

Influence of an increase in temperature and decrease in rainfall on canola production at Langgewens and Tygerhoek

PJA Lombard, Dr JA Strauss
and P Greeff
Directorate Plant Sciences
pietl@elsenburg.com



INTRODUCTION

There are two main production areas for canola in the Western Cape with different climatic conditions, namely the Swartland and southern Cape (Lombard & Nel, 2007; Lombard, Strauss & Smorenburg, 2008). Canola is produced for its high food quality oil and is the major oilseed crop in the Western Cape. There are three production factors that are of economic value, namely yield, oil and protein percentage.

The production potential in the Swartland is mainly influenced by four factors: total rainfall during the growing season, soil structure, depth and water-holding capacity (mm) (Anonymous 1985b and Anonymous 2008). Short rotation systems are followed in the Swartland (Hardy, 2007).

The production potential in the southern Cape is mainly influenced by the mean rainfall during the growing season, percentage stone fraction, and depth of the soil (Anonymous 1985a; Hardy, 2007; Anonymous 2008). The potential production season in the southern Cape is longer than that of the Swartland due to rainfall that is distributed over a longer period.

For this study two representative localities were selected namely Langgewens in the Swartland and Tygerhoek in the southern Cape. The Swartland, with its typical Mediterranean climate (dry summers and wet winters), has the highest rainfall during the months of April to September. During the trial period, Langgewens received 81.5% of its rainfall from April to September, compared to Tygerhoek (50.6%). Rainfall can be highly variable within season, with periodically hot dry periods in autumn and spring (Hardy, 2007).

Temperature influences all chemical and physical processes of plants. The diffusion of gases and the movement of water through the plant hasten with an increase in temperature. Temperature affects most biochemical processes including the activity of enzymes and their stability (Arnon, 1992). Higher temperatures, moisture stress and long days hasten maturity. These factors in combination can severely affect the formation of pods, seeds per pod, seed size and oil content (Canola Council of Canada, 2003).

The importance of canola as a rotation and cash crop in the Western Cape is undeniable, even more so in recent years where sustainable production has been key. The prediction for the Western Cape is an increase in temperature and decrease in rainfall (Johnston & Hewitson, 2009; Conway, 2008). The question can thus be raised: what will the impact be on the yield of canola? Will there be response differences between the three genotypes, and is the viability of the industry possibly at stake?

MATERIALS AND METHODS

Crop performance data taken from the Western Cape Department of Agriculture cultivar evaluation programme and corresponding weather data (ARC – Soil Climate and Water; SA Weather Service) were used in the analysis

Normal agronomic practices were followed to control weeds, insects and plant diseases. Plant nutrition was applied according to recommendations received from the Elsenburg soil laboratory. A randomised block design with three replicates was used at each site. The plot size was 5m by 2.1m (10.5m²).

The following values were calculated for four years to investigate the reaction of Australian cultivars in the Western Cape: mean post-anthesis temperature, minimum temperature (50% flowering and 60 days thereafter), maximum temperature (50% flowering and 60 days thereafter), post-anthesis heat units and in-season rainfall (planting until 60 days after 50% flower) (Hocking, Kirkegaard, Angus, Gibson & Koetz, 1997; Si & Walton, 2004).

Physiological maturity date was not collected in this study and is a limitation. In the data set, the mean temperature, minimum, maximum temperature and heat units were calculated for the period 50% anthesis to 60 days after anthesis.

Pearson correlation coefficients and linear regression analysis were used for the data 2004 to 2008. Since 2004, enough cultivars of a genotype were included in the national cultivar programme to

divide them into developmental groups, early and medium for this study. Linear regression analysis was applied for the relationship between early and medium development for 2004 to 2008 at both locations for all three canola genotypes. These relationships were examined on the basis of genotype (development group) x locality. Pearson correlation coefficients were used to determine the significance of correlations between selected variables and seed yield.

Influence of temperature on yield

Results: Langgewens

Later flowering genotypes are exposed to higher temperatures during flowering and the seed-fill period is shorter as result (Farré, Robertson, Walton & Asseng, 2002; Robertson, Holland & Bambach, 2004; Si & Walton, 2004; Aksouh-Harradj, Cambell & Mailer, 2006). In the local study the influence of minimum, mean and maximum daily temperature on seed yield was evaluated. The correlation coefficients between yield and temperature are given in Table 1.

Table 1: Coefficients of correlation for conventional genotype (early and medium) between yield, minimum, mean and maximum daily temperature for Langgewens (upper line = early development group, lower line = medium developmental group)

Conventional	Yield	Mean temp.	Maximum temp.	Minimum temp.
Yield	1	-0.78***	-0.74***	-0.78***
	1	-0.56**	-0.50**	-0.66***
Mean temp.	-0.78***	1	0.99***	0.96***
	-0.56**	1	0.99***	0.98***
Max. temp.	-0.75***	0.99***	1	0.92***
	-0.50**	0.99***	1	0.94***
Minimum temp.	-0.78***	0.96***	0.92***	1
	-0.66***	0.98***	0.94***	1

* P < 0.05, ** P < 0.01, *** P < 0.001

Both the conventional developmental groups showed a strong negative correlation coefficient to temperatures (Table 1). The linear correlations for the early conventional genotype to minimum, mean and maximum daily temperature were R² = 0.61, = 0.59 and = 0.55 respectively (Figures 1, 2 and 3). The medium conventional genotype showed less of a response and had R²s of 0.43, 0.31 and 0.25 respectively. Thurling & Vijendra Das (1979), Farré et al. (2002); Robertson Holland, Cawley, Potter, Burton, Walton & Thomas, 2002 and Si & Walton (2004) found that early flowering cultivars produced a higher seed yield because the seed matures under cooler and wetter conditions. Previous studies found a strongly negative relationship between seed yield and air temperature (Farré et al. 2002; Morrison & Steward, 2002; Si & Walton, 2004 and Abolfazl, Nassar, Afshin & AMIR 2008).

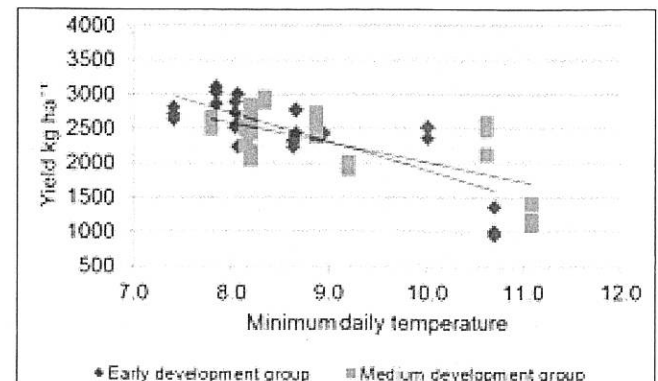


Figure 1: Linear regressions fitted between yield and minimum daily

temperature at Langgewens for the early and medium genotypic groups:

Conventional (early) development $y = -416.11x + 6063.4$, $R^2 = 0.61$

Conventional (medium) development $y = -285.05x + 4862$, $R^2 = 0.43$

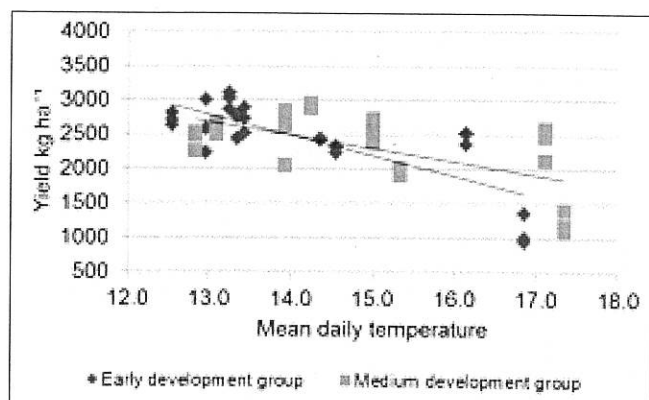


Figure 2: Linear regressions fitted between yield and mean daily temperature at Langgewens for the early and medium genotypic groups:

Conventional (early) development $y = -294.76x + 6614.3$, $R^2 = 0.59$

Conventional (medium) development $y = -171.14x + 4829.5$, $R^2 = 0.31$

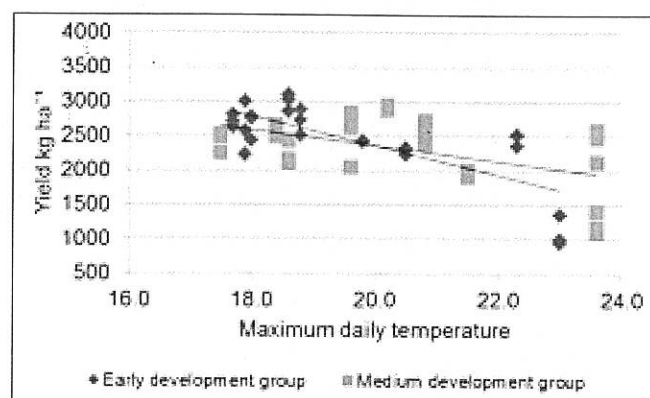


Figure 3: Linear regressions fitted between yield and mean maximum daily temperatures at Langgewens for the early and medium genotypic groups,

Conventional (early) development $y = -215.34x + 6665.4$, $R^2 = 0.55$

Conventional (medium) development $y = -116.16x + 4686.2$, $R^2 = 0.25$

Results: Tygerhoek

In this study the influence of minimum, mean and maximum daily temperature on seed yield was evaluated. The correlation coefficients between yields and temperatures are given in Table 2. The medium conventional group showed a negative correlation (-0.51 , $P < 0.05$) between yield and maximum temperature. There were no significant linear correlations between yield and maximum temperatures (Table 2).

At Langgewens the total in-season rainfall varied (from plant to 60 days following 50% flower) from 198.9mm to 493mm. Tygerhoek received less rainfall and varied between 126.6mm 349.4mm. Stored soil water was not taken into account.

Table 2: Coefficient of correlation for conventional genotype (early and medium) between yield, minimum, mean and maximum daily temperatures for Tygerhoek (upper line early development group; lower line medium development group)

Conventional	Yield	Mean temp.	Maximum temp.	Minimum temp.
Yield	1	-0.32	-0.26	-0.03
	1	-0.35	-0.51*	0.03
Mean temp.	-0.32	1	0.66***	0.80***
	-0.35	1	0.82***	0.80***
Max. temp.	-0.26	0.66***	1	0.11
	-0.51*	0.82***	1	0.33
Minimum temp.	-0.03	0.80***	0.11	1
	0.03	0.80**	0.33	1

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

Influence of in-season and post 50% flowering rainfall on yield

Results: Langgewens

The coefficient of correlation for conventional genotype (early and medium) between yield, oil, protein and in-season rainfall is given in Table 3. The correlation coefficients between yield and in-season rainfall for early conventional ($P < 0.05$), medium TT ($P < 0.001$) early ($P < 0.05$) and medium CI ($P < 0.001$) were significantly correlated.

Table 3: Coefficients of correlation for conventional genotype (early and medium) between yield, oil, protein, in-season rainfall and temperature at Langgewens (upper line early development group; lower line medium development group)

Conventional	Yield	Mean temp.	Min. temp.	In-season rainfall
Yield	1.00	-0.78***	-0.78***	0.44*
	1.00	-0.56**	-0.66***	0.36
Mean temp.	-0.78***	1.00	0.96***	-0.56**
	-0.57**	1.00	0.98***	-0.49**
Min temp	-0.78***	0.96***	1.00	-0.70***
	-0.66***	0.98***	1.00	-0.60***
In-season rainfall	0.44*	-0.56**	-0.70***	1.00
	0.36	-0.49**	-0.60***	1.00

* For $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

Previous studies have focused on the importance of post-flowering rainfall (Robertson & Holland, 2004; Robertson & Kirkegaard, 2005). There is considerable scatter in the data around the regression line from the effect of timing and intensity of rainfall. The seed yield of the early conventional genotype ($R^2 = 26$) showed a significant increase in seed yield as the in-season rainfall increased (Figure 4). However, both in-season and post 50% flowering rainfall showed a positive correlation as the total amount of rainfall increased.

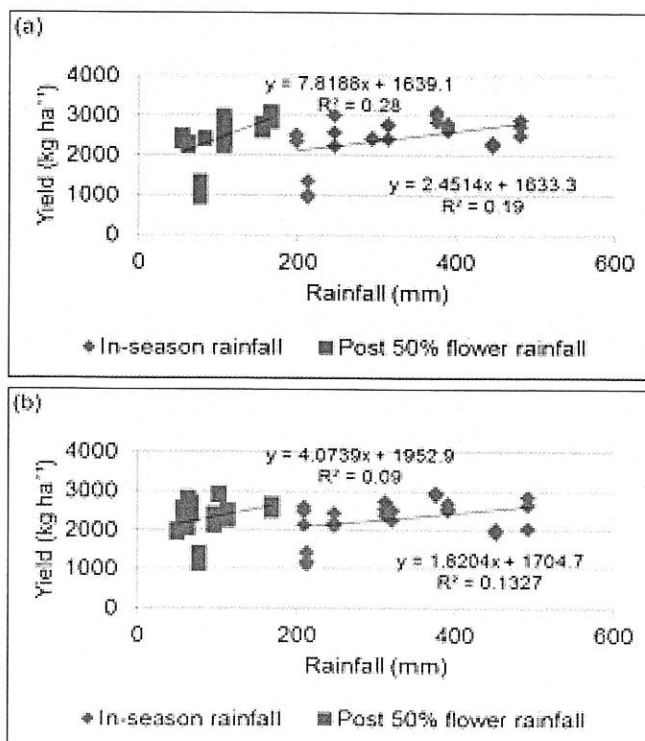


Figure 4: Linear regressions were fitted between yield, in-season and post 50% flowering rainfall for the early and medium conventional genotypes at Langgewens.

Results: Tygerhoek

The coefficients of correlation for conventional genotype (early and medium) between yield and in-season rainfall are given in Table 4. The correlation coefficients between yield and in-season rainfall for early conventional ($P < 0.05$) medium TT ($P < 0.05$) were significantly correlated. No linear correlation between yield and in-season rainfall occurred at Tygerhoek ($P < 0.05$) for the medium genotype.

Table 4: Coefficients of correlation for conventional genotype (early and medium) between yield, in-season rainfall and temperature at Tygerhoek (upper line early development group; lower line medium development group)

Conventional	Yield	Mean temp.	Min. temp.	In-season rainfall
Yield	1.00	-0.78***	-0.78***	0.44*
	1.00	-0.56**	-0.66***	0.36
Mean temp.	-0.78***	1.00	0.96***	-0.56**
	-0.57**	1.00	0.98***	-0.49**
Min temp	-0.78***	0.96***	1.00	-0.70***
	-0.66***	0.98***	1.00	-0.60***
In-season rainfall	0.44*	-0.56**	-0.70***	1.00
	0.36	-0.49**	-0.60***	1.00

* For $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

DISCUSSION

Temperature

The local study was executed under rain-fed conditions with no control over the timing of rainfall or temperatures. A previous study found that data will scatter along the line due to timing of heat and water stress (Si & Walton, 2004). Post-anthesis development periods shortened with an increase in temperature and a decrease in rainfall. The consequence of lower post-anthesis temperature is a longer grain-filling period, according to Farré et al. (2002); Robertson et al. (2004) and Aksouh-Harradj et al. (2006). Premature leaf shedding takes place during warm and dry conditions. Redistribution of dry matter from leaves provides 33-36% of the yield of the canola seed (Hocking et al. (1997).

Variation in response to temperature occurred at Langgewens, while no linear correlation was found between temperature and seed yield at Tygerhoek. An increase of 1°C in the minimum temperature with no difference in rainfall will result in a yield decline of 13.41% ha⁻¹ at Langgewens. Producers may experience a decline in yield of 201kg ha⁻¹ based on a yield of 1500kg ha⁻¹.

Although minimum temperature and in-season rainfall were highly correlated at both locations it is difficult to determine the relative importance of each factor (Si & Walton, 2004).

A dearth of information on the influence of minimum temperature on the canola plant is prevalent. Pritchard, Eagles, Salisbury & Nicolas (2002) found that an increase in minimum daily temperature affected oil content negatively (-0.29), ($P < 0.05$) but the maximum temperatures strongly influenced the seed composition (0.42) ($P < 0.001$). Australian studies found that seed yield is negatively influenced by an increase in mean post-anthesis air temperature (Hocking et al. 1997; Si & Walton, 2004; Abolfazl et al. 2009). Hocking et al. 1997 and Abolfazl et al. 2009 found a decline in seed yield of 289 kg ha⁻¹ and 303 kg ha⁻¹ to 338 kg ha⁻¹ respectively, with an increase by 1°C in the mean daily temperature.

Robertson et al. (2002) and Donnelly & Hume (1998) found that the yield difference was greater in the higher-yielding environments, which may explain the difference in response between the higher- yielding environment of Langgewens, and that of Tygerhoek with its lower trial yields. A combination of factors other than temperature and rainfall alone was responsible for the reaction in seed yield at Tygerhoek.

Rainfall

At Langgewens the in-season rainfall explained between 36%, and 44% of the variation in yield (coefficients of correlation). The results at Langgewens corresponded with what Robertson & Kirkegaard (2005) found: $R^2=30$, using 42 data sets. The scatter of the data around the regression line was caused by the effect of the timing of rainfall and heat stress. In a South African study on wheat production and rainfall, a correlation of $R^2=53$ was found (Blignaut, Ueckermann & Aronson, 2009).

No correlation was found between total in-season rainfall and yield at Tygerhoek. The in-season rainfall was less than at Langgewens, with more water-stress periods during the mid-growing season. High-intensity rainfall can cause water runoff or soil moisture that drains to below the root zone. This variation results in an ineffective measurement of data (Robertson & Kirkegaard, 2005). The occurrence of a high stone fraction in shallow soils at Tygerhoek, with the possibility of stored soil water at planting, may have contributed to there being no significant correlation ($P < 0.05$) between in-season rainfall and seed yield.

CONCLUSION

Canola is produced under rain-fed conditions in the Western Cape where large scale season-to-season variability in rainfall

and temperature occurs. It is evident that an increase in temperature and decrease in seasonal rainfall will affect the yield potential of canola negatively. The timing of water stress and high temperatures during the growing season complicated the accurate prediction of the negative impact of these factors.

References

- ABOFAZAL, F., NASSAR, L., AFSHIN, S. & AMIR, H.S.R. 2008. Seed yield and water use efficiency of canola (*Brassica napus* L.) as effected by high temperature stress and supplemental irrigation. *Agricultural water management*, 96: 132-140
- AKSOUH-HARRADJ, N.M., CAMBELL, L.C. & MAILER, R.J. 2006. Canola response to high and moderately high temperature stresses during seed maturation. *Canadian Journal of Plant Science*, 86: 967-980
- ANONYMOUS. 1985a. Landbou-Ontwikkelingsprogram, Suidkussubstreek: Beskrywing van boerdery gebiede. Stellenbosch: Winterreënstreek.
- ANONYMOUS. 1985b. Landbou-Ontwikkelingsprogram, Swartlandsubstreek: Beskrywing van boerdery gebiede. Stellenbosch: Winterreënstreek.
- ANONYMOUS. 2008. Canola handleiding: Groeiveristes en produksiepotensiaal. Protein Navorsing Stigting.
- ARNON, I. 1992. Agriculture in dry land, principles and practice: Climatic factors and their effect on crop production. Amsterdam: Elsevier Science Publishers B.V.
- BLIGNAUT, J., UECKERMANN, L. & ARONSON, J. 2009. Agriculture production's sensitivity to changes in climate in South Africa. *South African Journal of Science*, vol. 105
- CANOLA COUNCIL OF CANADA. 2003. Temperature, Frost, Hail. [Online]. Available: <http://www.canola-council.org/contents5.aspx> [8 May 2009]
- CONWAY, G. 2008. The science of climate change in Africa: impacts and adaptation. [Online]. Available: http://workspace.imperial.ac.uk/climatechange/public/pdfs/discussion_papers/Grantham_Institutue_-_The_science_of_climate_change_in_Africa.pdf
- LLY, M.J. & HUME, D.J. 1998. Photosynthetic rates and growth analysis of triazine-tolerant and normal rapeseed. *Canadian Journal of Plant Science*, 64: 1007-1010
- FARRÉ, I., ROBERTSON, M.J., WALTON, G.H., & ASSENG, S. 2002. Simulating phenology and yield response of canola to sowing date in Western Australia using the APSIM model. *Australian Journal of Agricultural Research*, 53: 1155-1164
- HARDY, H.B. 2007. Crop rotation for rain-fed crop production. *Agri Probe*, 4.4: 10-15
- HOCKING, P.J., KIRKEGAARD, J.A., ANGUS, J.F., GIBSON, A.H. & KOETZ, E.A. 1997. Comparison of canola, Indian mustard and linola in two contrasting environments. I. Effects of nitrogen fertilizer on dry-matter production, seed yield and seed quality. *Field Crops Research*, 49: 107-125
- JOHNSTON, P. & HEWITSON, B. 2009. Climate Change - some implications for SA and agriculture. Agribusiness and Climate Chance Conference: Somerset-West
- LOMBARD, P.J.A. & NEL, A. 2007. Die olie-inhoud van canola. *Canolafokus*, 35: September.
- LOMBARD, P.J.A., STRAUSS, J. & SMORENBURG, L. 2008. Proteïen- en vetinhoud van lupien kultivars. *Lupino*, 34 September
- MORRISON, M.J. & STEWART, D.W. 2002. Heat stress during flowering in summer rape. *Crop Science*, 42: 797-803
- PRITCHARD, F.M., EAGLES, H.A., SALISBURY, R.M. & NICOLAS, M. 2000. Environmental effects on seed composition of Victoria canola. *Australian Journal of Experimental Agriculture*, 40: 679-685
- ROBERTSON, M.J. & HOLLAND, J.F. 2004. Production risk of canola in the semi-arid subtropics of Australia. *Australian Journal of Agricultural Research*, 55: 525-538
- ROBERTSON, M.J., HOLLAND, J.F. & BAMBACH, R. 2004. Response of canola and Indian mustard to sowing date in the grain belt of north-eastern Australia. *Australian Journal of Experimental Agriculture*, 44: 43-52
- ROBERTSON, M.J., HOLLAND, J.F., CAWLEY, S., POTTER, T.D., BURTON, W., WALTON, G.H., & THOMAS, G. 2002. Growth and yield differences between triazine-tolerant and non-triazine-tolerant cultivars of canola. *Australian Journal of Agricultural Research*, 53: 643-651
- ROBERTSON, M.J. & KIRKEGAARD, J.A. 2005. Water use efficiency of dryland canola in an equi-seasonal rainfall environment. *Australian Journal of Agricultural Research*, 56: 1373-1386
- SI, P. & WALTON, H. 2004. Determinants of oil concentration and seed yield in canola and Indian mustard in the lower rainfall areas of Western Australia. *Australian Journal of Agricultural Research*, 55: 367-377
- THURLING, N. & VIJENDRA DAS, L.D. 1979. The relationship between pre-anthesis development and seed yield of spring rape (*Brassica napus* L.). *Australian Journal of Agricultural Research*, 31: 25-36