Optimum canola density
Bob French, Mark Seymour and Jackie Bucat, DPIRD

**Key messages**

- Optimum density to maximise canola gross margin depends on grain price, seed cost, seed size, germination percentage and field establishment.
- Open pollinated canola grown from farmer-retained seed has a higher optimum density than hybrid canola grown from new seed because its seed is cheaper.
- Deviating from the optimum by less than 10 plants/m² has a minor effect on gross margin but larger deviations can reduce it substantially.

**Introduction**

More crop plants in a unit area generally means greater economic yield. Eventually a maximum will be reached above which yield declines with further increases in density, but there is often a broad plateau where yield changes very little over a wide range of densities (Figure 1). It only makes economic sense to increase density when the extra yield is worth more than the cost of the extra seed required, so the economic optimum density occurs when the increase in revenue from raising density is equal to the cost of raising it. Crop optimum densities do not depend only on the shape of the yield-density response curves (such as shown in Figure 1) but also on other factors affecting revenue and costs associated with raising density. The most important of these factors are the price received for grain and seed cost. Seed size, germination percentage and field establishment are also important because they determine the seed rate required to achieve the desired crop density (see below).

Field establishment is the proportion of live seeds that become established plants, this can vary considerably in canola.

\[
\text{seed rate (kg/ha)} = \frac{\text{target density (plants/m²)} \times 100\,000\,000}{\text{field establishment} \times \text{seeds per kg} \times \text{germination} \%}
\]

**Figure 1** Grain yield response of open-pollinated (ATR Stingray and ATR Sturt) and hybrid (Hyola® 450TT) canola to increasing plant density at Katanning in 2013 (high rainfall, red symbols) and at Buntine in 2014 (low rainfall, blue symbols)
Our research

Between 2010-2014 we conducted 24 canola density × variety trials across the main canola production environments of Western Australia (Figure 2).

Each trial contained an open-pollinated (OP) and hybrid cultivar from the triazine-tolerant (TT) and Roundup Ready® (RR) herbicide resistance groups and some also contained imidazolinone-tolerant (IT) or Clearfield® cultivars. Yield response curves were fitted to data from these trials giving a total of 112 individual response curves. However, since RR OP cultivars are no longer available we will not consider them further in this article. We identified the optimum density for each response curve by choosing the critical point where the return from extra yield was exactly balanced by the cost of extra seed. This is a function of grain price, seed cost, seed size, germination percentage and field establishment; each depending on cultivar. The values we assumed for each are given in Table 1. For further details of how the critical slope was calculated see French et al. (2016) Crop and Pasture Science 67, 397-408.

There is a big difference between cultivar types in the critical slope, particularly between OP and other cultivars. This is mostly driven by seed cost; we assumed OP seed would be retained on farm at low cost, but fresh hybrid seed must be purchased each year which necessarily costs more. We also assumed a lower field establishment for OP cultivars based on consistent differences observed in our research. The values in Table 1 are means across all the trials in this dataset.

Results

Examples of response curves from high and low rainfall environments are shown in Figure 1. In these examples the optimum densities were 45 and 33 plants/m² respectively for ATR Stingray and Hyola® 450TT at Katanning and 36 and 26.5 plants/m² respectively for SturtTT and Hyola® 450TT at Buntine. The true optimum density for ATR Stingray at Katanning is likely to be higher than 45 but this was the highest density achieved in the trial. Table 2 summarises optimum density from these trials for OP and hybrid canola cultivars across rainfall zones, showing that optimum densities tend to be higher in better rainfall environments and are higher for OP cultivars than hybrids. While Figure 1 shows hybrids have a steeper response than OP cultivars at low density, the difference in optimum density is almost entirely due to the lower price of OP seed. The density response of RR hybrids was similar to TT hybrids so only a single category is presented for hybrids in each rainfall zone in Table 1.

Table 2 Recommended optimum densities for hybrid (RR & TT) and open-pollinated and open-pollinated canola in different rainfall regions of Western Australia

<table>
<thead>
<tr>
<th>Rainfall</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybrid</td>
<td>25-35</td>
<td>25-40</td>
<td>40-60</td>
</tr>
<tr>
<td>OP</td>
<td>30-40</td>
<td>40-50</td>
<td>50-70</td>
</tr>
</tbody>
</table>

Table 1 Assumed values for grain price, seed cost, seed size, germination percentage and field establishment (FE) for choosing optimum densities for different plant types in Western Australia

<table>
<thead>
<tr>
<th>Cultivar type</th>
<th>Grain price ($/t)</th>
<th>Seed cost ($/kg)</th>
<th>Seed size (seeds/kg)</th>
<th>Germination (%)</th>
<th>FE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT or TT OP</td>
<td>550</td>
<td>3</td>
<td>250 000</td>
<td>90</td>
<td>58</td>
</tr>
<tr>
<td>IT or TT hybrid</td>
<td>550</td>
<td>24</td>
<td>250 000</td>
<td>90</td>
<td>70</td>
</tr>
<tr>
<td>RR hybrid</td>
<td>505</td>
<td>32</td>
<td>250 000</td>
<td>90</td>
<td>70</td>
</tr>
</tbody>
</table>
Seeding

While it is possible to predict the optimum density for a cultivar in a particular environment within a broad range it is not possible to predict it precisely. It is also not possible to accurately predict what density will be achieved from a given seed rate because field establishment cannot be known until the crop has emerged. We therefore investigated how sensitive crop gross margin is to either failing to reach or exceeding the optimum. Using our standard assumptions for germination, seed size, field establishment etc. we calculated the changes in revenue and seed costs and therefore the change in gross margin for each response curve in our data set when density varied from the optimum. Figure 3 summarises these calculations.

Figure 3 presents mean changes in gross margin rather than results from individual trials so hides some detail, but we can draw some general conclusions. Deviating from the optimum by up to 10 plants/m² generally reduced gross margin by less than $10/ha but larger deviations resulted in much larger reductions. Gross margin was generally more sensitive to negative than to positive deviations from the optimum density so it is better to exceed the optimum slightly than to fall short. Deviation from the optimum had more effect on gross margin at low optimum densities (that is, hybrids in LRZ and MRZ) compared with higher optimum densities, although this is not very clear in Figure 3.
Conclusions

Optimum density for canola depends on both biological and economic factors. In Western Australia it can vary from as little as 10 to more than 100 plants/m², but generally falls in the range 25-70 plants/m².

- Optimum density is higher for open-pollinated cultivars grown from farmer-retained seed than hybrid cultivars where new seed is purchased each season. This difference is driven almost entirely by differences in seed cost, meaning the optimum density for OP canola is less if it is grown from purchased seed than retained seed.
- Optimum density is higher in high rainfall environments with good yield potential compared to low and medium rainfall environments.

- Small deviations in density from the optimum (less than 10 plants/m²) only slightly affect crop gross margin but larger deviations can have large effects. Generally, exceeding the optimum will have less effect on gross margin than falling short by the same amount.
- The appropriate seed rate to achieve a target plant density depends on germination percentage and seed size which can vary between and within cultivars so it is important to acquire and use this information. Field establishment is also important but can only be estimated.

Figure 4 Canola density trial at Buntine 2014