The response of hybrid and open-pollinated canola to the environment in southern Australia

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Abstract
Realising high yield potential of hybrid canola is strongly dependent on the environment and the profitability of hybrid technology must be assessed against open pollinated (OP) canola. This study compared the yield and gross margins of hybrid and OP canola across a wide range of environments in Western Australia (WA), and in the National Variety Trial network (NVT) across southern Australia. Hybrid canola had yield advantages over OPs in favourable environments where rainfall was high (>300 mm) and the growing season was long. However, in areas of low rainfall where yield potential was low (< 260 mm), hybrids showed little yield advantages over OPs. The gross margin analysis suggested that hybrid triazine tolerant, conventional and Roundup Ready canola was profitable in the medium and high yielding environments, but not profitable in the low yielding environments because the cost associated with seed outweighed any small yield benefit.

Key words
Hybrid, open-pollinated, gross margin.

Introduction
Canola production in Australia is moving into lower rainfall areas from its initial high rainfall zone (HRZ) heartland, and playing different roles, from cash crop in the HRZ to break crop in the low rainfall area, depending on yield potential and farming system need. Current canola cultivars offer a range of options to accommodate the needs of growers across the rainfall zones using hybrid (HB) and open pollinated (OP) cultivars with four of herbicide tolerances (HT) groups (triazine tolerant: TT; Roundup Ready: RR; imidazoline tolerant or more commonly used Clearfield: CL, and conventional: CV). OP TT canola seed is cheap (ca. $2/ha), offers robust weed control and has been widely adopted, despite the acknowledged yield penalty associated with the technology. Conversely, hybrid canola is more vigorous and weed-competitive, and can yield up to 20% more than OP cultivars in Australia and Canada (Brandt et al., 2007; Kirkegaard et al., 2012), but it is more expensive to grow as hybrid seed costs approximately $27-34/kg. Recently, canola breeding has gradually shifted from OP to hybrids because canola breeders value the income stream presented by hybrid production as seed cannot be retained by farmers. One of the important questions faced by growers is whether they should grow hybrid or OP canola, given the yield-cost trade-off and this is likely to depend upon yield potential of specific sites according to rainfall and growing season length. While hybrid canola might provide opportunities to achieve higher yield, is it more profitable at a given environment? This paper seeks to answer these questions and provide growers with guidelines to select the right varieties. It also serves to demonstrate to seed suppliers and breeders which varieties are likely to be relevant in different regions in the longer term and which direction breeding effort for canola should be focused.

Method and materials
A total of five field experiments using 19-20 canola varieties and two nitrogen (N) rates (0 and high, as appropriate for the rainfall zone) were conducted in the low (Merredin, 2014), medium (Cunderdin, 2013 and 2014), and high (Kojonup, 2013 and 2014) rainfall areas of Western Australia. Current cultivars were used, balanced by heterosis (OP and hybrid), herbicide group (TT, RR, CV and CL) and phenology as much as possible. Experiments were laid-out in a split-plot design with herbicide group as main plots to facilitate the contrasting herbicide treatments, and replicated three times at each location. The high N rate treatment increased with rainfall zone, from 80 kg N/ha at Merredin, 100 kg N/ha at Cunderdin, and 150-175 kg N/ha in Kojonup. At seeding, 20 kg N/ha was drilled as a base application, 50% of the remaining N was applied

at the six leaf stage and the other 50% at bud visible stage as urea. The seeding rates were set to achieve 40 plants m-2 based on seed weight and a *priori* germination rates. For each herbicide group, the corresponding herbicides were sprayed to control weeds. The plot size was 20 m by 1.54 m. The whole plot was harvested using a plot harvester and 1 kg of seed sample from each plot was collected to analyse oil, protein and moisture content using a calibrated FOSS Infratec. Yield was reported at 8% moisture and 42% oil content. In addition to these experiments, the NVT data from experiments in Western Australia, Victoria, New South Wales, and South Australia from 2010 to 2014 were provided by the Australian Crop Accreditation System Limited (ACAS). To minimize the effect of imbalance, only varieties tested at > 20 locations were included in the analysis. Finlay-Wilkinson (1963) analysis was used to quantify responsiveness to environment using the 2 N treatment means for each of the 5 trials to provide a total of 10 environment means from Merredin (2014), Cunderdin (2013, 1014) and Kojonup (2013, 1014) in regressions of varieties nested within heterosis and/or herbicide groups. The same Finlay-Wilkinson (1963) regression was performed on the NVT data. Residual plots were generated in both regression and ANOVA to detect errors and check for common, independent error variance. In order to estimate the gross margin of hybrid and OP systems, the yield of hybrid and OP canola was derived from the Finlay-Wilkinson linear regression equations from the NVT data. The N fertiliser input cost varied with yield while the other nutrients cost was set at $34/ha. The assumption was that 50 kg N/ha are required to produce 1 ton of canola grain. The cost of input for different herbicide systems and grain price for canola was based on current agronomic consultants' estimation. The grain price was set at $523 for CL, TT, and CV canola and $509 for RR canola. In order to make sure that breeders can recover their investment in OP canola varieties, we assumed $5/ton of end point royalty for OP canola and subtracted the end point royalty from the revenue for all OP canola.

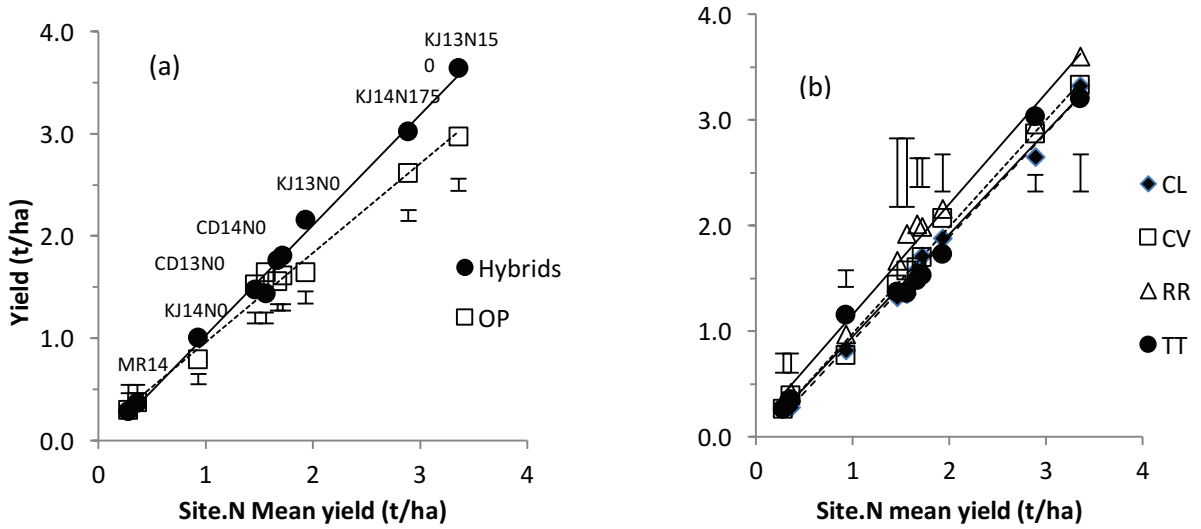

Fig. 1 The response of (a) hybrid and open pollinated (OP) canola, and (b) four herbicide systems (Clearfield: CL, conventional: CV, Roundup Ready: RR, and triazine tolerant: TT) to yield potential represented by the site.N mean yield at five site and year combinations in 2013 and 2014. The letters followed by two digits and N treatment represent the site (Kojonup: KJ, Cunderdin; CD, Merredin: MR), year and nitrogen treatment.

Results

A Finlay- Wilkinson (1963) approach of regressing hybrid and OP means against each site by year N treatment mean (e.g. low and high N means per site year) was very effective, capturing 96% of variance. The large slope differences were between hybrid (1.087±0.0018) and OP (0.883±0.03) canola (Fig.1a), with only minor cultivar differences within heterosis groups. This resulted in a fan-shaped response to site yield potential (Fig. 1a), where both heterosis groups emerge from a common yield at low yielding sites (0.32 for hybrid s and 0.33 for OPs at Merredin), and then separate as site mean yield > 1 t/ha. In contrast to the heterosis groups, there were no slope differences between the 4 herbicide tolerance groups, indicated by the parallel lines in Fig. 1b. However, RR canola had a consistent 0.2 t/ha ($P < 0.05$) yield advantage over the others (CL, CV and TT canola), captured by intercept differences in the regression.

Finlay- Wilkinson (1963) analysis was also very effective for showing national differences in canola responsiveness, capturing 94.4% of variance of NVT trials. When the data from 4 HT groups in WA, NSW,

Vic and SA were pooled, the accumulated analysis of variance showed that the heterosis group and its interaction with site and HT groups had significant effects on yield and that no interaction was observed between the state, HT and heterosis groups. Because the interaction between heterosis and HT groups was significant, we subdivided the dataset into TT, RR, CL, and CV groups for the Finlay-Wilkinson analysis. For TT and RR canola, hybrids had significantly ($P < 0.01$) greater slopes than their OPs (Fig. 2a, b). The slopes for hybrid and OP CL and for hybrid and OP CV were not significantly different (Fig. 2c, d). Both hybrid TT and RR canola had similar yields to OP canola when the site mean yield was low (<0.7 t/ha). However, as the site mean yield increased, the advantage of hybrid canola become more apparent and the responses of hybrids to environment were greater than OPs for TT and RR canola (Fig.2a, b). Although the responsive slopes were similar, hybrid CV produced higher yields than OP CV because of a significantly greater intercept difference (0.28 t/ha) (Fig. 4d). However, there was no significant difference in yield between hybrid and OP CL canola.

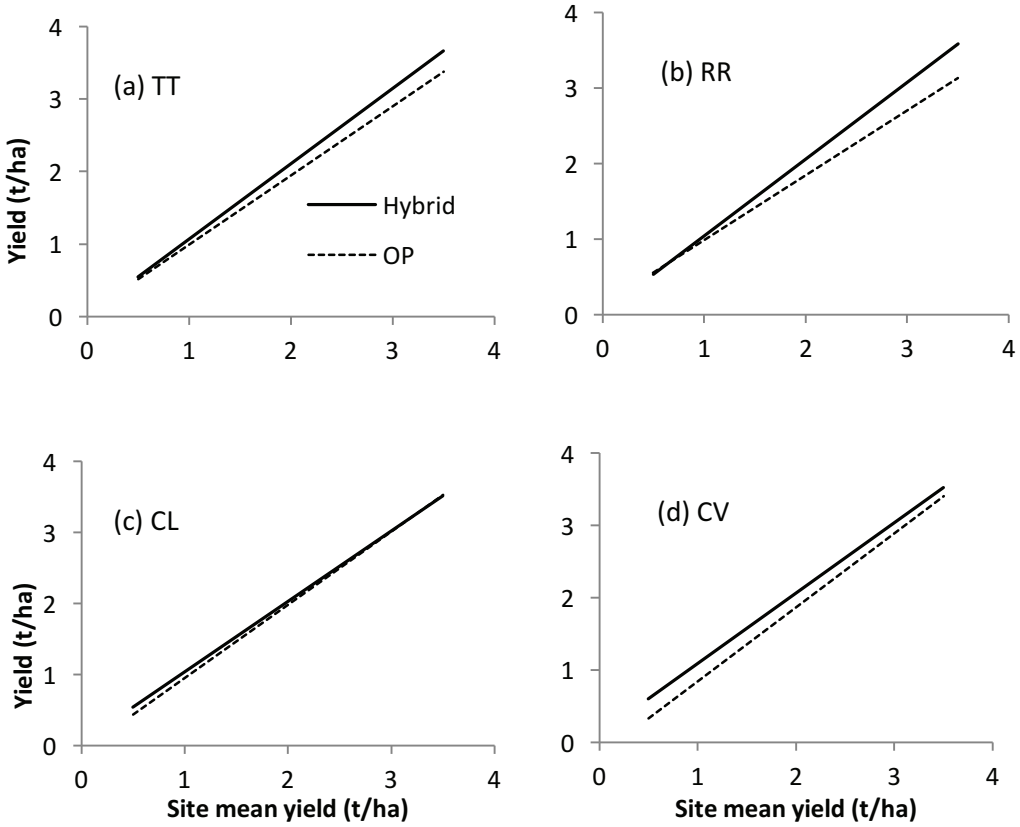

Fig. 2 Responses of hybrid and OP (a) TT, (b) RR, (c) CL and (d) CV canola to the environment in Western Australia, Victoria, New South Wales and South Australia from 2010 to 2014.

Given the fan-shaped yield responses of OP and hybrid canola, gross margins were strongly linked to yield potential: hybrid canola was profitable only when the gains from higher yield outweighed the additional seed cost. Differences in costs, value and yield responsiveness of OP and hybrid canola among the 4 herbicide groups lead to different yield-gross margin relationships (Fig. 3). In RR canola, the break-even yield between OP and hybrid was 0.7 t/ha (Fig. 3a) because OP RR canola is considerably less yield responsive than H hybrid RR canola. Conversely, the break-even mean yield was 1.3 t/ha for hybrid versus OP TT canola (Fig. 3a). For CL canola, hybrids were less profitable than OP CL canola because of similar yields and high cost associated with HYBRID seeds. Compared with OP CV, it was more profitable for hybrid (Fig. 3a) because hybrid CV always produced higher yield than OP CV (Fig. 2d). Given the prevalence of OP TT in Australian production, it is useful to set this as a standard in comparisons (Fig. 3b). Compared with OP TT canola, hybrid RR and hybrid CV become more profitable only when yield is greater than 2.4 t/ha and 1.0 t/ha (Fig. 3b), respectively, while hybrid CL is less profitable throughout the experimental yield range because of the most expensive herbicide cost among the 4 systems.

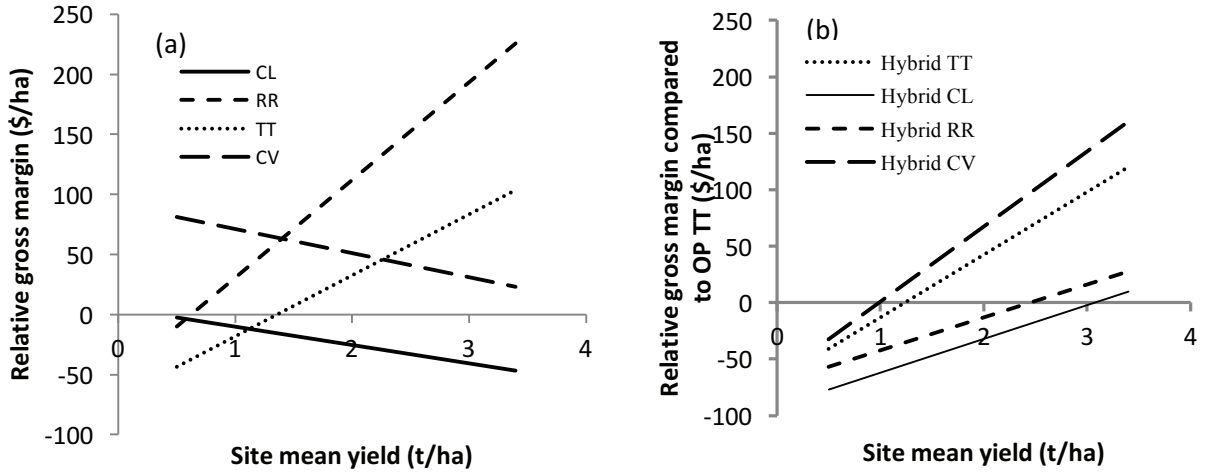

Fig. 3 The gross margin (GM) analysis of (a) hybrid canola for four herbicide tolerance groups (Clearfield: CL, conventional: CV, Triazine tolerant: TT, and Roundup Ready: RR) compared their open-pollinated counterparts and (b) hybrid canola compared to open-pollinated TT canola.

Discussion

Our study showed that the relative yield performance and profitability of hybrids over OPs strongly depends on site potential yields associated with growing season rainfall in Australia and the herbicide groups considered. This is in contrast to the consistently higher yield advantage and profitability of hybrids over OPs reported in Canada (Brandt et al., 2007). The greater yield and gross margin advantage of hybrids over OPs makes hybrids the best option in favourable environments where rainfall is relatively high (> 300 mm) and the growing season is relatively long. However, in areas of low rainfall coupled with high temperatures during the seed filling period, hybrids showed little yield advantages over OPs. The gross margin analysis suggests that hybrid RR and TT canola were profitable in the medium and high yielding environments where potential yield was high. However, they were not profitable in the low yielding environments because the cost associated with seeds outweighed the small yield benefit. This probably explains why around 80% of canola grown in Australia is still OP TT canola. This leads us to conclude that canola breeding in Australia must take into account this fact. The high potential yield and profitability of hybrid canola in favourable high rainfall areas will require canola breeding companies to use the advantage of heterosis to breed hybrid canola. However, the low profitability of hybrids in the low rainfall areas suggests there will be little market for hybrids and requires them to continue to embrace OP TT canola. The departure from breeding OP canola raises the necessity to restore the end point royalty system that allows breeders to recoup their investment. The end point royalty system has been very successful for wheat breeding. Whether an end point royalty system will work in canola is still in question because a much smaller area of canola (20% of wheat area) is grown. Furthermore, farmers can purchase a small amount of OP canola seed and grow them in nursery to produce seeds for next few seasons without need to purchase seeds every year. This makes the end point royalty system much more attractive to breeding companies.

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