Dry matter partitioning in canola (*Brassica napus* L.) and the impacts on grain yield in the High Rainfall Zone of south-eastern Australia

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Abstract
Crop research in the high rainfall zone (HRZ) of Southern Australia is focusing on improving canola grain yields to more closely reflect the production potential of the region. This research has involved a series of field experiments to identify superior varieties and traits, together with tailored management practices to increase yield. An analysis of data from seven of these experiments was conducted to gain a greater understanding of the genetic, environmental and management (G x E x M) factors influencing yield formation. The dataset provided more than 600 G x E x M combinations from five seasons, 60 cultivars and different management treatments at Hamilton. Seasons were highly variable with annual rainfall ranging between 69% and 143 % of the long term average (LTA) and spring rainfall (Sep-Nov) between 45% and 106% of the LTA. The range in the number of days between sowing and harvest for the 600 combinations was 186 to 236 days. Over the five seasons grain yields for individual treatments ranged from 1.5 t/ha to 9.5 t/ha. The proportion of grain relative to the total amount of above ground dry matter produced between first flower and harvest i.e. post-anthesis harvest index (PAnHI) ranged between 0.3 to 2.6. A PAnHI greater than one indicates that there has been a reliance on translocated DM from the pre-anthesis period. A PAnHI greater than one tended to occur more in drier seasons and for the later maturing winter crops. The significance of environmental factors relative to specific traits is now being further investigated under controlled environment conditions in the field where rain exclusion shelters and irrigation treatments will generate different levels of water stress. This research will determine if there is genetic diversity that can be exploited in translocating more pre-anthesis DM into grain.

Keywords: post-anthesis harvest index, winter canola

Introduction

Winter canola varieties (i.e. those with a vernalisation requirement) have only been commercially available in Australia since 2011. These winter varieties and later maturing spring types have provided yield advantages over the early and mid-maturing varieties of up to 20% across a wide area of the HRZ (Christy *et al.,* 2013, Riffkin *et al.,* 2012a). This is despite flowering up to four weeks later and filling grain under warmer and drier conditions than the earlier maturing spring types. Variety evaluation and management experiments conducted in the high rainfall zone (HRZ) over the past five years and have shown large differences in phenology, plant height, above ground dry matter (AGDM) accumulation and grain yields between the different winter and spring canola varieties. Data from seven of these experiments was analysed to gain a greater understanding of the genetic, environmental and management (G x E x M) factors influencing yield formation.

Material and Methods

Experiments were conducted on the Department of Economic Development Jobs, Transport and Resources (DEDJTR) research farm at Hamilton in Victoria (37°49'S, 142°04'E) over five years from 2010 to 2014. Soil type at Hamilton is a chromosol and the long term average (LTA) rainfall is 690 mm. The combined dataset which provided more than 600 G x E x M combinations from 60 cultivars and different management treatments on a single site has minimised confounding effects of location and soil type. Experiments included the evaluation of different varieties including spring, winter, semi dwarf, herbicide tolerant (triazine and Imidazolinone tolerance) and conventional types. Management experiments included different

N fertiliser rates (0, 25, 50, 175 kgN/ha) and timings (4 leaf stage, stem extension) and the application of an experimental growth regulator at 5 leaf and/or mid stem extension (Riffkin *et al*., 2012b).
The experiments were direct drilled into raised beds on April 30, 2010; April 29, 2011; May 18, 2012; May 7, 2013 and May 8, 2014. Sowing rate targeted 50 plants m^{-2} and weeds and pests were controlled as required. Quadrat cuts (0.5 m^{-2} per plot) were taken at the bud visible and 10% flowering stages to determine AGDM. At final harvest, grain yield, yield components and total AGDM were determined from two, one m^{-2} quadrats per plot. Post-anthesis harvest index (PAnHI) was calculated as;

$$\frac{\text{Grain weight at maturity}}{\text{Total AGDM from first flower to maturity}}$$

Results
The five seasons in which the experiments were conducted were highly variable (Figure 1). Rainfall in 2010 and 2011 were higher than the long term average. However, the higher falls in 2011 were due to exceptionally high events from January to April with lower than average rainfall in November and December. The spring irrigation applied to the irrigation treatments were 44 mm in 2010 and 215 mm in 2011. Rainfall in 2012 and 2014 were below average with only 75% and 45% of the LTA occurring in spring in 2012 and 2014 respectively. As in 2010, rainfall for 2013 provided good growing conditions throughout the year (Table 1).

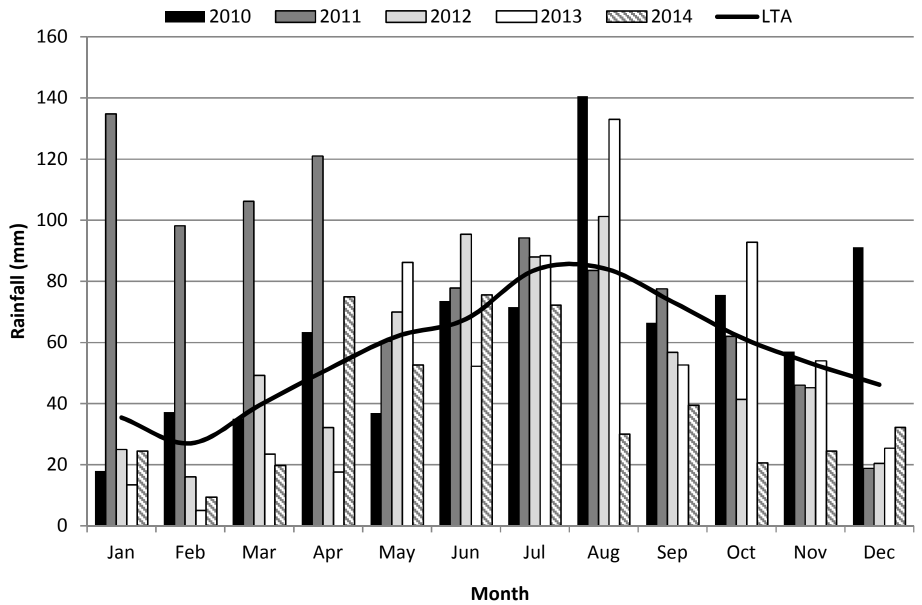

Figure 1: Month rainfall for the five seasons of field experiments (Bars, 2010-2014) and the long term average (line) at Hamilton.

The difference between treatments in the total number of days between sowing and harvest within the dataset was 50 days with the shortest time between sowing and harvest 186 days and the longest 236 days. The winter canola types reached anthesis on average 28 days later than the spring types (mean of all treatments) and accumulated more pre-anthesis AGDM (Table 2). There was little difference in the total amount of rain that fell during the grain fill period with 162 mm for the spring types and 155 mm for the winter types (mean of all years).

Table 1: Annual rainfall, growing season rainfall (GSR) rainfall and spring rainfall (Sept-Nov) for the five seasons of field experiments and amounts as a percentage of the long term average at Hamilton. Amounts do not include irrigation.

	Annual	GSR (A-N)	Spring (S-N)	%LTA (Annual)	%LTA (GSR)	%LTA (Spring)
2010	767	585	199	112	109	106
2011	981	623	186	143	116	99
2012	641	530	143	94	99	76
2013	644	577	199	94	107	106
2014	476	390	84	69	73	45
LTA	685	537	188			

Grain yields for individual treatments within the dataset ranged between 1.5 t/ha to 9.5 t/ha. Mean annual grain yields were between 3.8 t/ha in 2014 and 7.5 t/ha under irrigation in 2010. The winter types tended to yield better than the spring types. Greater HI were generally achieved in the years with higher spring rainfall and under irrigation (Table 2).

Table 2: Mean above ground dry matter (AGDM) at anthesis, grain yields, harvest indices, post-anthesis harvest index (PAnHI) and the proportion of treatments with a PAnHI greater than one for the different seasons between 2010 and 2011 at Hamilton.

Treatment	Anthesis AGDM (Kg/ha)	Grain Yield (t/ha)	Mean PAnHI	%PAnHI >1
2010 Rain fed	5660	6.5	0.52	0%
2010 Irrigated	6060	7.5	0.52	0%
2011 Rain fed	8820	5.6	0.91	30%
2011 Irrigated	9650	6.2	0.96	38%
2012 Rain fed	9790	5.8	0.97	36%
2013 Rain fed	9220	6.3	0.76	10%
2014 Rain fed	8200	3.9	1.14	57%
Spring Types	7590	5.7	0.72	17%
Winter Types	9470	6.2	0.93	30%

Post-anthesis harvest indices for individual treatments ranged between 0.3 to 2.6. Mean PAnHI and the number of treatments with a PAnHI greater than one were generally more in the years where spring rainfall was lower than the LTA (Figure 2). Similarly mean PAnHI and the number of treatments with PAnHI greater than one was higher for winter types compared to the spring types.

Discussion

Different seasonal conditions and canola types influenced dry matter partitioning and provided a wide range in grain yields and HI. Harvest indices were comparable to wheat when the cost of glucose conversion to starch or oil were considered. Generally, PAnHI was higher in the years where spring rainfall was lower suggesting that in these years the dry matter accumulated pre-anthesis contributed more to grain yield than in wetter years where grain yield came more from net assimilation during the grain filling period.

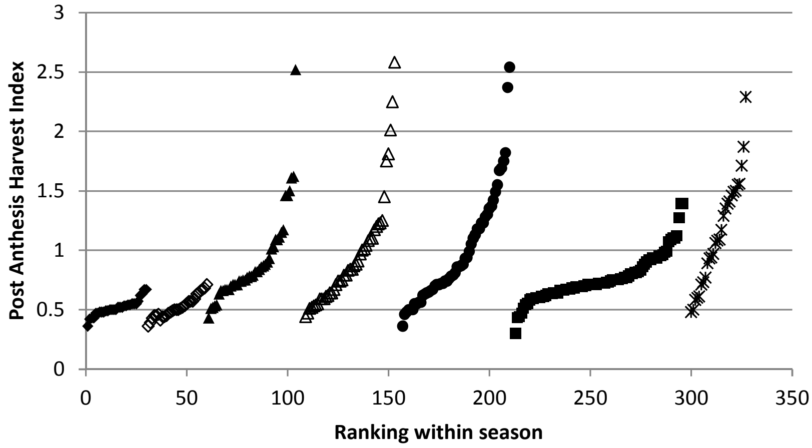

Figure 2: Post anthesis harvest index (PAnHI; proportion grain to total above ground dry matter accumulated between first flower and harvest). Results are from five field experiments from 2010-2014 at Hamilton, 2010; diamonds, 2011; triangles (solid symbols are for rainfed treatments and open symbols are for irrigated), 2012; circles, 2013; squares and 2014; stars (rainfed). Data is ranked from lowest to highest PAnHI within each season.

Winter varieties appeared to rely more on pre-anthesis dry matter to fill grain than the spring varieties. Although the winter varieties flowered considerably later than the spring varieties (approximately four weeks), there was little difference in the total amount of rain that fell during the grain filling periods (7 mm, mean of all seasons). There was also little difference in PAnHI between the irrigated and rainfed treatments in 2010 and 2011. These observations suggest that factors other than rainfall are influencing dry matter partitioning to grain. The winter varieties had approximately 25% more AGDM at anthesis than the spring varieties. This may have provided a source of reserves for grain filling especially in the drier years. The significance of environmental factors relative to specific traits is now being further investigated under controlled environment conditions in the field where rain exclusion shelters and irrigation treatments will generate different levels of water stress. From this experiment we expect to improve our understanding of environmental factors which influence dry mater partitioning in canola and identify important traits relating to grain yield. This will help inform breeding programs and develop management decisions to give greater, more stable grain yields for growers in the HRZ.

References

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