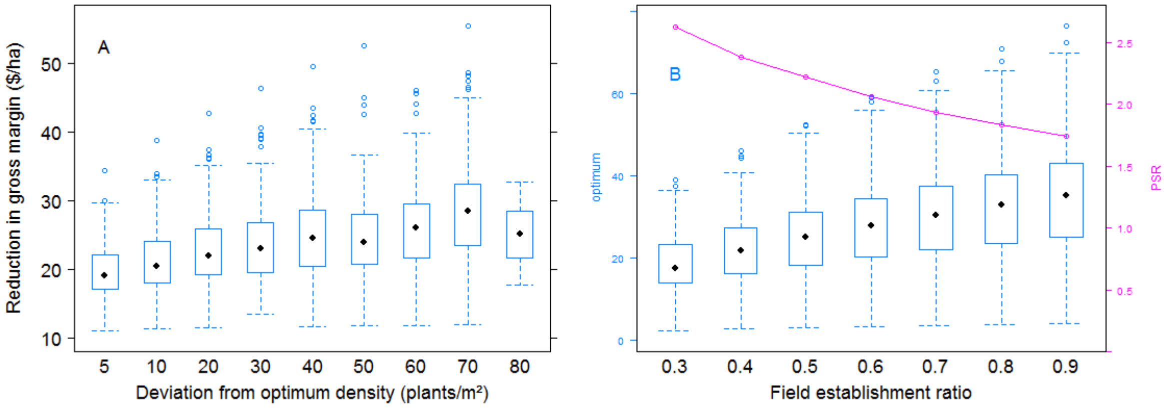

Figure 2. Box plot of canola optimum densities calculated for different seed cost:grain price ratios (A) and different values for field establishment (B). Panel B also shows seed rate (kg/ha) required for the median optimum density at each level of field establishment. These calculations assume 250,000 seeds/kg and 90% germination. Panel A assumes 70% field establishment and panel B a cost:price ratio of 50 ($25/kg for seed and $500/t for grain). Interpretation of boxplots as in Figure 1. Each boxplot is derived from 109 values.

Poor field establishment also reduces optimum density (Figure 2B) by increasing the cost of raising density. It can be thought of as equivalent to increasing seed cost. A natural response to getting fewer plants per kg of seed is to increase seed rate, so lower optimum densities in this case may seem counter-intuitive, however Figure 2B also shows the calculated seed rate required to establish the median optimum density is indeed higher at low values of field establishment.

It is impossible to know with 100% certainty what the precise optimum density for a canola crop is at sowing time. But how important is it to hit the optimum, or even to get close to the optimum? To investigate this we subtracted the predicted canola gross margin at a range of densities from the predicted gross margin at the optimum density. Figure 3 shows that gross margin generally changes by less than $20/ha for deviations from the optimum of 20 plants/m² or less. Furthermore this effect is fairly consistent between individual experiments. In the case of OP TT cultivars using farm-retained seed there was less than $10/ha penalty for undershooting the optimum by as much as 60 plants/m² in some cases. However deviating by more than 20 plants/m² from the optimum leads to larger economic penalties with hybrid and RR cultivars, especially when deviating below the optimum.

Conclusion

Canola optimum densities in Western Australian agricultural areas are generally in the range 25-40 plants/m² for hybrid varieties which translates to seed rates of 1.5 to 3 kg/ha. The precise seed rate depends on seed size and germination percentage. Open-pollinated TT cultivars whose seed can be produced on farm can have much higher optimum densities by virtue of their lower seed cost. While many of the predicted optimum densities for this plant type were outside the density range achieved in our trials and must be treated with caution we can conclude that optima are often at least as high as 60 or 70 plants/m². The large differences in seed cost for different canola plant types has implications for optimum densities, and in the case of OP cultivars that can be retained on farm optimum density is higher than for newly-purchased seed. Poor field establishment reduces optimum density but increasing seed rate is an appropriate strategy in conditions expected to give poor establishment since more seed will be required to establish the optimum under those conditions. Missing the optimum density need not lead to large economic losses. In the case of hybrid cultivars the economic penalty of missing the optimum by 10 plants/m² is generally less than $10/ha. This is a considerable margin of error given mean optimum densities for hybrids range from 25 to 40 plants/m². However we recommend aiming higher than the optimum if in doubt about conditions since economic penalties are higher for undershooting than overshooting the optimum. High densities also lead to greater competition against weeds, a benefit that is not taken into account in the optimum calculations. The case with OP TT cultivars is different since we cannot confidently give precise optimum estimates, at least when using farmer retained seed. However economic penalties for missing the optimum are much smaller than for hybrids over a wider range so aiming for densities in the range 50-60 plants/m² is appropriate.

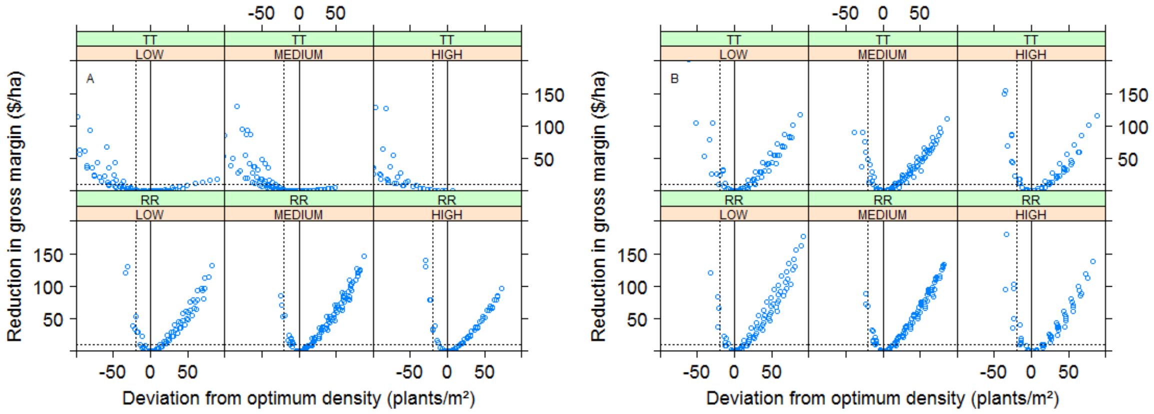

Figure 3. Effect of deviating from the optimum density on canola gross margin in low, medium, and high rainfall environments in Western Australia for open-pollinated (A) and hybrid (B) triazine-tolerant and Roundup Ready® cultivars. The dotted horizontal line shows a gross margin reduction of $20/ha and the two vertical lines show deviations of 0 and -20 plants/m² from the optimum density.

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