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Behavioral variations due to effects of day length on yield and related characteristics of some *Brassica juncea* L. genotypes under hot humid continental conditions

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Abstract

The search for new oil seed crops in the low rainfall drought Central Anatolia has attracted researchers to profitable alternative crops like *Brassica* species in recent years. Breeding of a suitable oilseed crop for the Central Anatolia will provide a new rotational break for controlling soil borne diseases, weeds and drought stress that are very difficult to manage with prevailing agricultural practices. *Brassica juncea* L. is an important oilseed crop and is newly introduced in Turkey. This study was conducted to evaluate the developmental responses to 4 different day lengths and cosequently climatic conditions to screen 38 *B. juncea* genotypes for some oil yield related agronomic charachterisitics under hot humid climatic conditions of Yenimahalle, Ankara, Turkey. It was noted that early and delayed sown genotypes had synchronization towards flowering in the month of June with 15 h 01 min to 15 h to 39 min day length photoperiod. The results showed a significant effects of sowing dates day lengths and consequently climates upon genotypes for oil yield and agronomic traits. The maximum mean crude oil yield (38.4 g m^{-2}) was obtained from AK genotype. The results clearly describe that early sowing provides long period of vegetative growth with increased intake of photosynthates to plant sinks; that is not possible under late sowings.

Keywords: Minerals, Nutrition, Organic farming, Wheat bran

Introduction

Brassica juncea L. (brown mustard) is extensively used for extraction of industrial oils. They are also used as vegetable, spice, and production of pharmaceutical formulations (Kokcu et al., 2015; Kayacetin, 2020). *B. juncea* have an annual growth habit, herbaceous, yellow flowering ensued by seedset and are deep rooted (Guner et al., 2012). Occurrence of phenological events and yield of Brassica species are strongly related to day length related ontogenetic changes and climatic variations (Kar and Chakravarty, 2000).

B. juncea require a period of short, intermediate or neutral, short-long and long days for gradual moving from vegetative phase to flowering phase (Kumar et al., 2018). A delay in sowing dates (with increase or decrease in day length) can decrease seed yield from about 10 to 50% in different Brassica species and influence phenological development of crop plants (Shargi et al., 2011; Shekhawat et al., 2012). Phenological development in Brassica species change significantly by photoperied and temperature (Robertson et al., 2002). Sowing dates can have a significant and variable impact on different genotypes depending on their genetic backgrounds. No information is available on the response of *B. juncea* to spring sowing dates (long day length) for the genotypes grown in Turkey.

The target of the present study was to determine the optimum spring and mild summer sowing time or day lengths with gradual changing day length from short to long days + temperature on growth, development and yield performance of 38 improved *B. juncea* genotypes under hot humid continental

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climatic conditions.

Materials and Methods

The experiments were conducted during the growing seasons of 2017 at at the experimental fields located at Yenimahalle Ankara, Turkey (39°12′ - 43°6′ N, 35°58′ - 37°44′ E, and 925 m altitude), with hot humid continental conditions classified as Dsa type in the Koppen-Geiger climate classification system. The study compared performance of 38 *B. juncea* genotypes obtained from USDA gene bank and obtained from Konya, Turkey. These were multiplied and selected for use in the experiment in Central Research Institute for Field Crops during 2012-2017. All genotypes were grown under natural conditions without using any fertilizer or pesticides. Each genotype was sown manually in plots having three m long three rows for each genotype with 30 cm long unreplicated row spacings and sowing depth of ~1.0-1.5 cm and seed rate of 6000 kg ha^{-1} (Kayacetin, 2019). Sowing was done on four different spring dates (25th March–11 h 27 min to 13 h 26 min or short day length, 10th April-13 h 01 min to 14 h 37 min short to short–long day length, 25th April–13 h 01 min to 14 h 37 min short–long day length to intermediate day length and 10th May–14 h 02 min to 15 h 35 min long day length) and temperature.

Meteorological data pertaining to vegetation period (from March to August) of long term and 2017 climatic conditions of Yenimahalle, was obtained from the Meteorology Stations of the Central Field Crops Research Institute, Ankara, Turkey. There was total precipitation of 194.9 and 277.9 mm, average temperature of 17.0 and 17.6 ºC, and an average humidity of 53.5 and 51.3%, respectively during the experimental period (Table 1).

Table 1. Monthly meteorological data of mustard during growing season at the experimental area and photoperiod (h)

Climatic factors		Months					Total/Mean/ Max./Min.
		March	April	May	June	July	
Total precipitation (mm)	Long years	36.7	46.7	49.9	34.2	14.3	181.8
	2017	46.1	19.8	96.2	102.8	0.0	264.9
Mean relative humidity (%)	Long years	63.2	59.0	56.5	52.1	45.1	55.2
	2017	59.6	49.8	55.7	58.3	38.4	52.4
Mean temperature (ºC)	Long years	6.4	11.5	16.2	20.3	23.8	15.6
	2017	8.1	11.2	15.7	20.3	25.5	16.2
Maximum temperature (ºC)	Long years	21.4	25.7	29.3	33.6	36.2	36.2
	2017	19.9	27.2	29.2	35.8	38.3	38.3
Minimum temperature (ºC)	Long years	-5.9	-0.8	4.1	8.1	11.4	-5.9
	2017	-1.5	-1.0	5.0	9.0	14.2	-1.5
Photoperiod (h)	Max.	13 h 26 min	14 h 37 min	15 h 35 min	15 h 39 min	15 h 38 min	
	Min.	11 h 27 min	13 h 01 min	14 h 02 min	15 h 01 min	15 h 00 min	

Data were obtained from Meteorology Stations of the Central Field Crops Research Institute, Ankara, Turkey

The soil analysis during 2017, from the soil taken at a depth of 0-20, 21-40 cm showed low organic matter (1.32%), in alkaline (pH 7.81), limey (5.3%), and clay-loamy soils of the experimental plots (Table 2). The soil analysis was carried out at The Soil, Fertilizer and Water Resources Institute, Ankara, Turkey.

Table 2. Soil sample features belonging to the experimental area

Depth (cm)	Texture	Saturation content (%)	Total salt (%)	pH	Lime (%)	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})	Organic Substance (%)
0-20	Clay loamy	56.0	0.025	7.81	5.3	93	1260	1.35
21-40	Clay loamy	56.0	0.025	7.81	5.2	105	2400	1.28
Mean		56.0	0.025	7.81	5.3	99	1830	1.32

Data were obtained from Soil, Fertilizer and Water Resources Institute

The data about growth parameters including seedling emergence, 50% flowering and 90% physiological maturity, plant height, number of branches, number of capsules, and thousand seed weight were measured manualy; whereas, seed yield, seed weight and yield of individual genotypes was measured at about 8.5% moisture content (CFIA, 1999) on middle single rows as an average of 5 randomly selected plants for each genotype (Yousaf et al., 2002).

The oil content was determined by grinding 10 g of powdered samples of each genotype and hexane extracted using Gerhard 2000 apparatus for determining the crude oil content.

The mean, maximum and minimum values were calculated for all investigated parameters.

Results and Discussion

The days to emergence (8.3-14.9 d), days to 50% flowering (29.5-57.5 d), days to maturity (26.5-48.5 d), plant height (25.7-124.6 cm), number of branches (2.9-5.3 branch plant^{-1}), number of capsules (46.2-113.8 capsul plant^{-1}), thousand seed weight (0.8-1.8 g), seed yield (5.9-101.0 g m^{-2}), crude oil content (11.9-25.0%) and crude oil yield (0.7-25.8 g m^{-2}) showed differences among genotypes and the effects of varying environmental conditions at the time of 4 sowing dates used in the study (Table 3).

Among 38 genotypes the days to emergence, days to 50%

flowering, days to maturity, plant height, number of lateral branches, number of capsules, thousand seed weight, seed yield, crude oil content and crude oil yield changed between 10.3-19.3 d, 44.8-55.3 d, 31.0-38.3 d, 40.5-168.2 cm, 3.0-5.8 branch plant^{-1}, 54.9-118.3 capsul plant^{-1}, 0.5-2.2 g, 6.8-122.4 g m^{-2}, 19.2-27.7% and 1.7-38.4 g m^{-2}, in the same order for all genotypes (Table 3). Day length changed from 11 h 27 min to 13 h 26 min, 13 h 01 min to 14 h 37 min, 14 h 02 min to 15 h 35 min, 15 h 01 min to 15 h to 39 min and 15 h 00 min to 15 h 38 min during March, April, May, June and July 2017 respectively.

Days to emergence (d): Average of the genotypes relating to days to emergence showed maximum number of 14.9 d on 10th May or long days sowing date and the minimum days to emergence (8.3 d) on 25th March (short days) sowing date showed the effects of day length on seed germination (Table 3). Long day length with increased temprature, low soil moisture and relative humidity and precipittion induced poor seed germination taking more days to emerge from soil alongwith poor plant growth. Contrarily, short day length (March sowing) with appropriate low temperature, appropriate soil moisture, relative humidity and precipitation induced rapid seed germination and growth in agreement with (Angadi et al., 2003, Kayacetin et al., 2019). Taking an average of sowing dates the maximum days to emergence was determined as 13.0 d for B18 genotype while the minimum days to emergence was 10.3 d noted with number of other genotypes. This might be due to day length interaction with the genetic potential of the respective *B. juncea* genotypes.

Days to 50% flowering (d): As a mean of genotypes, the average longest days to 50% flowering (57.5 d) was obtained on 25th March sowing date while the mean earliest days to 50% flowering (29.5 d) was noted on 10th May (long days) sowing date (Table 3). This showed that first sowing on 25th March short day sowing helped the genotypes to to take the longest vegetative period with CO_2 assimilation and before transforming them for reproductive or generative phase; whereas, the condition reversed for 10th May long day sowing. Environmental conditions were harsh but day length conditions were appropriate for going of the genotypes from vegetative to generative phase reproductive phase. Tobe et al. (2013) evaluated early sown *B. napus* on 30th March short day conditions and found delayed 50% flowering and capsules induction compared to the late sown genotypes on 14th April 29th April and 14th May under temperate conditions at Ardabil (Iran). Similar findings were noted by Kumar et al. (2004) under semi arid tropic conditions. This study determined minimum days (44.3 d) to 50% flowering for AC1 genotype and the maximum days (48.3 d) to 50% flowering for B24-25-26 genotype.

Days to maturity (d): As a mean of genotypes; the maximum days to maturity (48.5 d) was obtained on 25th March short day sowing date, while the minimum days to maturity (26.5 d) was observed on 10th May long day sowing date (Table 3). Again, the time sowing was very effective and the prevailing environmental conditions (temperature, precipitation and humidity) and day length at earlier sown 25th March short day sowing had comulative positive effects at the time of harvesting. Therefore, 25th March short day sowing date was evaluated as the best and most appropriate sowing condition for these genotypes. Whereas 10th May long day sowing condition in interaction with prevailing environmental conditions was inapropriate and failed to induce the required positive generative stimulus to the plants of respective genotypes. Similar results were reported by Tobe et al., 2013. The maximum days to maturity were determined as 38.3 d for B20 genotype while the minimum days to maturity (d) were noted as 35.0 d for B16-17-18-21-24-25-26 genotypes. This could be attributed to different genetic potentials and backgrounds of the studied genotypes as affected by day length or 4 different photoperiods.

Plant height (cm): Mean of genotypes for plant height was the maximum for the genotypes sown on 25th March short days (113.8 cm) while the minimum height (46.2 cm) was noted on 10th May (long days) sowing. The results revealed that plant height decreased with delaying sowing dates. Plant height was maximum on 25th March (short days) sowings. This can be due to sowing date day length and prevailing environmental conditions during sowing. The day length changed from 11 hours 27 minutes to 15 hours 38 minutes in April to July before flowering. They had maximum time to grow and induce leaves with increased photosynthesis and CO_2 assimilation. This resulted in better plant length and plant yield on earlier sown genotypes. The results confirm earlier findings of Jat (2014) and Gawariya et al. (2015). The maximum plant height was noted as 118.3 cm for B20 genotype; whereas, the minimum plant height was obtained as 68.4 cm for B26 genotype. Variations in plant height at each sowing of different genotypes could be due to genetic backgrounds of the species included in this study.

Long days photoperiod and sub-optimal temperature conditions which prevailed during the emergence and subsequent vegetative growth inhibited vegetative growth on the late sown genotypes that forced the respective genotypes to mature earlier with earlier generative phase induction in late sown genotypes on 10th May (long days) sowing. March sown genotypes had long period of shoot growth necessary for improved plant height. This is desired for appropriate vegetative and reproductive growth. May sown genotypes received long day length of 14 h 02 min to 15 h 35 min; however on reaching optimum day length, the genotypes bolted and flowered precociously with reduced cell elongation and division and nutrient accumulation irrespective of their growth period. These results are in conformity to those reported by Thurling and Das (1980).

Number of branches (branche plant^{-1}): The significant differences among different sowing dates was determined for each genotype. The maximum number of branches (5.3 branch plant^{-1}) was obtained on 25th March (short days) sowing date while the minimum or least number of branches (2.9 branch plant^{-1}) was noted on the genotypes sown on 10th May (long days) sowing date. Induction of maximum number of branches plant^{-1} was noted on all genotypes on 25th March (short days) sowing date due to long period of growth and CO_2 assimilation before enetering of the genotypes into generative phase. Similar results have also been reported by Gawariya et al. (2015); Muhal and Solanki (2016). Average sowing dates showed the maximum number of 5.8 branches plant^{-1} for AC1 genotype;

whereas, the minimum number of 3.0 branches plant^{-1} were obtained for A10 genotype. This could also be due to variable genetic potential of the genotypes under consideration for each sowing and the prevaling environmental conditions at the time of sowing and harvest.

Table 3. Effect of sowing dates on growth, development and yield of the brown mustard genotypes used

Treatments	Days to emergence (d)	Days to 50% flowering (d)	Days to maturity (d)	Plant height (cm)	Number of branches (branch plant^{-1})	Number of capsules (capsul plant^{-1})	Thousand seed weight (g)	Seed yield (g m^{-2})	Crude oil content (%)	Crude oil yield (g m^{-2})
Sowing dates										
25th March	8.3	57.5	48.5	113.8	5.3	113.8	1.8	101.0	24.8	25.8
10th April	10.7	55.0	37.8	110.8	4.3	103.8	1.6	82.6	25.0	21.5
25th April	13.9	49.3	28.2	100.0	3.5	100.0	1.5	57.8	22.0	13.3
10th May	14.9	29.5	26.5	46.2	2.9	46.2	0.8	5.9	11.9	0.7
Average	11.9	47.8	35.3	92.7	4.0	91.0	1.4	61.8	18.3	15.1
Max.	14.9	57.5	48.5	113.8	5.3	113.8	1.8	101.0	25.0	25.8
Min.	8.3	29.5	26.5	46.2	2.9	46.2	0.8	5.9	11.9	0.7
Genotypes										
A2-Turkey, İzmir	10.3	48.0	35.3	92.2	4.8	92.2	1.3	122.4	23.2	37.2
A3-Turkey	10.3	48.0	35.3	101.3	3.9	101.3	1.5	84.5	24.2	27.3
A4-Turkey	10.3	48.0	35.3	95.4	4.2	95.4	1.5	72.4	23.5	22.5
A5-Turkey, Tekirdag	10.3	47.0	36.3	98.9	4.0	98.9	1.7	84.0	25.6	27.9
A6-Turkey, Kayseri	10.3	47.0	36.3	94.0	3.8	94.0	1.6	81.3	23.5	25.0
A7-Turkey, Tekirdag	10.3	47.0	36.3	95.5	3.8	95.5	1.6	76.2	25.8	25.3
A9-Turkey, Tekirdag	10.3	48.0	35.3	99.8	3.8	99.8	1.6	84.6	26.0	28.4
A10-Turkey, Kirklareli	10.3	48.0	35.3	100.4	3.0	100.4	1.4	79.5	23.9	25.0
A11-Turkey, Edirne	10.3	48.0	35.3	95.4	3.4	95.4	1.4	76.1	26.6	26.2
B4-Turkey	10.3	48.0	35.3	99.0	3.9	99.0	1.6	72.6	23.3	22.2
B5- Turkey, Tekirdag	10.3	48.0	35.3	103.1	4.8	103.1	1.6	69.1	24.8	22.7
B6-India	10.3	47.0	36.3	108.0	4.2	108.0	1.7	72.8	24.6	23.2
B7-India, Rajasthan	10.3	46.5	36.8	109.2	4.1	109.2	1.9	84.3	26.0	29.0
B8-Pakistan	10.3	47.0	36.3	100.8	3.8	100.8	2.2	65.6	24.2	20.6
B10-India	10.3	46.5	36.8	109.7	3.7	109.7	1.6	72.9	24.4	23.5
B12-Pakistan	10.3	47.0	36.3	104.4	3.8	104.4	1.8	80.1	26.0	27.7
B13-China	10.3	47.0	36.3	113.6	3.7	113.6	1.6	46.9	23.2	14.6
B14-China	10.3	48.3	35.0	115.1	3.8	115.1	1.5	89.2	25.3	29.4
B15-Pakistan	10.3	48.0	35.3	110.6	4.5	110.6	1.4	80.3	25.7	26.9
B16-Canada	10.3	48.3	35.0	115.2	3.8	115.2	1.3	82.0	23.6	24.8
B17-Canada	10.3	48.3	35.0	116.7	3.6	116.7	1.5	56.7	26.4	19.9
B18-United States, California	13.0	45.5	35.0	69.7	4.1	69.7	1.7	49.3	24.6	15.7
B20-Russian Federation	10.3	48.3	38.3	118.3	4.1	118.3	1.8	85.0	27.4	31.1
B21-Russian Federation	10.3	48.3	35.0	115.4	3.8	115.4	2.0	67.9	26.3	23.6
B22-China, Xizang	10.3	46.0	37.3	87.2	4.1	87.2	1.6	69.6	25.4	23.2
B23-Pakistan	10.3	46.0	37.3	100.0	3.8	100.0	2.2	102.5	26.8	35.2
B24-Germany	10.3	48.3	35.0	111.2	3.5	111.2	1.8	60.4	26.8	21.4
B25-Germany	10.3	48.3	35.0	111.8	4.2	111.8	1.5	87.8	25.4	29.2
B26-Italy, Calabria	10.3	48.3	35.0	68.4	4.0	68.4	1.4	53.3	24.4	17.2
B27-United States, Minnesota	10.3	46.0	37.3	106.8	4.1	106.8	1.7	90.6	24.5	28.9
B28-United States, Minnesota	10.3	46.0	37.3	106.4	4.3	106.4	1.4	93.0	25.5	31.8
BJ99-India	10.3	47.8	35.5	107.4	4.3	107.4	1.4	69.1	24.8	22.6
BJ20-India	10.3	48.0	35.3	108.9	4.2	108.9	1.6	95.3	25.9	32.4
AC1-India	10.8	44.8	38.0	78.3	5.8	78.3	1.5	109.0	24.9	36.5
AC2-India	11.5	46.5	35.5	81.0	5.3	81.0	1.6	41.5	24.1	13.4
B30-India	10.3	45.3	38.0	86.6	3.9	86.6	1.9	74.2	27.7	26.3
B33- India	10.3	46.0	37.3	85.2	4.2	85.2	2.0	40.6	25.6	13.6
AK-Turkey, Konya	10.3	47.8	35.5	106.2	3.9	106.2	1.8	114.2	25.2	38.4
Average	10.4	47.3	36.0	100.7	4.1	100.7	1.6	77.3	25.1	25.5
Max.	13.0	48.3	38.3	118.3	5.8	118.3	2.2	122.4	27.7	38.4
Min.	10.3	44.8	35.0	68.4	3.0	68.4	1.3	40.6	23.2	13.4

Number of capsules (capsule plant^{-1}): The maximum number of capsules (113.8 capsul plant^{-1}) were obtained on 25th March (short days) sowing date while the minimum number of capsules (46.2 capsul plant^{-1}) were obtained on 10th May (long days) sowing date. The plant needs long period of vegetation to grow and mature for higher yield. This is possible if vegetative period of growth is prolonged. This condition was provided by the e 25th March short days sowing of 38 genotypes ending up with maximum yield. The highest number of capsules plant^{-1} were noted due to this effect i.e. long period of vegetative growth. As expected precocious induction of generative phase had negative effects on growth and yield number of capsules plant^{-1} due to shorter period of growth to reach generative phase. The genotypes sown on during subsequent dates had shorter periods of vegetative growth generative phase ended up with reduced number of capsules leading to minimum number of capsules plant^{-1} on 10th May (long days) sowing. These plants from each of 38 genotypes were smaller in height and ultimately ended up with less number of branches and capsules plant^{-1}. The results are approved and confirmed by Gawariya et al., 2015. The maximum number of capsules was determined with 118.3 capsule plant^{-1} for B20 genotype; whereas, the minimum number of capsules (54.9 capsul plant^{-1}) were noted on B26 genotype. This might be primarily due to the environmental and photoperiod effects aided with genetic background in agreement with Kumar et al., 2008).

Thousand seed weight (g): Comparing average thousand seed weight of genotypes; the maximum thousand seed weight (1.8 g) was detected on genotypes sown on 25th March (short days). The minimum thousand seed weight (0.8 g) was recorded on genotypes sown on 10th May (long days). The plant needs long period of vegetation to grow before entering maturity. On account of favourable weather conditions, improvement in growth and yield up with the maximum seed weight gain in all genotypes of the 25th March short days sowings as described in this section. Precocious maturing due to 10th May sowing had negative effects on growth and thousand seed weight of genotypes as they had less time to transform from vegetative to generative phase. Higher temperature, drought and changed photoperiod during later phases of growth shortened the crop growth period and forced earlier maturity that resulted in reduced thousand seed weight and ultimately the minimum seed yield under subsequent sowings. High temperatures at flowering phase also cause reduction in seed yield leading to pollen sterility. Similar results were reported by Singh and Lallu-Singh (2014); Muhal and Solanki (2016). The maximum thousand-seed weight was determined with 2.2 g B8 and B23 genotypes. As a average of sowing dates; the minimum thousand seed weight was obtained (1.3 g) for B16 genotype (Table 3). The differences in the thousand-seed weight could be due to plastic genetic potential of the genotypes under 4 different environmental conditions induced by the effects of photoperiod for the genotypes in this study (Yousaf et al., 2013).

Seed yield (g m^{-2}): The maximum seed yield (101.0 g m^{-2}) was determined on 25th. March short days sowing date while the minimum seed yield (5.9 g m^{-2}) was noted on 10th May (long days) sowing date. The seed yield losses occured due to 10th May based late sowing date that decreased precocious entering into generative phase and ended up with low seed yield. The findings of Kar and Chakravarty (2000), also supported that precocious induction of generative phase in plants along with delayed sowing affected completation of seed formation, yield and decreased. This, with ultimate consequence of weak rudimentary and feeble seed induction. It is supposed that differences among sowing dates have plastic genetic potential under different photoperiod and environmental conditions like varying air temperatures, precipitation, humidity and the genetic potential of the genotypes in agreement with the results of Tripathi et al. (2005) and Tobe et al. (2013). Neog et al. (2013) also said that delayed sowing decreased the dry matter production. Angadi et al. (2003) showed that, *B. juncea*, *B. napus* and *B. rapa* significantly differed in optimum day/night temperatures; High temperatures, low humidity and precipitation and photoperiod at sowing and flowering also affected capsule development and yield. Every genotype needed two types of photoperiods necessary for vegetative and generative growth. A disruption in any of these, resulted in serious losses to yield. The results showed that the genotypes sown on 10th March, received appropriate photoperiod for vegetative growth ensued by optimum generative photoperiod to induce flowering. This emphasise that the flowering of the plant must be synchronized to an appropriate length of day light for CO_2 assimilation. March sowing allowed plants belonging to all genotypes have longer vegetative growing phase followed by entering in to generative phase. That was inverse in case of May sown genotypes receiving less time for vegetative and generative growth with overall negative implications on all quality and agronomic properties of the genotypes used in this study. 25th March (short days) sowing date accumulated more growing degree days due to long periods of sunshine. These gradually received increasing day length photoperiod in comparison to 10th May (long days) sowing date with less sunshine days of 14 h 02 min to 15 h 35 min day light photoperiod with lesser vegetative growth.

All genotypes began to recover from the stress by continuing flowering after returning to 20/15 °C. The maximum seed yield was determined in A2. A2 and AK (122.4 and 114.2 g, respectively) genotype. The differences in the seed yield of genotypes were due to the better performance of genotypes under the existing agro-climatic conditions of Ankara. This difference might be due to well adaptation and genetic potential of Brassica genotypes. Similar results were obtained by Yousaf et al. (2013) in other Brassica genotyppes under hot humid agro climatic conditions of Bahawalpur, Pakistan. The climate of Yenimahalle Ankara lies in the Central Anatolia with hot humid climate. The Bahawalpur lies very close to River Sutlej and Beyas with hot humid climate. The similarity between the two climates could be a potential reason for similarity in the results. Thurling and Das (1980) analyzed the reaction of six cultivars of spring rape (*B. napus*) to varieties in terms of planting dates. They demonstrated that both the span of vegetative phase and time of sowing of seeds was significant determinants in measuring yield of seeds. It was likewise demonstrated that variety in seed yield was fundamentally connected with variations in term of stem lengthening. They likewise found a direct connection between the plant growth rate and the average photoperiod, while the connection between the growth rate during warm days and the average photoperiod was curvilinear at low average photoperiod.

Kayacetin et al. (2019) also determined the adaptation of the Brassica species using planting season (spring and autumn planting) and locations in the terms of growth of the crop (emergence, 50% inflorescence, physiological maturity and total cultivation days), in 8 different locations under spring sowing conditions. They found that required total temperature for germination (118 ºC), flowering (453 ºC) and ripening (872 ºC) was higher during first year of study compared to the second year of study (71, 440, 620 ºC, respectively). They also found that the first year seed yield (1830 kg ha^{-1}) was higher compared to second year seed yield (1585 kg ha^{-1}). They further noted that plants from early spring sowing showed increased seed yield compared to the plants obtained from late spring sowing; because of the tendency of genotypes to mature earlier (short duration) by accumulating less heat units and long day length.

Crude oil content (%): A comparison among genotypes showed that the sowing dates day length affected the maximum crude oil content. Maximum crude oil content (25.0%) was determined on 10th April sowing, while the minimum crude oil content (11.9%) was recorded on 10th May (long days) sowing date. The crude oil content (24.8%) of 25th March (short days) sowing was statistically similar to 10th April sowing (25.0%). This suggest that a sowing date between these dates had no significant negative effect on quality parameters of these genotypes. Contrarily, Tobe et al. (2013) reported that 30th March sown spring canola had significantly higher percentage of oil as compared to 14th April, 19th April and 14th May sown crops. The difference in results could be due to different agro ecological and photoperiod conditions in the two experiments. Delayed sowing date cause a reduction in crude oil content due to precocious ripening under hotter and drier conditions (Pritchard et al., 2000). Comparing sowing dates the maximum crude oil content of 27.7% for B30 genotype while the minimum crude oil content of 23.2% for B13. The differences in the crude oil content could be due to genetic potential of the genotypes as affected by meteorological conditions and photoperiod (Yousaf et al., 2013).

Crude oil yield (g m^{-2}): A comparison among genotypes showed the maximum crude oil yield (25.8 g m^{-2}) was found on 25th March (short days) sowing date; whereas, the minimum crude oil yield (0.7 g m^{-2}) was noted on 10th May (long days) sowing date. Average of sowing dates among genotypes showed that the maximum crude oil yield was found for AK (38.4 g m^{-2}) while the minimum crude oil yield was noted for AC2 (13.4 g m^{-2}) genotype. 25th March (short days) sowing date and the genotypes AK had high seed yield, crude oil content and crude oil yield was maximum.

Conclusions

Following conclusions were drawn

Regardless of the dates of sowing all *B. juncea* genotypes used in this study flowered at the same synchronised time when the appropriate photoperiod was available.

Yield performance of *B. juncea* in regard to sowing date was distinctive and important for each period for its use as profitable alternative crop for hot humid climates. Each sowing date after first sowing; meant subsequent decrease in time of vegetative and generative growth of the next sown plants and ultimately studied agronomic characteristics of *B. juncea* genotypes in close association with their genetic background.

Out of 38 studied genotypes, the AK and A2 proved the best in performance in terms of growth, development and yield performance.

Compliance with Ethical Standards

Conflict of interest

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Author contribution

The author read and approved the final manuscript. The author verifies that the Text, Figures, and Tables are original and that they have not been published before.

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