International Journal of Agriculture, Environment and Bioresearch

Vol. 5, No. 03; 2020

ISSN: 2456-8643

PHENOLOGICAL RESPONSES OF SOME CANOLA (Brassica napus) GENOTYPES TO TEMPERATURE REGIMES DURING REPRODUCTIVE DEVELOPMENT

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https://doi.org/10.35410/IJAEB.2020.5504

ABSTRACT

The objective was to screen some canola genotypes for heat tolerance and possible selection of heat tolerant genotypes for planting at more tropical South Africa regions. The study was conducted for two years in glass house of department of Agronomy, University of Stellenbosch South Africa. Randomized complete block design was used. Seven canola genotypes selected from early and mid-maturing groups of canola genotypes presently planted in the Western Cape, South Africa canola production area were grown in 3 litre plastic bags filled with a mixture of sand and compost at ratio of 1:1 and irrigated with fully balanced nutrient solution at EC=2.0 in two glasshouses at night/day temperature regimes of 10/15ºC and 15/20ºC. Number of days, growing degree days (GDD) and photothermal units (PTU) from planting to visible flower buds appearance, first flower opening, seed ripening and seed physiological maturity were recorded. Plants were sampled for leaf area (LA) and above ground dry mass (DM) at budding, flowering and seed physiological maturity stages. Days after planting, GDD and PTU at budding, flowering and physiological maturity were correlated with leaf area, dry mass, number of pods plant-1 and pod dry mass plant-1 at budding, flowering and physiological maturity stages to determine whether there were relationships between the variables. The results showed that increasing daily mean temperature from 12.5ºC to 17.5ºC, on average, reduced the duration of flowering time by 10.38 days, time to beginning of seed-filling by 25.39 days and from planting to physiological maturity by 28.09 days. However, there were variations among canola genotypes with regard to heat tolerance. These reductions in the duration may however change if plants were grown at different day lengths. Increased GDD and PTU due to higher mean daily temperatures decreased the total above ground dry mass, number of pods plant-1 and pods dry mass at final harvest.

Keywords: Temperature, Canola, Phenology, Reproductive, Genotypes.

1. INTRODUCTION

Canola (Brassica napus) is increasingly becoming an important field crop in South Africa. It can be used to produce high quality cooking oil and margarine, animal feed, biofuel (Anonymous 2006) and in crop rotation systems to break the disease chain and improve weed management (Burton et al., 2008). In Canada, about 7.4 million ha of canola were grown at the great-plains province during 2009 (Statistics Canada 2010). In Australia two million hectares were sown to canola in 1999 but declined to half that due to drought in early years of this millennium.

Vol. 5, No. 03; 2020

ISSN: 2456-8643

Recently it however recovered to 2.69 million ha in 2012 (www.Australian oilseed federation 2013). Oil from canola seed is low erucic acid content (Anonymous 2006).

In Canada canola is planted in late April or early May, where-after it grows rapidly during the short summer season that has long warm days and is harvested in end September or early October. Although canola will flower much sooner at daylight lengths of 16 to 18 hours, it will eventually also flower at much shorter daylight lengths but after a longer period, (Kirkegaard et al., 2012). In South Africa and Australia canola is also planted in April or May but the growth take place during winter period with daylight lengths of 9.5 hrs in May to 12 hrs in September and is harvested during October. The phenological development affects the success of canola production and is largely controlled by temperature (Morrison et al., 1992). Accurate timing of these phenological events is generally considered the most important factor determining crop adaptation and maximum yield in a particular environment (Fischer 1979, Richard 1991).

In general development of an annual crop from emergence to maturity can be divided into three major phenological developmental phases: from emergence to flower buds initiation-vegetative development, from floral buds initiation to anthesis-reproductive development and from anthesis to physiological maturity -seed filling (Craufurd and Qi 2001, Ritchie 1991, Siebert and Ewert 2012). However, canola developmental stages can be divided into six phases according to Harper and Berkenkamp (1975): Phase 0-Pre-emergency, Phase 1-Seedling, Phase 2-Rosette, Phase 3-stem elongation, Phase 4-flowering, Phase 5-Seed maturation. Under climate change scenario, increase in both the mean and extremes of temperature are expected for many parts of the world (IPCC 2001). These changes can impact largely on the growth and phenological development of crops. Temperature and to less extent photoperiod have been reported to be the major environmental factors that determine the timing and duration of each of the phenological phases in the physiological development of crops (Roberts et al., 1993). Many models have been developed to explain the phenological phases that take place during growth and development of crops (Alocija and Ritchie 1991, Matthews and Hunts 1994), while the physiological mechanisms that govern the transition from one phenophase to another are strongly influenced by environmental factors and have been described using photothermal models (Summerfield et al., 1991).

Photoperiod has been reported to be the principal factor that determines the time of floral initiation and hence anthesis date in many crop species (Burtero et al. 1999). Photoperiod, for example affects floral development of rice (Oryza sativa L.) (Coolhaas and Wormer 1953), caryopteris (Piringer et al., 1963), wheat(Triticum aestivum L.) (Slafer and Rawson 1994), barley (Hordeum vulgare L.) (Kernich et al., 1996) and quinoa (Chenopodium quinoa willd) (Burtero et al., 1999). However, it is not clear whether the duration of the reproductive phase is affected directly (immediate response) by the photoperiod experienced during this phase or indirectly (delayed response) by photoperiod experienced in earlier developmental phases. The delayed effects on reproductive development could be because of the fact that more leaf primordial are formed under an extended duration of the vegetative period and this means that anthesis has to wait longer because more leaves have to appear and all the leaves must appear before anthesis will occur (Kiniry et al., 1992). The underlined assumption here is that the total leaf number cannot be altered after the end of vegetative growth phase by transfer conduct

Vol. 5, No. 03; 2020

ISSN: 2456-8643

during anthesis and seed filling. However, Slafer and Rawson (1995) and Kernich et al.,(1996) have shown that time from the end of leaf appearance to anthesis is affected by the photoperiod after floral initiation, but not leaf number in wheat and barley respectively.

Ritchie and Smith (1991) reported that temperature regime is a major factor controlling the rate of leaf appearance. Hence "phyllochron" is defined as a constant interval of thermal time between successive leaves appearance. However the effect of temperature on the time interval between successive leaves' appearance (phyllochron) is crop specific for the different field conditions (Cao and Moss, 1989). For chenopodium photoperiod was reported to decrease the ''plastochron" (the time between initiation of two successive primordia) with transfers from inductive to marginally or vice versa (Thomas, 1961). A photothermal duration effect on seed maturation processes has been demonstrated for soybean (Glycine max (L) merril), peanut (Arachis hypogeal L), bambaranut (Vigna subterrenea (L) verdc), rice (Oryza sativa), muccuna spp, maize (Zea mays L), sorghum (Sorghum bicolor) and field pea (Pisum sativum) (Bagnall and King 1991; Birch et al., 1997; Craufurd and Qi 2001; Craufurd et al., 2003, Linnemam 1993; Morandi et al., 1998; Poggio et al., 2005 and Qi et al., 1998). It has also been reported that photothermal regime influence vernalisation sensitivity of crops. Plants vernalised for 50 days showed greater response to photoperiod than those vernalised for 15 days. As the duration of stem enlongation lengthened in photoperiod-sensitive genotypes by exposure to less inductive photoperiods, a higher number of fertile florets at anthesis are produced, leading to an increased grain number and thereby to higher yield (Gonzalez et al., 2003).

The timing of leaf emergence, flowering and seed filling as influenced by photothermal exposure and duration is critical in crop production, especially in the Mediterranean environment with its characteristic period of increasing temperatures and water stress that occur towards the end of the growing season. This study has not been conducted on canola because it is a relatively new crop in South Africa. This study was therefore conducted to determine the effect of temperature regimes on phenology of canola in order to enhance its agronomical management and maximally exploit its productive potentials under South African climatic conditions.

2. MATERIALS AND METHODS

The study was conducted in controlled glasshouse environment at department of Agronomy, University of Stellenbosch, South Africa. Experiment was laid out as a completely Randomized design (CRD) with two temperature regimes (15/20^{o}C and 10/15^{o}C night/day) and seven genotypes (Hyola 571 CL, AGAMAX, 45Y86, 44Y84, Hyola 50, 43Y85, and Hyola 575 CL) of canola as treatments. Four replications were used and single plant represents an experimental unit. Provision was made for three sampling times.

The seven genotypes of canola were planted (four seeds per 3 litre plastic bags filled with the mixture of sand and compost at ratio of 1:1 and irrigated with fully balance nutrient solution at 2.0 EC) in two glasshouses. The genotypes belonged to different maturity groups: 45Y86 and Hyola 50 (mid-maturing),44Y84 (mid-early) and 43Y85, AGAMAX, Hyola 571 CL and Hyola 575 CL (early maturing). During the seedling stage, plants were thinned to one per bag. The plants were irrigated twice a day to re-fill the bags to field water capacity.

Vol. 5, No. 03; 2020

ISSN: 2456-8643

Daylight length (number of hours of sunshine) was obtained from the South African weather service (http//www.Weathera.com). Crops were planted on 11 February 2014 and the final harvest was done on 14 July 2014 with the result that the day length varied between 13:20 hours at planting and 10:48 hours during the final harvest. The light intensity in the glasshouses and outside exposed environment were measured weekly at 12h00 from the seedling stage of the plants and averages of 211.6 µmolm-2s-1 for 15/20^{o}C glasshouse, 249.1 µmolm-2s-1 for 10/15^{o}C glasshouse and 481.5 µmolm-2s-1 for outside environment were obtained. Temperature loggers were put in each glass house to record the actual temperature of the glass houses to make sure that the set temperatures were achieved.

The number of days required to reach the following growth stages (GS) according to Harper and Berkenkamp (1975) were recorded: visible inflorescence at center of rosette or budding (GS 3.1); first flower open (GS 4.1); beginning of seed filling) (GS 4.4); lower pods filled to full size and become translucent (GS 5.1); and seeds in lower pods turn brown which is physiological maturity (GS 5.4).

Number of days was multiplied by the mean of the set night/day temperatures 17.5^{o}C for 15/20^{o}C and 12.5^{o}C for 10/15^{o}C to calculate the growing degree days (GDD). While the growing degree days (GDD) x mean daylight length (sunrise to sunset) was used to compute the photothermal units (PTU) needed by different genotypes to reach the above described growth stages Plants in both glasshouses were sampled at the budding, full flowering and physiological maturity stages to determine the leaf area (LA) and dry mass (DM) aGer being oven dried for 48hrs at 80^{o}C. Number of pods plant-1 (NPP) was recorded at final harvest (physiological maturity) stage and pods dry mass (PDM) plant-1 were also obtained aGer oven drying the samples for 48hrs at 80^{o}C. Days aGer planting (DAP), GDD and PTU at budding, flowering and physiological maturing stages were correlated with LA, DM, NPP and PDM at budding, flowering and physiological maturing stages to determine whether there were relationships between the variables.

An appropriate analysis of variance (ANOVA) was performed, using Statistica soGware, version 12®. The Bonferroni test's least significant difference (LSD) values were calculated at the 5% probability level to compare treatment means.

3. RESULTS AND DISCUSSION BUDDING

Budding stage is characterized by appearance of flower buds in the terminal region and stem elongation (Slauenwhite and Qaderi. 2013). Number of days, GDD(ºCd) and PTU(ºCdhr) required by the seven genotypes to budding stage from planting date in response to day/night temperature regimes of 10/15ºC and 15/20ºC is shown in Figure 3

At the lower temperature regime of 10/15ºC, genotypes required significantly a greater number of days from planting to budding stage than at the higher temperature regime of 15/20ºC (Figure 3). At the 10/15ºC temperature regime genotypes required about 42.5 days from planting to budding and Hyola 50, 44Y84, 43Y85 and 45Y86 were not significantly different from each, other but required significantly more days from planting to budding than other genotypes. At the 15/20ºC temperature regime genotypes required about 38.71days from planting to budding and

Vol. 5, No. 03; 2020

ISSN: 2456-8643

Hyola 50, 44Y84 and 43Y85 did not differ significantly, but required more days than other genotypes.

In contrast to number of days, genotypes required significantly more GDD at higher night/day temperature regime of 15/20ºC than at the lower night/day temperature regime of 10/15ºC (Figure 3b). On average 677.5ºCd were required by genotypes at the 15/20ºC temperature regime. Similar to number of days Hyola 50, 44Y84 and 43Y85 were not significantly different to each other but required significantly more GDD than Hyola 571, Hyola 575, AGAMAX and 45Y86. At the 10/15ºC temperature regime, genotypes required 529.91ºCd on average from planting to budding. Hyola 50, 44Y84 and 43Y85 were not significantly different from each other but required significant more GDD than other genotypes.

Genotypes PTU requirements from planting to budding stage differ between the temperature regimes (Figure c). At the higher temperature regime of 15/20ºC genotypes required significantly more PTU than at the lower temperature regime of 10/15ºC. On average 8398.59ºCdhr were required at the 15/20ºC temperature regime from planting date to budding stage and there were no significant differences between genotypes. At the lower temperature regime (10/15ºC) genotypes required on average 4737.63ºCdhr from planting to budding stage with significant differences between genotypes. Hyola 575 and 43Y85 required significantly less PTU than other genotypes.

Increase in night/day temperatures from 10/15ºC to 15/20º resulted in reduced number of days, increased GDD and PTU from planting to budding stage. Except for PTU at the 15/20ºC, genotypes showed significant differences with regard to number of days, GDD or PTU required from planting to budding stage. In general, later maturing genotypes such as Hyola 50, 45Y86 and 44Y85 tend to need more days and GDD, but not PTU to reach the budding stage when compared to earlier maturing Hyolal575, Hyola 571 and AGAMAX. However cultivar 43Y85 which is classified as an early maturing cultivar responded in a similar way than later maturing genotypes. Angadi et al., (2000) similarly observed different responses for three Brassica species to temperatures of 20/15ºC, 28/18ºC and 35/15ºC at the onset of the reproductive growth phase. Results agreed with the findings of Hartel (2012) who reported that canola grown under mean temperatures of 10.2ºC and 13.2ºC required 75 and 62 days from sowing to stem enlongation (budding) stage and subsequently accumulated 760ºCd and 747ºCd respectively.

Vol. 5, No. 03; 2020

ISSN: 2456-8643

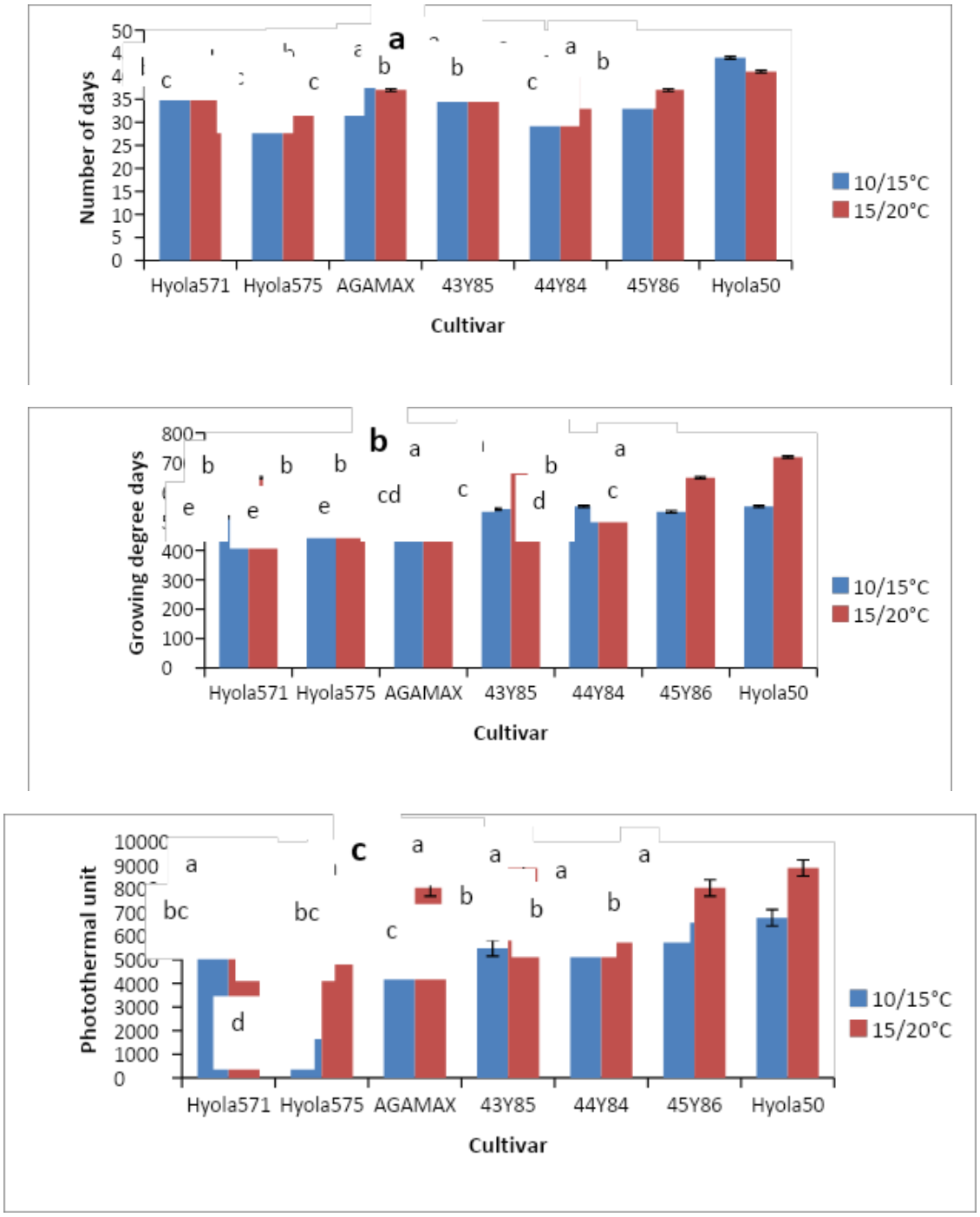


Figure 1. Effect of temperature on a) the number days, b) growing degree days (ºCd) and c) photothermal units (ºCdh) required from planting till the appearance of flower buds on the terminal stem region of different genotypes. Values/ bars with the same alphabetical lettering do not differ significantly at P=0.05

Vol. 5, No. 03; 2020

ISSN: 2456-8643

Flowering

Number of days, GDD and PTU required for all genotypes from planting to flowering (growth stage 4.1) in response to night/day temperature regimes of 10/15ºC and 15/20ºC are shown in Figure 4.At the 10/15ºC temperature regime genotypes required significantly more days from planting to flowering than at the 15/20ºC temperature regime (Figure 4a). At 10/15ºC genotypes required 60.32 days on average to reach the flowering stage, but significant differences were noticed between genotypes. Hyola 50 did not require significantly more days than 44Y84, but required significantly more days to flower than other genotypes. At 15/20ºC, genotypes on average required 50 days from planting to flowering, genotypes 44Y84, Hyola 50, 43Y85 and 45Y86, required significantly more days to flower than other genotypes.

The GDD requirement from planting to flowering increased significantly with an increase in night/day temperature from 10/15ºC to 15/20ºC (Figure 4b). On average, 871.25ºCd were required at 15/20ºC compared to 754.02ºCd at 10/15ºC. No significant differences were recorded at 15/20ºC between genotypes, 44Y84, 43Y85, Hyola50 and 45Y86, but these genotypes required significantly more GDD from planting to flowering than Hyola 571, Hyola 575 and AGAMAX. At 10/15ºC, Hyola 50 required with the exception of 45Y84, significant more GDD from planting to flowering than other genotypes.

Similarly, PTU requirement from planting to flowering also increased with increase in night/day temperature from 10/15ºC to 15/20ºC (Figure 11c). At higher temperatures of 15/20ºC genotypes required on average 10651ºCdhr compared to 9096ºCdh at 10/15ºC. Genotypes Hyola 50, 45Y86, 44Y84 and 43Y85, required significantly more PTU from planting to flowering than other genotypes at the higher temperature regime of 15/20ºC. At 10/15ºC, Hyola 571 required the lowest number of PTU and Hyola 50 the largest number of PTU to reach flowering stage.

Higher night/day temperature of 15/20ºC reduced number of days but increased GDD and PTU needed to develop from planting to flowering when compared to a lower night/day temperature of 10/15ºC. Genotypes responded differently at each temperature regimes with respect to number of days, GDD and PTU needed to reach flowering stage. The rate of biochemical reactions, including those involved in flowering are generally speed up as temperature increases. Therefore, the reduction in number of days to flowering of 10.38 days on average at higher temperature regime compared to the lower temperature regime could be as a result of this catalytic acceleration of biochemical processes involved as also shown by quite a number of previous studies (Fitter and Fitter, 2002, Hepper 2003, Kaesha 2009). Robertson (2002) also reported that increased temperature between 12 and 20ºC reduced number of days to flowering in 21 canola genotypes. Similar results were also reported by Tacarindua et al., (2013) for soybeans grown in a temperature gradient chamber.

On average, later maturing genotypes such as Hyola 50, 45Y86 and 44Y84 required more days, GDD and PTU to reach flowering stage than early maturing Hyola 471, Hyola 575 and AGAMAX. However, 43Y85 which is described as an early maturing cultivar but from a different breeding company, responded more like later maturing genotypes of the same breeding company. Robertson et al. (2002) reported that an early maturing canola type such as Monty required the range of 44-109 days to flowering, while mid maturing genotypes such as Hyola 42

Vol. 5, No. 03; 2020

ISSN: 2456-8643

required from 44-118 days and late maturing Pinnacle required from 47-124 days to flower, depending on day length and soil fertility conditions. Similarly, Slauenwhite and Qaderi (2013) reported that there were significant differences between four canola genotypes with respect to number of days to flowering and GDD accumulated at flowering.

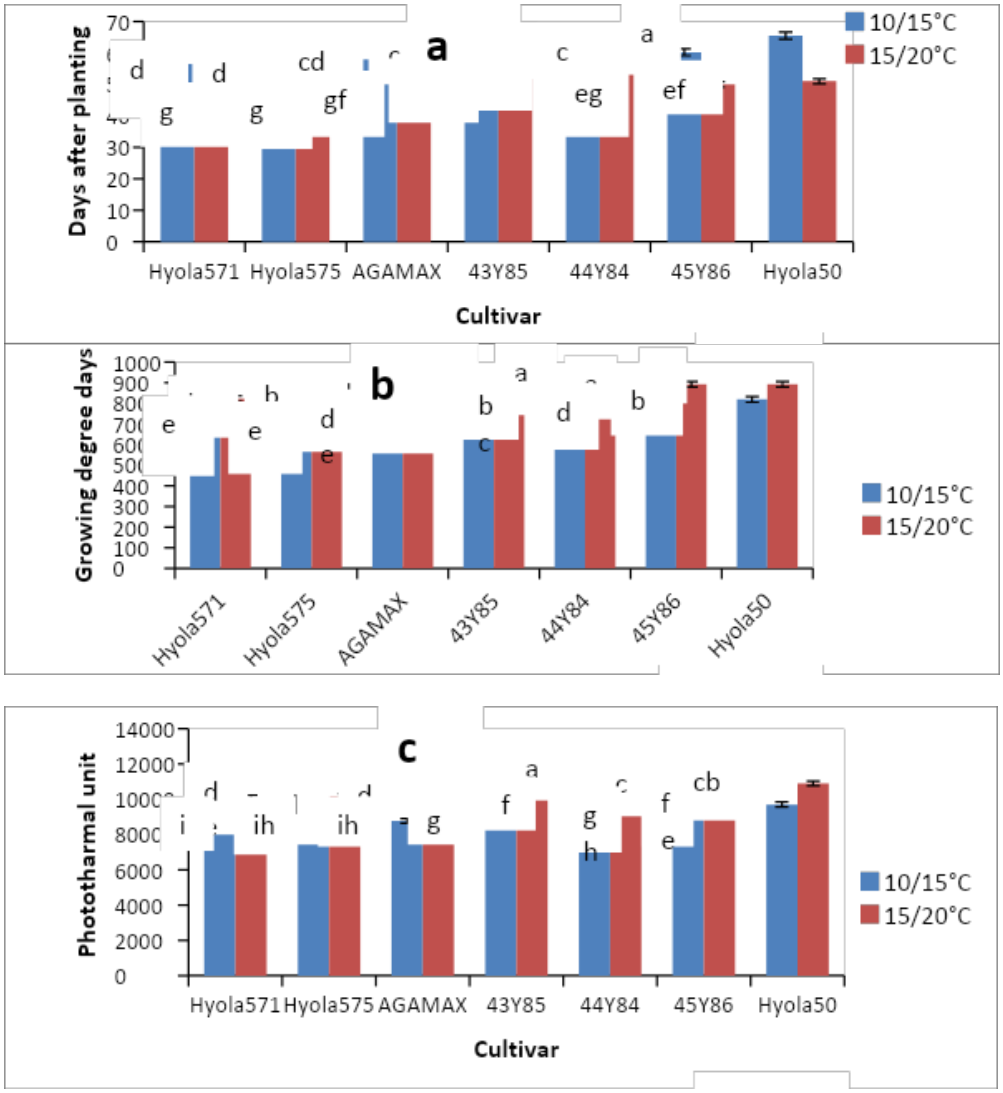


Figure 2. Effect of temperature on a) the number days, b) growing degree days (ºCd) and c) photothermal units (ºCdh) required from planting till the opening of the flower buds of different genotypes. Values/ bars with the same alphabetical lettering do not differ significantly at P=0.05

Seed ripening

Number of days after planting, GDD and PTU required by different genotypes grown at either 10/15ºC or 15/20ºC temperature regimes to reach the seed ripening stage (growth stage 5.1) are

Vol. 5, No. 03; 2020

ISSN: 2456-8643

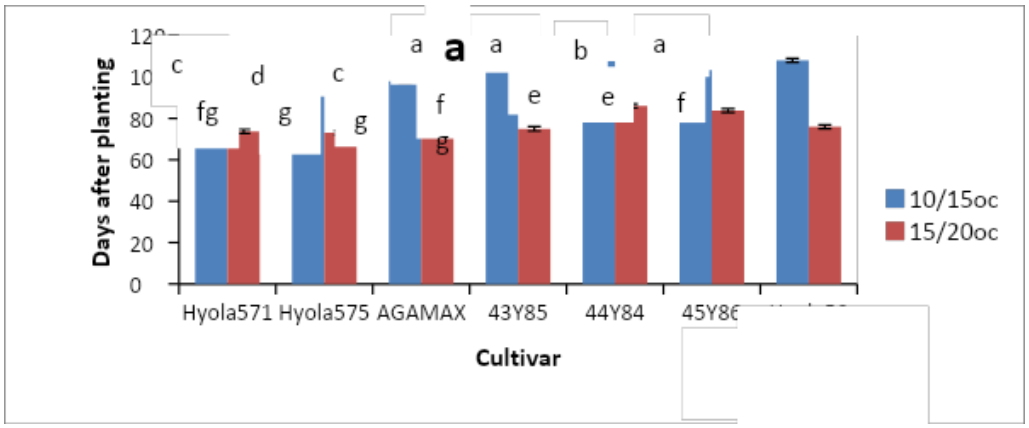
shown in Figure 5. Number of days from planting to seed ripening stage was significantly more when grown at 10/15ºC compared to 15/20ºC (Figure 5a). On the average, 102.42 days were required to reach seed ripening at the 10/15ºC compared to 77.21 days at 15/20ºC temperature regime. Significant differences between genotypes were recorded. Hyola 50, 44Y84 and 43Y85 required more days at 10/15ºC while 44Y84 and 45Y86 required significantly more days at 15/20ºC to reach seed ripening stage than other genotypes.

With the exception of 43Y85 and Hyola 50, all genotypes required significantly more GDD from planting to seed ripening at the 15/20ºC temperature regime than at the 10/15ºC temperature regime (Figure 5b). On average, 1347.64ºCd were required from planting to seed ripening at the 15/20ºC temperature regime, with 44Y84 and 45Y86 requiring significantly more GDD than other genotypes. At the 10/15ºC temperature regime genotypes required on average 1277.23ºCd to reach the seed ripening stage and with the exception of 43Y85 and 44Y84, Hyola 50 required significantly more GDD than other genotypes.

Similarly, with exception of 43Y85, PTU requirements for genotypes to reach the seed ripening stage were significantly more at 15/20ºC at 10/15ºC (Figure 5c). On average 15347.7ºCdhr were required from planting to seed ripening at the 15/20ºC temperature regime. Cultivar 44Y84, required significantly more PTU than other genotypes. At the 10/15ºC temperature regime, 14108.23ºCdhr were required on average but Hyola 50, 44Y84 and 43Y85 required significantly more PTU than other genotypes.

The increase in night/day temperatures from 10/15ºC to 15/20ºC reduced the number of days and with the exception of 43Y85 and Hyola 50 increased GDD and PTU from planting to seed ripening. Although significant differences were recorded between genotypes and their responses to increasing night/day temperature, responses did not show a clear relationship with maturity grouping.

Hartel (2012) reported that the responses of crops to mean temperatures of 10.2ºC and 13.2ºC after the end of flowering were increased at a greater rate compared to before flowering.



Vol. 5, No. 03; 2020

ISSN: 2456-8643

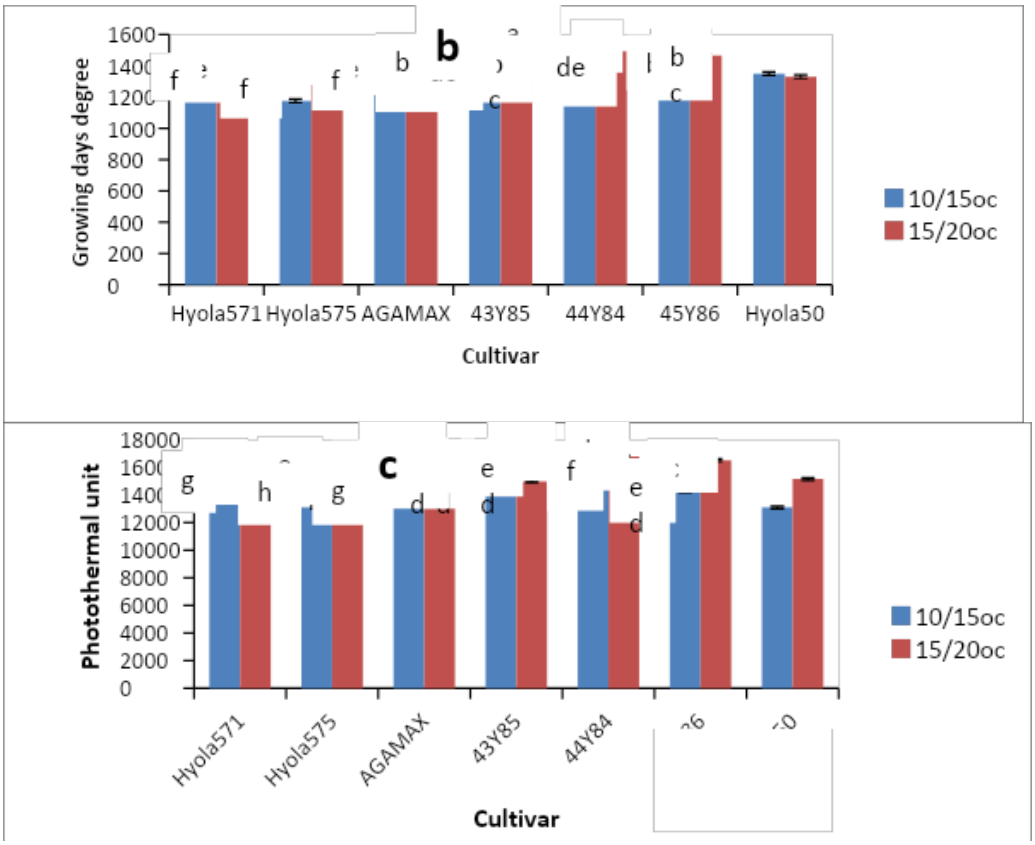


Figure 3. Effect of temperature on a) the number days, b) growing degree days (ºCd) and c) photothermal units (ºCdh) required from planting till seed ripening of different genotypes. Values/ bars with the same alphabetical lettering do not differ significantly at P=0.05

Physiological maturity

Number of days, GDD and PTU required by genotypes from planting to physiological maturity at 10/15ºC and 15/20ºC temperature regime are shown by Figure 6. Genotypes required significantly more days from planting to physiological maturity stage when grown at 10/15ºC than at 15/20ºC (Figure 6a). On average about 141.29 days were required from planting to physiological matured stage at a temperature of 10/15ºC, with cultivar 44Y84 requiring significantly more days than other genotypes. Hyola 50 and 45Y86 required more days than early maturing Hyola 571, Hyola 575, AGAMAX and 43Y85. At the 15/20ºC temperature regime, 113.20 days were required on average, with a similar trend between genotypes except for no significant difference between 44Y84 and 45Y86.

In contrast to number of days, GDD requirement from planting to physiological maturity were significantly more at the 15/20ºC temperature regime compared to 10/15ºC (Figure 6b). On average genotypes required 1981.04ºCd from planting to physiological maturity at 15/20ºC. Differences do exist between genotypes, with 44Y84, with the exception of 45Y86, requiring

Vol. 5, No. 03; 2020

ISSN: 2456-8643

significantly more GDD than other genotypes. Hyola 50 also requires more GDD than early maturing Hyola 571, Hyola 575, AGAMAX and 43Y85. At the 10/15ºC temperature regime genotypes required on average 1766.07ºCd from planting to physiological maturity and differences between genotypes showed a similar trend than for 15/20ºC.

The PTU requirement from planting to physiological maturity showed a similar trend than GDD with significantly more PTU required at 15/20ºC than at 10/15ºC (Figure 6c). On average, 21811.29ºCdhr were required at the 15/20ºC temperature regime. As in the case of GDD, 44Y84, with exception of 45Y86, required significantly more PTU than other genotypes, while Hyola 50 also required more PTU than early maturing Hyola 571, Hyola 575, AGAMAX and 43Y85. Whereas, at the 10/15ºC temperature regime, 18404.86ºCdhr were required on average and differences between genotypes were similar to that at the higher temperature regime. .

At physiological maturity an increase in night/day temperatures from 10/15ºC to 15/20ºC reduced number of days but increased GDD and PTU requirement of all genotypes tested. Significant differences were recorded between genotypes with mid maturing genotypes 44Y84, 45Y85 and to a lesser extend also Hyola 50 requiring significantly more days, GDD and PTU from planting to reach physiological maturity than early maturing Hyola 272, Hyola 575, AGAMAX and 43Y85.

The same trends of genotypes responses to the two temperature regimes with regard to number of days, GDD and PTU were observed as at budding, flowering and seed ripening with the exception that cultivar 43Y85 which behave similar to mid maturing genotypes at earlier growth stages, suddenly confirms its classification as an early maturing cultivar. It is also noteworthy that this particular cultivar shared most of morphological and physiological characteristics of mid-maturing type but only seem to have a shorter pod filling period. Therefore it appeared that 43Y85 has a unique physiological mechanism of rapid seed-filling and ripening processes which enabled it to catch up with early maturing genotypes after sharing the physiological trait(s) for lateness from germination to the beginning of seed-filling

Vol. 5, No. 03; 2020

ISSN: 2456-8643

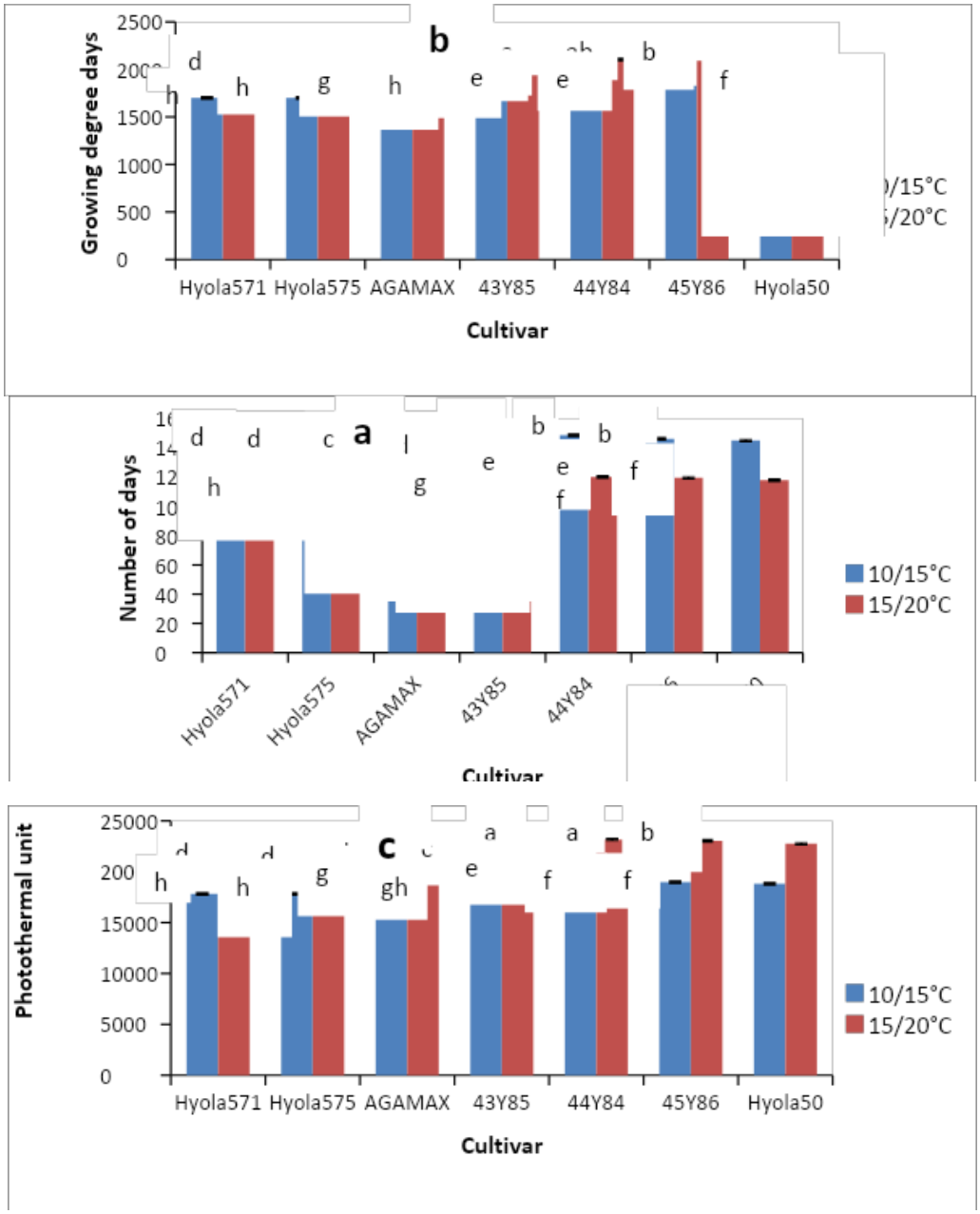


Figure 4 Effect of temperature on a) the number days, b) growing degree days (ºCd) and c) photothermal units (ºCdh) required from planting till physiological maturity of different genotypes. Values/ bars with the same alphabetical lettering do not differ significantly at p=0.05

Simple relationships between DAP, GDD and PTU and plant components at budding, flowering and final harvest stages.

In general poor correlations were observed between physiological parameters (DAP, GDD and PTU) and plant components (Table 1). This was especially true for correlations between GDD as

Vol. 5, No. 03; 2020

ISSN: 2456-8643

well as PTU with plant components. In both cases correlation coefficients did not show any trend with regard to plant growth stages (planting to budding, planting to flowering or planting to final harvest) and negative correlation were recorded for most plant components. This somewhat surprising result may be ascribed to the negative effects of the higher temperature regimes on most plant components while the higher temperature regime results in increases in GDD and PTU. Data from both temperature regimes were combined (because of the limited data points) to determine the relevant relationships and stronger correlations should be possible if enough data is available to do correlations for specific temperature regimes.

Correlations between the number of days after planting and plant components were generally positive and did show improving r-values with time (growth stage of the crop). The best correlations of r= 0.7259; r= 0.6097 and r= 0.5566 were shown between number of days to final harvest and plant dry mass (DM), pod dry mass (PDM) and number of pods per plant (NPP). The implication of these results is that as number of days from planting to final harvest increase dry mass, number pods plant-1 and pods dry mass at final harvest of canola genotypes increase. Whereas, increased GDD and PTU decreased total above ground dry mass, number of pods plant-1 and pods dry mass at final harvest.

Table 1 Simple relationships between some physiological and morphological traits of Canola genotypes

	DAP	BD	FL	FH
LA		-0.2311	0.3922	0.4822
DM		-0.3582	0.4320	0.7259*
PDM		0.4884	0.53323*	0.6097*
GDD		0.2860	0.0076	-0.1371
LA		0.4926	-0.6316*	-0.5056*
DM		-0.6227*6	-0.5947*-	-0.6013*
NPP		-0.6329*	-0.5750*	-0.5385*
PDM		-0.6329*	-0.5750*	-0.5385*
PTU		0.3257	0.5835*	-0.2240
LA		0.5085*	-0.0599	-0.5945*

Vol. 5, No. 03; 2020

ISSN: 2456-8643

DM	-0.4991	-0.6113*	-0.6400*
NPPP	-0.5610*	-0.5845*	-0.5989*
PDM	-0.5610*	-0.5845*	-0.5989*

*Significant at 5% probability. Number of days aGer planting (DAP), growing degree days (GDD), photothermal unit (PTU) from planting to budding (BD), planting to flowering (FL) and planting to final harvest(FH) and leaf area (LA), dry mass (DM), number of pods plant-1 (NPPP) and pod dry mass (PDM)

4. CONCLUSIONS

The results showed that increasing daily mean temperature from 12.5ºC to 17.5ºC , on average, reduced the duration from planting to visible flower buds appearance by 5.79 days, flowering time by 10.38 days, time to beginning of seed-filling by 25.39 days and from planting to physiological maturity by 28.09 days. However, there were differences among the genotypes. These reductions in the duration may however change if plants were grown at different day lengths. Increased GDD and PTU due to higher mean daily temperatures however, decreased the total above ground dry mass, number of pods plant-1 and pods dry mass at final harvest

In general, the results indicate that mid maturing genotypes, Hyola50, 45Y86 and 44Y84 and interestingly early maturing 43Y85 responded in similar manner during early growth stages, while Hyola 571, Hyola 575 and AGAMAX responded alike at both temperature regimes with respect to number of days, GDD and PTU. The mid-maturing genotypes and 43Y85 required more days, GDD and PTU from planting date to each of the growth stages studied. However at the physiological maturity, 43Y85, as classified, responded more like an early-maturing cultivar.

Therefore, it can be concluded that genotypes responded differently to night/day temperature regimes of 10/15ºC and 15/20ºC with respect to number of days, GDD and PTU from planting to budding, flowering, seed ripening and physiological maturity. Genotypes with intrinsic trait(s) for lateness tend to require more number of days, GDD and PTU from planting to these growth stages. Increases in night/day temperatures from 10/15ºC to 15/20ºC reduced number of days from planting date to all the growth stages and with exception of vegetative growth phase, increased GDD and PTU at all growth stages studied.

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Vol. 5, No. 03; 2020

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