Adaptation of winter canola (*Brassica napus*) for grain and dual-purpose use in Australia's high rainfall zone

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Abstract

We conducted grazing and defoliation experiments at high rainfall sites in the ACT, NSW and SA to investigate the adaptation of later-maturing winter (W) and winter x spring (W-S) canola (*B. napus*) varieties for grain and dual-purpose use. The W and W-S varieties, not commercially available in Australia, out-yielded currently available late-spring (S) varieties for the earliest sowing times (March/early April) and provided more forage for grazing sheep. Yield variability of the longer-season types (from 5 t/ha to crop failure) warranted further risk analysis (sowing opportunities, frost and heat risk) using the APSIM Canola model parameterised for W varieties using growth and development observations made during the experiments. Based on the experimental results and simulation, it appears there is scope to develop longer-season varieties for dual-purpose grazing and grain production to capitalise on early sowing opportunities in Australia HRZs.

Key Words

grazing crops, feed-gap, mixed farming, forage rape, feed-base

Introduction

In Australia, *Brassica napus* has been utilised as an autumn-sown oilseed crop (canola) using spring-types with little vernalisation requirement, or as spring-sown forage crops (fodder-rape) using winter types with high vernalisation requirements (not harvested for grain). The potential to develop *B. napus* as a dual-purpose crop, grazed in winter and harvested for oilseed, has been investigated in Australia since 2004. Growers in medium-rainfall areas of southern NSW have successfully adopted a system utilising commercially available spring varieties sown 2-3 weeks earlier than normal (from mid-April) and grazed in early winter prior to bud elongation, with minimal impact on final yield or oil content (Kirkegaard *et al.,* 2008a) (Figure 1). The feasibility of utilising later-maturing winter varieties in cooler, long-season HRZ areas was also demonstrated in field experiments near Canberra ACT, where the later maturity provided opportunities for earlier sowing, a longer grazing period, and higher yield potential of both grazed and un-grazed crops (Figure 1) (Kirkegaard *et al.,* 2008b).

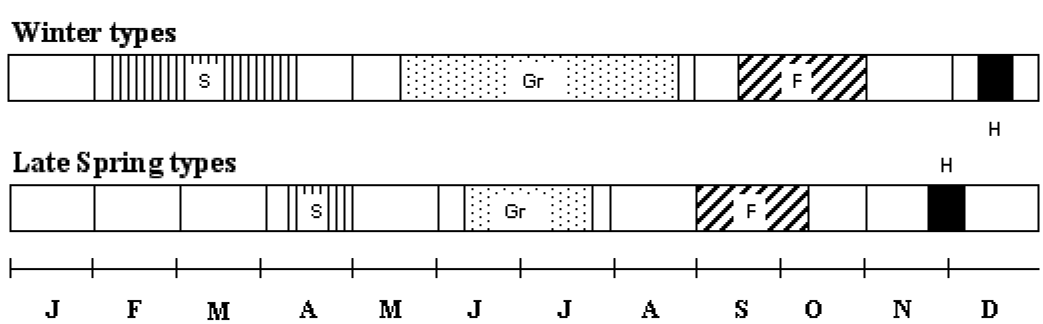

Figure 1. Timing of sowing (S), grazing (Gr), flowering (F), and harvest (H) windows for late-spring dual-purpose canola as currently adopted, and early-sown winter canola in high rainfall zones.

Australia has an estimated 6M ha of arable land in high rainfall zones (HRZs) distributed across several southern States where later-maturing crops may be well adapted (Zhang, 2007). The area of dual-purpose milling quality wheat expanded rapidly in these areas following their release in 2006 (Virgona *et al.,* 2006) and cropping continues to advance into higher rainfall districts of southern and eastern Victoria (Riffkin *et al.,* 2007). Intensive cereal production in sequence with grass-based pastures in these areas can lead to disease and grass weed problems, and a broad-leaf dual-purpose crop with high grain value such as canola, would increase profitability and flexibility of the mixed farming system (Kirkegaard *et al.,* 2008b). We compared the performance of later maturing winter (W) and winter x spring (W-S) canola varieties with currently available late-spring (S) varieties in defoliation and grazing experiments in ACT, SA and NSW and used simulation and climate risk analysis to assess the potential advantages of these varieties in the HRZ.

Methods

A collection of 36 canola (*Brassica napus*) lines including a range of maturity types (W, W-S, S) were previously screened in 2007 for their dual-purpose suitability in defoliation experiments at Canberra, ACT and Naracoorte, SA (Kirkegaard *et al.,* 2008a). We present data for a selected set of best-performing hybrid lines from those experiments, and subsequent grazing experiments to exemplify the performance of the different phenology types (W - Taurus; W-S - CBI406; S - 46Y78) under different HRZ environments.

Defoliation experiments. Defoliation experiments were conducted in Canberra (2007) and Naracoorte (2007, 2008). The canola was sown on two dates generally within the early sowing window for each site. The experiments were arranged as split-split-plot design in 3 blocks, with entries randomized within sowing time main plots, and individual plot size was 2 m x 12 m. Defoliation treatments were imposed on one half of each plot in mid-winter using a forage harvester to cut and remove green biomass to a height of ~10cm. Measurements included plant establishment, biomass at, and removed by defoliation, timing of key phenological stages and grain yield using bordered quadrat cuts (0.4 – 0.8 m^2).

Grazing experiments. In Canberra (2007, 2008) and Young, NSW (2008) the same lines were assessed in replicated plots established in larger commercial paddocks using temporary fences to control the grazing time and intensity. Grazing was managed according to the guidelines emerging from previous studies (Kirkegaard *et al.,* 2008a,b) which suggested grazing prior to bud elongation >10cm (i.e. avoiding bud removal) minimized yield penalties related to grazing. The experiments compared W and S types sown within appropriate sowing windows for each type to facilitate grazing and minimize yield loss. A similar set of plant measurements was conducted as for the defoliation experiments.

Simulation and climate risk analysis. The APSIM canola model (Keating *et al.,* 2003) was used to predict crop growth and development in relation to important climate drivers such as sowing opportunity and the risk of frost and heat stress in different HRZ environments. Phenological parameters for W and W-S varieties were developed which captured the observed differences in crop development at the 3 sites. We then conducted a preliminary analysis of the timing of key crop growth stages in different HRZ areas which were considered in relation to the risks of sowing opportunity (25mm over 5 days), frost and heat stress to predict yield outcomes. The simulation analysis involved a factorial combination of 3 sites (Young, Canberra and Naracoorte) and their 3 relevant sowing dates (33%, 50% probability of a sowing opportunity, and the typical sowing date for spring canola) and 3 cultivars (W, W-S, S). Simulations were run for 110 years (1900 to 2009) using local Patched Point climate data and soils parameterised using local soil description. Key phenological dates (bud-visible, flowering and maturity) and biomass and yield at these dates were reported. Frequency of light frost (<2^oC), heavy frost (<0^oC) during early grain-filling (140 to 500 degree-days after start of flowering) and heat stress (>29^oC during period of 630 degree days after start of flowering) were determined.

Results

Defoliation experiments. In 2007, all varieties and sowing times were cut on the same date, planned to co-incide with the predicted end of the grazing window. In Canberra, the W canola had a clear yield advantage from early sowing and there was very little impact of defoliation as it was cut at BV stage and flowering was not delayed (Table 1). The undefoliated W-S and S canola had lower yield and a significant yield penalty when defoliated, associated with significant delays in flowering. Dry spring conditions in 2007 (60% of LTM) exacerbated the impacts of delayed maturity on yield. In S2, the yield of undefoliated crops was similar among maturity types, however the delay in flowering associated with defoliation again reduced the yield of the W-S and S varieties, but not the W canola.

Naracoorte is a more Mediterranean environment with a later sowing window than Canberra. In 2007, ideal growing conditions throughout the season generated good yields in all maturity groups in undefoliated treatments. Consistent with the Canberra results, the longer maturing W variety out-yielded the other varieties on both of these early sowing dates. There was less impact of defoliation on yield for all varieties at this site in 2007, presumably as a result of the earlier developmental stage at which cutting occurred (flowering duration data not available). In 2008, a later autumn break delayed sowing, and winter waterlogging and a dry spring generated less favourable conditions for crop growth and recovery after defoliation. Under these conditions the W varieties yielded poorly due to later flowering, while the W-S and S varieties had similar yield when undefoliated. In 2008 at Naracoorte, each variety was defoliated at the same developmental stage (bud visible) so the W types were defoliated later in the season than earlier types. The later sowing and drier spring conditions (44% LTM) generated significant yield reductions associated with relatively short flowering delays caused by defoliation in the W-S and S varieties in 2008.

Table 1. Effect of defoliation or grazing on flowering time and yield of winter (W), winter x spring (W-S) and late-spring (S) canola varieties at three sites in SE Australia

Site	Year	Sow	Var.	Graze/Cut			Flowering window		Yield (t/ha) (sem)	
				Time	dse.d/ha	Stage	UD	D	UD	D
Canberra	2007	21/3	W	13/8	Cut	BV	15/9-19/10	15/9-19/10	4.0 ? 0.2	4.0 ? 1.0
			W-S	13/8	Cut	BE30	17/8-11/10	9/9-19/10	3.1 ? 0.3	1.6 ? 0.3
			S	13/8	Cut	Fl-P	26/7-28/9	9/9-14/10	2.6 ? 0.4	1.2 ? 0.1
		5/4	W	13/8	Cut	BV	15/9-17/10	18/9-19/10	3.0 ? 0.6	3.6 ? 0.5
			W-S	13/8	Cut	BE20	2/9-14/10	19/9-19/10	3.2 ? 0.8	2.2 ? 0.1
			S	13/8	Cut	BE50	13/8-6/10	10/9-17/10	3.3 ? 0.2	1.5 ? 0.2
Narac'te	2007	17/4	W	23/7	Cut	V	18/8	NM	2.9 ? 0.2	2.6 ? 0.3

			W-S	23/7	Cut	V	2/9	NM	2.0 ? 0.1	1.9 ? 0.1
			S	23/7	Cut	BE45	12/8-22/9	NM	2.4 ? 0.3	1.9 ? 0.1
		1/5	W	23/7	Cut	V	20/9	NM	2.9 ? 0.1	2.4 ? 0.2
			W-S	23/7	Cut	V	9/9	NM	2.7 ? 0.1	2.8 ? 0.3
			S	23/7	Cut	BE20	20/8-2/10	NM	1.7 ? 0.1	2.3 ? 0.2
	2008	12/5	W	17/9	Cut	BV	28/9-30/10	3/10-8/11	0.7 ? 0.2	0.8 ? 0.1
			W-S	5/9	Cut	BV	22/9-28/10	27/9-2/11	2.6 ? 0.5	1.6 ? 0.1
			S	12/8	Cut	BV	31/8-17/10	11/9-23/10	2.1 ? 0.4	1.3 ? 0.1
		2/6	W	25/9	Cut	BV	3/10-11/11	8/10-10/11	0.6 ? 0.1	0.4 ? 0.1
			W-S	10/9	Cut	BV	25/9-2/11	26/9-31/10	1.8 ? 0.5	1.2 ? 0.1
			S	5/9	Cut	BV	15/9-22/10	20/9-25/10	1.5 ? 0.3	0.9 ? 0.1
					Grazing experiments					
Canberra	2008	3/4	W	24/6-1/9	1088	BV	20/9-21/10	22/9-24/10	3.1? 0.1	3.0 ? 0.1
		23/4	S	8/8-14/8	174	BE10	4/9-15/10	8/9-20/10	2.8 ? 0.1	2.2 ? 0.2
	2008	4/4	W	1/7-27/8	1087	BV	20/9-25/10	20/9-25/10	5.0 ? 0.5	4.5 ? 0.5
		21/4	S	10/7-8/8	800	BE5	5/9-15/10	18/9-24/10	4.8? 0.25	4.9 ? 0.6
Young	2008	7/4	W	16/6-3/8	1555	V	22/9-	23/9-20/9	5.0 ? 0.2	4.6 ? 0.2

					19/10			
16/4	S	2/7-30/7	700	BE30	25/8-7/10	1/9-13/10	4.7 ? 0.3	4.9 ? 0.1

V=vegetative; BV=bud visible; BE10=bud elongated 10cm; UD=un-defoliated; D=defoliated; NM=not measured

Grazing experiments. At both sites in 2008, early-sown winter varieties and later sown spring varieties generated similar grain yield when not grazed and there were only minor impacts of grazing on yield when it was well timed according to the growth stage for each variety (Table 1). However, the major benefit for the winter types was the significantly longer grazing window and higher grazing intensity (and hence animal production) made possible by the earlier sowing and higher vegetative biomass produced prior to winter.

Simulation and risk analysis. The new phenology parameters provided good prediction of flowering time (RMSD = 3d) and yield (RMSD = 0.6 t/ha) for the experimental data sets. The simulation analysis showed S canola reached the close of the grazing window (just before bud-visible) 16 to 46 days faster than W canola (range is for Naracoorte S3 to Young S1), while W-S canola and other sowing dates fell within this range. As a result of the earlier close of the grazing window, biomass for grazing was reduced for S compared to W canola by 1.7-2.2, 1.9-2.3, and 0.9-1.5 t/ha at Young, Canberra and Naracoorte, respectively. Although the grazing window closed later for later sowings, the period from sowing to bud-visible was shorter and potential biomass for grazing was reduced. Generally, biomass was highest at Canberra and lowest at Naracoorte where the shallow soil limited crop productivity. Flowering was also delayed with later sowing and was later for W than S canola. Within the sowing windows investigated, heat-stress risk was negligible at all sites. Frost risk for early sown S canola (late July at Young – late August at Naracoorte) was significant during early grain-filling (average 16 frost days in the critical period at Canberra to 8 at Naracoorte). Frost risks were substantially reduced with later sowing (6 to 9 days for S2) and for the later-flowering W cultivar (2-3 days only). Long-term simulations predict median yields across the 3 sowing times of 3.7, 3.6, and 2.5 t/ha at Canberra, Young and Naracoorte respectively. There was no yield advantage of early-sown W canola over S canola sown in the later (normal) sowing window at Canberra or Young, and only a small benefit (2.7 cf 2.3 t/ha) at Naracoorte.

Discussion

The advantage of early-sown, longer-season canola varieties for dual-purpose use in these HRZ areas has been clearly demonstrated in these experiments, consistent with the long-established principles for dual-purpose cereals. Currently available spring canola varieties sown early (March in NSW, or mid-April in Naracoorte) were prone to high frost risk if un-grazed, or to significant yield penalties if grazing occurred after bud elongation. Although well-timed grazing of early-sown spring varieties could potentially be used to delay flowering into the appropriate window to avoid frost (Kirkegaard *et al.,* 2008a), success would require very careful grazing management to facilitate crop recovery. The flexibility provided by a wide early sowing window, the longer safe grazing period, and the demonstrated capacity for good yield recovery (as proposed in Figure 1) has been clearly demonstrated for the longer-season types in these experiments. There was little evidence of yield penalties associated with not grazing these early-sown W varieties, even when compared with un-grazed spring varieties sown at normal sowing window. This robust performance of W types is similar to that reported at Hamilton by Riffkin *et al.* (2007). Given the varieties tested in these experiments are unadapted, imported European lines, there seems good scope to develop and make available a long-season dual-purpose canola option for mixed farms in Australia's HRZ, although herbicide tolerance options may be a useful further development for success.

Despite the advantage of the longer-season types from the early sowings, the un-grazed Australian spring variety performed surprising well at sowing times normally considered too early for canola in these areas (early April in Canberra, late April in Naracoorte). Indeed there was little difference in the un-grazed experimental yields between the W canola sown in early April and S canola sown in mid-April in the

Canberra and Young grazing experiments, an outcome supported by the simulation experiment over 100 years of historic weather data at the sites (yield 3.7 t/ha). Notwithstanding the somewhat elevated frost risk, these data suggest that earlier sowing times may be appropriate for grain-only current spring varieties.

Conclusion

These experimental and preliminary simulation results suggest there may be scope for commercial production of longer-season W and W-S maturity types for dual-purpose and grain production in some HRZs in Australia. The specific advantage of the longer-season types was most obvious from early sowing opportunities at each site (March and early April) where the yield of both grazed and un-grazed crops was equal to, or exceeded that of currently available late-spring varieties. Further work is warranted to determine the likely areas where such varieties may have potential as part of a mixed farming system.

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