Potential for dual-purpose crops in Australia's northern crop-livestock regions

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Abstract

The potential to expand the use of dual-purpose cereals and canola from traditional areas (e.g. southern NSW) into Australia's northern cropping region was investigated using experiments and simulation. Preliminary simulation and climate analysis at 3 locations in the high rainfall zone of the northern cropping region (Quirindi, Pittsworth and Armidale) showed early-sowing opportunities (mid-March to early-May) occurred regularly at these locations (65-80% of years). Winter wheat and canola sown early during March and April had similar simulated mean yield potential to spring varieties sown later, but provided an average of 80-100 days of grazing during the 'safe' grazing window prior to stem elongation. Experiments in 2010/11investigated the impact of cutting/grazing times on grain yield and phenology for a range of winter and spring canola and cereal phenology types sown early or in the normal window. Grain yields of spring canola and cereals were significantly reduced (up to 60%) by early defoliation in the reportedly "safe" phenological window, presumably due to shorter recovery time from the end of grazing to flowering in northern regions. Refinements to current grazing recommendations may be required to avoid yield penalties. Long-season, dual-purpose winter cereals and canola sown early had the potential to yield the same or more than spring varieties sown in the 'normal' window, suggesting there may be potential for these crop phenology types in the higher rainfall zone of the northern region.

Introduction

The success of dual-purpose cereals and canola in southern Australia has prompted interest in the opportunities to expand this practice into other regions of Australia's mixed crop-livestock zone (Moore 2009; Kirkegaard *et al.* 2012). In the northern crop-livestock region (i.e. northern NSW and southern Queensland) small areas of dual-purpose crops are regularly sown in some areas and tactically in some seasons, but there are a number of advantages to increasing their use. First is the ability to capitalise on early sowing opportunities (e.g. March to April) to sow longer season varieties and/or use grazing to manipulate phenology to ensure flowering remains in the appropriate window. Second, grazing could be used for canopy management to slow early season crop water use and ensure more water is available for the vital grain filling period. Third, forage-only crops (e.g. oats) could be replaced or complimented to provide feed during June – August, when pasture growth and quality is often low. Finally, in current livestock-dominated systems on the northern tablelands and slopes, dual-purpose crops could provide break-crop options to control problematic weeds and allow pasture improvement to occur more easily. This paper summarises some recent investigations of the potential to expand dual-purpose cereals and canola into new regions of the northern higher rainfall zone.

Methods

Plant opportunity analysis

The frequency of early sowing opportunities and associated risk of establishment failure was investigated at 4 locations in a south-north transect of the high rainfall regions of the northern cropping zone (Gulgong, Quirindi, Armidale, Pittsworth). Long-term climate records (1889-2010) obtained from the SILO database were analysed for occurrences of sowing opportunities during fortnightly intervals, from 1 February to 30 June. A sowing opportunity was defined as rainfall exceeding pan evaporation over a 7 day period (Unkovich 2010). Risk of crop establishment failure due to a false break was calculated as the percentage of sowing opportunities in that 'sowing window' where further effective rain (rainfall > evaporation over 7 days) did not occur in the following 6 weeks.

Preliminary simulation analysis

Using APSIM Wheat and Canola, crops were simulated over 50 years (1959 to 2009) using local Patched Point climate data from the SILO database and soils parameterised using local soil descriptions for 3 of the locations in the HRZ of the northern cropping zone. A factorial of cultivar-phenology types for both wheat and canola (representing a winter, facultative winter, late spring and early spring type) and sowing times at 2-weekly intervals from 8 March to 28 June were used to derive a match of crop phenology and sowing time

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to the optimal flowering time (lowest risk of heat and frost). In all simulations soil water content was set to 60% of plant available water on 1 February each year and allowed to vary thereafter according to historical rainfall. To elucidate a full range of simulation outcomes for different sowing dates in all years, the top 30 cm was assumed wet to field capacity on the specified sowing dates to ensure crop establishment. Plant density was set at 150/m^2 for wheat and 60/m^2 for canola. Soil mineral N content (to 1.2 m) at sowing was 150 kg N/ha for wheat and canola. An additional topdressing of 50 kg N/ha at Zadok stage 31 in wheat and 100 kg N/ha at bud elongation in canola was assumed. Grazing was simulated with 25 DSE/ha beginning when > 1.5 t DM/ha was available and finishing when the crop reached GS30/bud elongation or < 0.4 t DM/ha was present. Frost and heat events were used to calculate a cumulative stress factor to correct grain yield for these stresses (details in Table 1).

Field experiments

Three field experiments in 2010 and 2011 compared grain yield for a range of cereal and canola cultivars varying in phenology when sown early (early-mid April) or late (in the normal window of mid-late May) and when grazed/mown or left un-defoliated. In all experiments, grazing/mowing was not optimised for each phenology type – it occurred at the same time for all cultivars for each time of sowing and hence will have been later or earlier than recommended for some varieties. Defoliation corresponded with bud emergence in canola or GS30 in wheat for the longer-season varieties sown early, and the short-season varieties sown later. Grain yield was determined from 1 m^2 quadrats per plot, which were oven dried and hand-threshed.

Results

Sowing opportunity analysis

Early sowing opportunities occur regularly at the 4 locations tested in the northern cropping zone, with a sowing opportunity in > 25% of years in any fortnightly window from February to June (Fig 1). Over the period from mid-March to end of April the frequency of years with a sowing opportunity was 80% at Armidale, 70% at Gulgong, 65% at Quirindi and 60% at Pittsworth (data not shown). The risk of a 'false break' was highest at Quirindi and Pittsworth when sowing before April, with >25% of these sowing opportunities followed by little effective rain. Overall, this suggests there are many early sowing opportunities that could be exploited if grazing in combination with appropriate phenology were used to ensure flowering does not occur during periods of high frost risk.

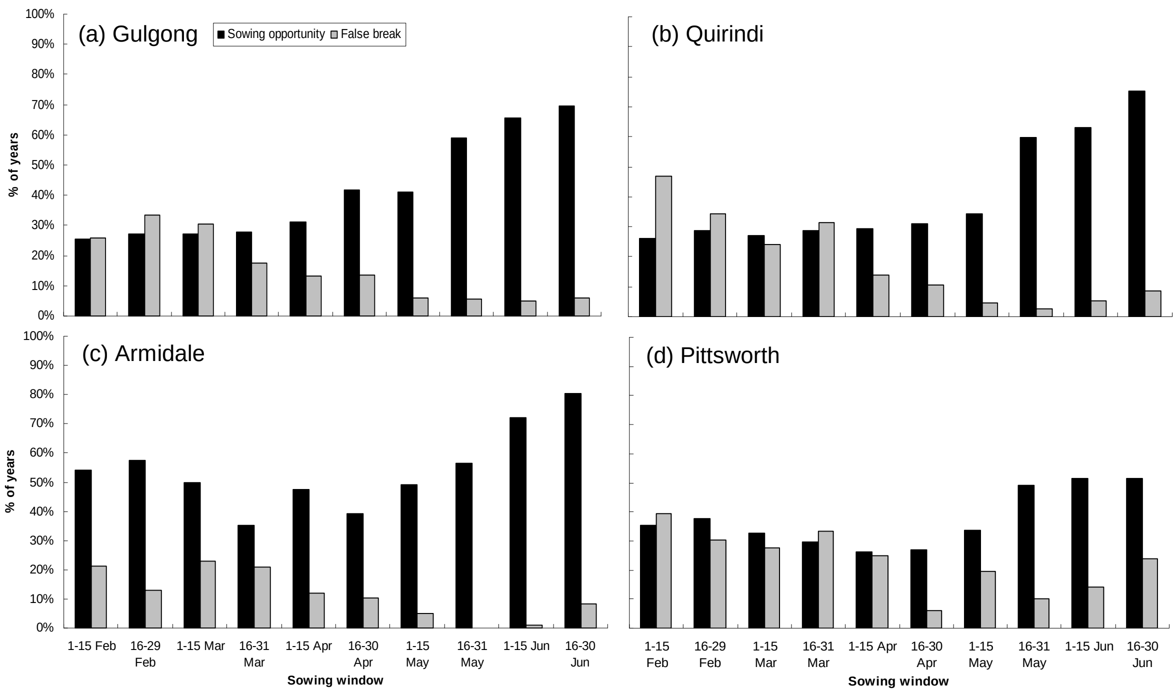

Figure 1. Frequency of years with a sowing opportunity (i.e. rainfall > pan evaporation over 7 days) and the likelihood of a false break i.e. no further effective rain in the subsequent 6 weeks for fortnightly sowing windows at 4 locations in the high rainfall areas of the northern cropping zone

Preliminary simulation analysis

For the 3 locations, simulated average potential grain yields for early-sown winter-type varieties were >4.7 t/ha for wheat and > 3.6 t/ha for canola. Yields are likely to be 0.7-1.0 t/ha lower than this if frost and heat stresses are accounted for. An additional early season grazing for 77-100 days from wheat (i.e. 1900-2500 DSE.days at 25 DSE/ha) and 50-75 days from canola (i.e. 1200-1900 DSE.days at 25 DSE/ha) could be obtained prior to stem elongation in these environments (Table 1).

Table 1. Simulated average grain yields and number of days of grazing in the 'safe' window (i.e. between 1.5 t DM/ha and GS30/bud elongation) that could be obtained from early sown (Mid March to late April) winter wheat and canola at 4 locations in the high rainfall areas of the northern cropping zone

Location	Wheat			Canola		
	Potential yield (t/ha)	Frost-heat limited yield (t/ha) [A]	Days of grazing	Potential yield (t/ha)	Frost-heat limited yield (t/ha) [A]	Days of grazing
Quirindi	4.7-4.9	4.0-4.1	79-92	3.8-3.9	2.8-3.1	55-75
Armidale	5.3-5.6	4.4-5.2	77-109	4.0-4.1	2.9-3.1	50-75
Pittsworth	4.8-4.9	3.9-4.1	79-92	3.6	2.4-2.8	53-75

[A] Mild (32-34^{o}C max.), moderate (34-36^{o}C max.) and severe (>36^{o}C max.) heat stress between start of flowering and early grain fill reduced yield by 15, 40 and 70% in canola and 10, 20 and 30% in wheat. Mild (0-2^{o}C min.), moderate (-2-0^{o}C max.) and severe (<-2^{o}C max.) frost between during flowering and early grain fill reduced yield by 1, 2 and 10% in canola and 10, 20 and 90% in wheat.

Field experiments

All experiments had exceptional growing seasons and produced above average yields for these environments in un-defoliated treatments. The early-sown canola at Warialda had a variable establishment (10-15 plants/m^2) due to little follow-up rain after sowing. The late-sown crops at Armidale also were slow to establish due to cold, wet weather following establishment. These are both real risks with these sowing times in these environments.

In general, the shorter season canola varieties yielded more than the longer-season varieties irrespective of sowing time (Table 2). The exception was at Armidale where long-season winter types had higher yields than the spring types when sown early, and this was reversed in the later sowing. The strongly winter cultivars (CBI406, Taurus) were very late to flower at Warialda and did not produce sufficient grain to warrant harvesting despite the favourable season. Un-grazed spring varieties (Hyola 76, Hyola 50, 46Y78 and Garnet) all yielded more when sown later in mid-May than when sown early (Table 2). Later-sown crops had similar maturity biomass, but had higher harvest indices, suggesting that frost or other stresses may have reduced yield in these varieties when sown early. At Gunnedah in 2010, later sowing had higher yield potential in all varieties, mainly due a higher HI in later sown crops. At Warialda, crop biomass was much higher in earlier sown crops but there was little difference in yield because early-sown crops had lower HI (0.15-0.17) than the later-sown crops (0.25-0.36).

Table 2. Grain yield (t DM/ha) of ungrazed and grazed canola varieties varying in phenology (shortest season type at top) when sown early and late (normal) at three locations in northern NSW

Site	Early sown			Late sown		
Variety	Un-grazed	Grazed	Δ Yield	Un-grazed	Grazed	Δ Yield
Gunnedah 2010 [A]		*21 Apr*			*17 May*	
Hyola 76	1.9	1.8	-0.1	4.5	1.9	-2.6
Garnet	2.8	1.8	-1.0	3.5	2.4	-1.1
46Y78	2.5	1.5	-1.0	3.1	1.2	-1.8
CBI406	1.2	1.5	+0.3	2.4	1.6	-0.8
CBI306	0.7	1.0	+0.3	2.4	1.7	-0.6
Taurus	0.8	0.8	0.00	1.2	1.7	+0.5
Armidale 2011		*7 Apr*			*17 May*	
Hyola 50				3.9	1.9	-2.0
46Y78	3.8	2.5	-1.3	4.4	1.6	-2.8
CBI406	5.4	2.7	-2.7	3.6		
Taurus	4.4	3.3	-1.0	3.4		
Warialda 2011		*7 Apr*			*22 May*	
Hyola 50	4.0	4.4	+0.4	3.7	4.1	+0.4
46Y78	1.4	5.7	+4.3	2.4	4.3	+1.9
CBI406		3.2				
Taurus		2.1				

[A] mowing was used instead of grazing.

In canola, grain yield response to grazing ranged from a 0.5 t/ha increase in yield to a 2.8 t/ha reduction in yield (Table 2). Grazing of late-sown crops resulted in larger yield reduction than grazing of crops sown earlier. At Warialda yield increased in the grazed 46Y78, though the cause is unclear.

In the cereal crops, early sowing at both Warialda and Armidale produced higher un-grazed grain yields in the longer-season varieties than the shorter-season varieties (Table 3). In both cases the winter wheat cv. Mackellar had a grain yield of more than 6.5 t DM/ha and triticale yields were > 5.5 t DM/ha. At Warialda, in the later sowing there was little difference in un-grazed grain yield amongst cultivars. When sown later in the normal window, grain yield of the winter wheat Mackellar was reduced compared to the earlier sowing and grain yield was higher in the spring wheats and barley (Gregory, Kennedy, Sheppard) (Table 3).

In the cereals, grain yield response to grazing ranged from a 0.8 t/ha increase in yield to a 5.8 t/ha reduction in yield (Table 3). Grazing of the late-sown crops at Warialda occurred after the ‘safe’ phenological period in all cereal varieties except Mackellar and large grain yield reductions were observed. In the early-sown crops, grazing increased yield in short-season spring varieties (e.g. Gregory, Kennedy, Sheppard) (0.1-0.5 t/ha) which may be related to delayed phenology reducing frost damage.

Table 3. Grain yield (t DM/ha) of un-grazed and grazed cereal varieties varying in phenology (longest season type for each species at top) when sown early and late (normal) at two locations in northern NSW

Site		Early sown			Late sown		
Variety		Un-grazed	Grazed	Δ Yield	Un-grazed	Grazed	Δ Yield
Warialda 2011			*7 Apr*			*17 May*	
Triticale	Endeavour	9.4	3.6	-5.8	6.6	2.3	-4.3
	Tobruk	6.4	5.3	-1.1	6.6	2.3	-4.3
Wheat	Mackellar	6.8	5.2	-1.6	4.8	2.2	-2.6
	Wedgetail	5.0	4.5	-0.4	4.8	1.9	-2.8
	Gregory	4.3	3.8	-0.5	4.9	1.5	-3.3
	Kennedy	2.8	3.2	+0.5	4.7	2.8	-1.9
Barley	Urambie	4.4	3.0	-1.4	5.3	3.5	-1.8
	Sheppard	2.6	2.4	-0.2	4.0	4.3	+0.3
Armidale 2011			*7 Apr*			*22 May*	
Triticale	Endeavour	5.7	4.8	-0.9			
	Tobruk	5.8	6.6	+0.8			
Wheat	Mackellar	7.1	6.6	-0.6			
	Wedgetail	5.9	4.4	-1.5			
	Gregory	3.8	4.0	+0.2			
Barley	Urambie	5.8	6.4	+0.5	8.1	7.1	-1.0
	Sheppard	2.0	2.4	+0.4	6.2	5.3	-0.9

Conclusions

Overall, these modelling analyses and experimental findings suggest there is significant potential to expand dual-purpose use of crops in the northern grains region. In particular, it seems that early sowing of long-season cereal varieties, or grazing early-sown short season varieties to delay phenology, have some potential in mixed grain-livestock regions (e.g. Warialda). On the northern Tablelands (e.g. Armidale) there appears to be a significant opportunity to develop grain production using winter cereals and canola that can also provide high quality winter feed for livestock. However, there are a range of agronomic and socio-economic issues that will need to be explored to optimise the use of dual-purpose crops in this area. Grain yields of spring canola and cereals were significantly reduced (up to 60%) by early defoliation in the safe window, which may be a result of the shorter recovery time from the end of grazing to flowering in northern regions and refinements to phenology-based grazing recommendations may be required to avoid yield penalties.

References

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