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Effect of planting time and plant growth habits on phenological, physiological traits and associated with seed yield in African sarson (*Brassica carinata)*

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ABSTRACT

An experiment was conducted during two consecutive years to study the effect of planting times (15 October, 5 November and 25 November) and cultivars differing for growth habits (BJC-13-1, BJC-13-2, BJC-13-3, BJC-13-4) newly developed determinate type and (PC-5 indeterminate variety) on phenology and physiological traits of African sarson (Brassica carinata A. Braun). The experiment was laid out in split plot design with three replications keeping planting times in main plot and genotypes in sub-plots. Planting time had a significant influence on both phenology and physiological traits of African sarson. The early sown crop took less number of days (66) for flowering while late sown crop took more number of days (79). There was drastic reduction in flowering period (20.8days), siliquing duration (23.3days) and reproductive phase(27.2days). Early planted (15 October) cultivars intercepted more PAR, higher LAI and SPAD-chlorophyll values resulting in higher yield. The interactive effects of planting dates and the cultivars were significant ($p < 0.05$) for most of the features, which showed variable trends for the changes in the cultivars in response to planting dates. In all the cultivars, there was considerable deterioration in most of the studied traits due to delayed planting. Seed yield had positive association with siliquae duration (0.436), reproductive phase (0.426), SPAD (0.540) and LAI (0.701**) with first planting (15 October) whereas with late planting (5 November) correlation existed between seed yield and LAI (0.073) and PAR interception (0.086) while with only flowering duration (0.772**) with 25 November sowing.*

Keywords: *Brassica carinata*, planting time, phenology, physiological traits, correlation

INTRODUCTION

Ethiopian mustard (*Brassica carinata* A. Braun), a new emerging oilseed crop possesses a number of advantages over other *Brassica* species. It is tolerant to heat and drought stress conditions, possesses high protein content, low crude fibre in seed, highly productive, disease and pest resistant. It has good shatter resistance as well as large seed size. It is currently being evaluated as an option to the traditional canola/mustard cultivation, especially for low rainfall areas of the world (Zada *et al.* 2013). Inspite of these strong positive attributes, the crop suffers from several limitations like longer crop duration, poor harvest index, low oil quality characterized by high level of erucic acid, unacceptable level of meal glucosinolates and long plant stature. High erucic acid content in Ethiopian mustard has attracted a growing interest in using it in non-food applications (biodiesel, biopolymers, lubricants, soaps and surfactants). Sowing at proper time allows sufficient growth and development of a crop to obtain a satisfactory yield and different sowing dates provide variable environmental conditions within the same location for growth and development of crop and yield stability. Besides the environment, improved cultivars play a vital role in the crop production. To exploit the yield potential, certain agronomic practices need to be manipulated with different environments. Planting time is one of the most important non-monetary input which influences productivity of seed and oil to great extent. Breeding efforts have led to the development of dwarf and determinate plant types of Ethiopian mustard at Punjab Agricultural University, Ludhiana (India). Therefore, there was a dire need to study the phenological and physiological aspects of such determinate dwarf genotypes of Ethiopian mustard to harness the production potential with optimum sowing time.

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MATERIAL AND METHODS

Field experiments were conducted at the research farm of Oilseeds section, Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana during two consecutive winter seasons 2014-15 and 2015-16 (30^0 56' N 75^0 48' E, 247 meters above the mean sea level). The soil of experimental site was loamy in texture, neutral in reaction (pH = 7.0) and low in organic carbon, available nitrogen (207kg ha^{-1}), phosphorus (22.1 $kgha^{-1}$) and potassium (236.3 kg ha^{-1}). Experiment was laid in split plot design in three replications keeping sowing dates (15 October, 5 November and 25 November) in main and 5 genotypes of *B. carinata* (BJC-13-1, BJC-13-2, BJC-13-3, BJC-13-4) determinate plant types and PC-5, an indeterminate variety in sub-plots. Planting was done with hand driven drill keeping row to row distance of 30 cm and plant to plant distance of 10 cm. All the recommendations of package and practices were followed to raise a healthy crop. Phenological traits viz., days to initiation of flowering, 50% flowering, completion of flowering, flowering period, days to initiation of siliqua, 50% siliquae formation, completion of siliquae formation, siliquae duration, reproductive phase were computed with respect to planting dates. Physiological maturity in terms of days was also recorded. SPAD-chlorophyll values, LAI and PAR interception were recorded at 100% flowering between 11.00 A.M. to 2.00 P.M. The Soil Plant Analysis Development (SPAD) unit of Minolta Camera Co., Japan has developed SPAD 502 Chlorophyll Meter as a hand held self-convenient and light weight device for non-destructive estimation of amount of chlorophyll present in the leaves. For each observation second and third fully opened leaf from top was randomly selected from ten plants of each plot. The mean value of ten readings was reported as SPAD value. Care was taken that midrib of the leaf did not fall under sample area (sensor) of the instrument. The leaf area index (LAI) of the plant was recorded with Digital Plant Canopy Imager (CI-110) at random in each treatment. This instrument also reads the quantum response through wavelength range of 400-700 nm for Photosynthetic Flux Density (PPFD) and was used for PAR measurement. Observations were recorded just above soil surface i.e. beneath the crop canopy. The instrument was kept along the rows of the genotypes in the plot. Three readings were taken from top of crop surface. Correlation coefficients were computed for various studied traits with seed yield.

RSULTS AND DISCUSSION

Phenological traits

Planting time had visible effect on phenological behaviour of the crop differing for inflorescence type. Early sown (15 October) cultivars took lesser number of days for flower initiation, 50% flowering and completion of flowering as compared to later two dates of planting i.e. 5 November and 25 November while the trend was reverse in PC-5 an indeterminate cultivar. The number of days for achieving different phases of flowering declined progressively with delayed planting. Genotypic mean of planting time recorded lesser number of days for flower initiation, 50% flowering and completion or 100% flowering in determinate cultivars while PC-5 took more number of days for completion of these phases. Average of planting time revealed increase in number of days for flower initiation by 10.3 and 13.4 when planted at second and third date (Table 1). Early sown crop took lesser number of days to complete emergence than the late sowings and flowering was much advanced in late sowing as reported in *B. rapa* by Akhter *et al.* (2015) and rapeseed mustard varieties/lines by Alam *et al.*(2014). Determinate cultivars achieved 50% flowering almost at the same time while PC-5 took more days as indicated by genotypic mean. Average of planting time revealed increase in number of days to 4.5 and 6.2 days at second and third planting date. 50% flowering in mustard was delayed due to delayed sowing from 8 November to 18 December (Patel *et al.* 2004). However, the first sowing of rapeseed (*B. campestris*) genotype needed the highest (34 days) compared to second, third and fourth planting in canola (Tobe *et al.* 2013).Significant variation for completion of flowering occurred within the genotypes and with planting dates. PC-5, an indeterminate cultivar took more days than the four determinate plant types. 100% flowering occurred earlier at first planting date while cultivars took 6.1 and 7.5 days more when planted at second and third date. Flowering

Table 1: Phenological traits at three planting times in *B. carinata* cultivars differing for inflorescence types

Genotype	Days to flower initiation				Days to 50% flowering				Days to flowering completion				Flowering period (days)				Days to initiation of siliquae			
	D1	D2	D3	Mean	D1	D2	D3	Mean	D1	D2	D3	Mean	D1	D2	D3	Mean	D1	D2	D3	Mean
BJC-13-1	57.2 ±2.3	72.2 ±1.0	78.2 ±1.9	69.2	73.5 ±1.4	81.5 ±2.4	87.2 ±1.2	80.7	85.0 ±6.9	94.2 ±0.7	98.7 ±1.1	92.6	27.8 ±4.7	22.0 ±1.6	20.6 ±0.8	23.5	60.7 ±3.0	76.5 ±0.8	81.3 ±2.1	72.8
BJC-13-2	57.4 ±2.2	70.9 ±0.4	76.7 ±2.0	68.3	72.8 ±1.0	81.2 ±2.4	86.0 ±0.7	80.0	84.5 ±7.4	94.0 ±0.4	99.0 ±1.1	92.5	27.2 ±5.3	23.2 ±0.4	22.3 ±0.8	24.2	61.0 ±2.8	74.8 ±0.4	79.7 ±1.3	71.8
BJC-13-3	59.7 ±3.2	73.0 ±2.9	76.5 ±1.0	69.7	75.4 ±3.0	80.8 ±2.7	86.2 ±0.8	80.8	87.0 ±3.8	94.9 ±0.9	97.4 ±1.1	93.1	27.3 ±0.7	21.9 ±3.7	20.9 ±0.4	23.4	62.7 ±3.4	76.3 ±3.1	80.5 ±0.9	73.2
BJC-13-4	58.2 ±2.0	71.3 ±0.4	77.9 ±1.8	69.1	75.7 ±3.2	80.9 ±2.4	87.2 ±1.4	81.3	85.2 ±6.8	93.8 ±0.3	98.7 ±0.9	92.6	27.0 ±4.8	22.5 ±0.4	20.9 ±1.0	23.5	61.5 ±2.4	75.2 ±0.4	82.0 ±2.6	72.9
PC 5	97.4 ±2.8	93.7 ±3.9	87.0 ±1.3	92.7	114.7 ±1.1	110.5 ±1.0	96.5 ±1.0	107.2	121.5 ±3.2	116.5 ±0.4	106.5 ±0.7	114.9	24.2 ±0.6	22.8 ±4.0	19.5 ±0.7	19.5	104.2 ±5.6	95.2 ±4.3	90.0 ±1.1	96.5
mean	65.9 ±12.5	76.2 ±6.1	78.7 ±3.5		82.4 ±12.8	86.9 ±8.0	88.6 ±3.9		92.6 ±10.6	98.7 ±8.9	100.1 ±3.7		26.7 ±2.1	22.5 ±3.2	20.8 ±1.0		70.0 ±13.6	79.6 ±5.9	82.7 ±5.3	
CD 5 %	Y = 0.68, DOS = 0.58, G = 0.54, Y x DOS = 0.82, Y x G=0.76, DOS x G=0.93,Y x DOS x G = 1.32				Y = 0.58, DOS = 0.49,G = 0.32, Y x DOS = 0.69, Y x G = 0.45, DOS x G = 0.55, Y x DOS x G = 0.78				Y = 0.32, DOS = 0.49, G = 0.37, Y x DOS = 0.70, Y x G = 0.52, DOSxG=0.64, Y x DOS x G = 0.91				Y = 0.66, DOS = 0.25, G = 0.42, Y x DOS = 0.35, Y x G = 0.59, DOS x G = 0.73,Y x DOS x G = 1.04				Y = 0.74, DOS = 0.48, G = 0.36, Y x DOS = 0.68, Y x G=0.51, DOS x G = 0.62,Y x DOS x G = 0.88			
	Days to 50% siliquae Formation				Days to completion of siliquae formation				Siliquing duration (days)				Reproductive phase (days)				Days to maturity			
BJC-13-1	119.0 ±0.8	108.0 ±6.2	96.0 ±1.3	107.7	138.0 ±3.6	120.5 ±7.4	104.2 ±0.4	120.9	77.4 ±0.8	44.2 ±8.1	22.8 ±2.2	48.1	80.9 ±1.5	48.5 ±8.3	26.0 ±2.0	51.8	164.5 ±0.4	144.5 ±0.4	123.5 ±1.0	144.2
BJC-13-2	119.7 ±0.4	109.4 ±6.7	96.0 ±1.3	108.4	138.0 ±3.2	120.0 ±8.2	103.9 ±0.4	120.6	77.0 ±0.5	45.2 ±8.3	24.2 ±1.3	48.8	80.7 ±1.1	49.2 ±8.3	27.2 ±2.0	52.4	164.5 ±0.4	144.5 ±0.4	123.5 ±1.0	144.2
BJC-13-3	120.5 ±1.5	107.0 ±7.1	96.0 ±1.3	107.8	138.3 ±4.2	119.0 ±8.0	69.4 ±0.4	108.9	75.7 ±0.9	40.9 ±11.1	25.7 ±1.0	47.4	78.7 ±1.2	44.5 ±10.9	29.2 ±1.2	50.8	165.5 ±0.4	144.5 ±0.4	123.5 ±1.0	144.5
BJC-13-4	120.7 ±1.1	111.0 ±7.2	96.0 ±1.3	109.2	138.2 ±4.4	118.9 ±7.8	69.0 ±0.7	108.7	76.7 ±2.0	43.7 ±7.9	21.5 ±3.1	47.3	80.0 ±2.5	47.5 ±7.8	25.7 ±2.4	51.1	164.5 ±0.4	144.5 ±0.4	123.5 ±1.0	144.2
PC 5	145.5 ±1.0	140.2 ±3.7	106.0 ±1.3	130.6	160.5 ±4.1	147.0 ±3.8	112.5 ±1.6	140.0	56.4 ±9.7	51.9 ±8.1	22.5 ±2.7	43.6	63.2 ±6.9	53.4 ±7.7	25.5 ±2.9	47.4	187.0 ±0.3	165.5 ±0.4	145.5 ±0.4	166.0
mean	125.1 ±9.7	115.1 ±8.4	98.0 ±3.2		142.6 ±7.8	125.1 ±8.0	91.8 ±2.7		72.6 ±5.8	45.2 ±2.4	23.3 ±1.4		74.8 ±4.7	50.9 ±2.2	27.2 ±1.6		169.2 ±7.1	148.7 ±6.7	127.9 ±7.0	
CD 5 %	Y = 0.93, DOS = 0.39, G = 0.34, Y x DOS = 0.55, Y x G = 0.48, DOS x G=0.59, Y x DOS x G = 0.83				Y = 0.16, DOS = 0.34, G = 0.36, Y x DOS = 0.48, Y x G = 0.51, DOS x G=0.63, Y x DOS x G = 0.89				Y = 0.26, DOS = 0.49, G = 0.48, Y x DOS = 0.69, Y x G = 0.68, DOS x G=0.83, Y x DOS x G = 1.17				Y = 0.76, DOS = 0.85,G = 0.64, Y x DOS = 1.21, Y x G = 0.90, DOS x G =1.11,Y x DOS x G = 1.57				Y = 0.34, DOS = 0.22, G = 0.16, Y x DOS = 0.31, Y x G = 0.23, DOS x G = 0.28, Y x DOS x G = 0.39			

period was longer during first planting in all the cultivars and was much advanced in the later two dates. Flowering duration was comparable in BJC-13-1, BJC-13-3 and BJC-13-4 as indicated by genotypic mean. Average flowering period was reduced by 4.2 and 5.9 days with late plantings. The longest flowering period (31 days) and shortest (23 days) has been recorded in spring canola by Tobe *et al.* (2013). Delayed planting of oilseed rape led to a significant decline in flowering period (Shamsi *et al.* 2012).Initiation of siliqua took longer time in PC-5 at three planting dates (Table 1). Determinate cultivars took lesser days for siliqua initiation at first planting but the days increased concomitantly as the plantings were delayed. However, in PC-5, siliqua initiation was earlier as with second (95.2days) and third (90.0days) planting dates. Mean of the planting dates indicated comparable but lesser days for siliqua initiation in determinate cultivars than in indeterminate cultivar (PC-5). Late sowing (29 November) delayed pod initiation in *B. juncea* as compared to early sowing (30 October) as reported by Singh *et al.* (2014). Cultivars took less days for siliqua initiation with first date which increased to 9.8 and 12.4 days with two late plantings.

Mean of two years also showed that in PC-5, days for 50% siliquing were more than the four determinate types at three sowing dates. Cultivars took more days for 50% siliquing at first planting time and the days declined with delayed planting. Four determinate cultivars took 96.0 days for 50% siliquae formation at third planting date. Within genotypic mean, PC-5 took 130.6 days while BJC-13-1 and BJC-13-3 took almost 107.0 days. Average of planting time revealed more days to reach 50% siliquing at first planting which was reduced by 10.0 and 27.1 days at second and third planting. Similar findings have been reported by Tobe *et al.*(2013) where longest time (75.4days) to reach 50% pod development belonged to first sowing and shortest time of 47.6 days belonged to last sowing. Trend for 100% siliquing was similar to 50% siliquae formation. Overall, cultivars took lesser days for completion of siliquae formation by 17.5 and 50.8 days during 5 and 25 November planting compared to 15 October planting. Siliquae duration declined with delayed planting being highest when cultivars were planted at first date (15th October). Early planting (15 October) had maximum siliquae duration in determinate cultivars; PC-5 at second sowing date (15 November) and duration was comparable at third sowing date (Table 1). Siliquing duration was 72.6 days and was reduced by 27.4 and 49.3 days at second and third sowing date according to average planting times. Genotypic mean revealed maximum siliquae duration of 49.8 days in BJC-13-2. Two years of study indicated significant variation for reproductive phase among the genotypes differing for stem growth habits and also with sowing dates. Reproductive phase had a similar trend as recorded for siliquing duration in the present investigation. BJC-13-2, as per genotypic mean had reproductive phase of 52.4 days. Average planting time reported a decline in reproductive phase with delayed planting to 23.9 and 47.6 days with second (15 November) and third (25 November) sowing respectively, over first date of sowing 15 October(Kaur *et al.* 2019).

Numbers of days were significantly more in 15 October sowing for physiological maturity as compared to 5 and 25 November sowing. However, PC-5 took more days to mature at three planting dates compared to four determinate cultivars. In comparison to the means of cultivars, physiological maturity was achieved in statistically similar number of days in determinate cultivars while cultivar PC-5 took 166.0 days. Comparison of the average effects of planting times revealed cultivars matured earlier by 20.5 days when planted at second date and took 41.9 days less to mature at third planting date. These results are in consonance with the study of Patel *et al.*(2013) and Alam *et al.*(2014).The effects of planting dates and the cultivars on phenological features were significant ($p < 0.05$), delayed planting caused a significant reduction in length of flowering period, siliquing duration and reproductive phase. However, days to flower and siliqua initiation and also 50% and 100% flowering increased in determinate plant types and declined in indeterminate cultivar. The reduction in crop duration, reproductive phase may be attributed to higher temperature and increased photoperiod in later sowing dates due to which heat requirements of different phases were met earlier under late planting. However, statistically significant reduction in rest of the pheno-phases were recorded with delayed planting (Shamsi *et al.* 2012 and Akhter *et al.* 2015).

Table 2: Physiological traits in *B. carinata* cultivars as influenced by planting dates and inflorescence types at 100% flowering stage (mean of 2 years)

Genotype	SPAD-chlorophyll values				Leaf area index				Photosynthetic active radiation			
	D1	D2	D3	Mean	D1	D2	D3	Mean	D1	D2	D3	Mean
BJC-13-1	39.2 ±0.9	37.0 ±0.5	33.3 ±0.4	36.5	1.30 ±0.03	1.28 ±0.09	1.27 ±0.05	1.28	93.5 ±0.7	84.9 ±2.3	71.3 ±1.1	83.2
BJC-13-2	39.5 ±1.7	38.4 ±1.4	33.6 ±0.2	37.2	1.84 ±0.05	1.40 ±0.15	1.30 ±0.10	1.51	93.0 ±1.2	84.1 ±1.4	75.3 ±1.2	84.1
BJC-13-3	40.9 ±0.3	36.5 ±1.4	35.2 ±0.9	37.5	1.64 ±0.02	1.51 ±0.05	1.39 ±0.10	1.51	95.0 ±0.6	85.7 ±1.1	71.9 ±0.5	84.2
BJC-13-4	41.1 ±1.2	39.5 ±0.3	37.9 ±0.3	39.5	1.65 ±0.10	1.57 ±0.05	1.42 ±0.08	1.55	92.0 ±0.7	85.5 ±1.6	77.8 ±2.1	85.1
PC 5	39.6 ±1.0	37.6 ±0.2	35.0 ±0.9	37.4	1.73 ±0.01	1.65 ±0.01	1.42 ±0.01	1.60	94.9 ±1.1	86.6 ±1.3	77.1 ±0.7	86.2
Mean	40.1 ±0.6	37.8 ±0.8	35.0 ±1.3		1.63 ±0.14	1.48 ±0.11	1.36 ±0.05		93.7 ±0.9	85.3 ±0.7	74.7 ±2.1	
CD 5 %	Y= 0.42, DOS= 0.32, G = 0.35, YxDOS=NS, YxG=0.49, DOSxG=0.61, YxDOSxG=0.86				Y = 0.01, DOS = 0.01,G = 0.01, Y x DOS = 0.02, Y x G =0.02, DOSxG = 0.02, Y x DOS x G = 0.03				Y=0.53, DOS= 0.79, G=0.89, YxDOS=1.13, YxG=1.25, DOSxG= 1.54,Y x DOS x G= 2.17			

Table 4: Correlation coefficient between phenological and physiological traits with seed yield at first planting date (below the diagonal) and second planting date (above the diagonal)

	I.F	50% F	100% F	F.D	I.S	50% S	100% S	S.D	R.P	M	SPAD	LAI	PAR	SY
I.F	1	0.996**	0.999**	0.937**	0.999**	0.983**	0.994**	0.889**	0.672**	0.997**	-0.165	0.644**	0.778**	0.503*
50% F	0.999**	1	0.999**	0.961**	0.997**	0.994**	0.994**	0.926**	0.732**	0.999**	-0.098	0.632**	0.735**	0.535*
100% F	0.999**	0.998**	1	0.954**	0.998**	0.990**	0.995**	0.908**	0.701**	0.999**	-0.126	0.648**	0.754**	0.529*
F.D	-0.638**	-0.646**	-0.624**	1	0.936**	0.974**	0.962**	0.964**	0.822**	0.961**	0.093	0.631**	0.574*	0.662**
I.S	0.999**	0.999**	0.999**	-0.635**	1	0.984**	0.996**	0.899*	0.688**	0.997**	-0.162	0.623**	0.769**	0.499
50% S	0.999**	0.999**	0.998**	-0.661**	0.999**	1	0.991**	0.939**	0.781**	0.994**	0.012	0.676**	0.728**	0.509*
100% S	0.999**	0.998**	0.999**	-0.628**	0.999**	0.999**	1	0.933**	0.739**	0.998**	-0.109	0.605**	0.716**	0.552*
S.D	-0.999**	-0.999**	-0.999**	0.645**	-0.999**	-0.999**	-0.998**	1	0.917**	0.920**	0.129	0.454	0.467	0.629**
R.P	-0.998**	-0.997**	-0.998**	0.652**	-0.997**	-0.997**	-0.995**	0.998**	1	0.725**	0.466	0.359	0.273	0.443
M	0.999**	0.998**	0.999**	-0.624**	0.999**	0.998**	0.999**	-0.999**	-0.997**	1	-0.094	0.647**	0.744**	0.529*
SPAD	-0.252	-0.232	-0.262	-0.346	-0.264	-0.239	-0.283	0.243	0.206	-0.273	1	0.279	-0.19	-0.159
LAI	0.283	0.269	0.268	-0.792**	0.282	0.301	0.273	-0.295	-0.295	0.275	0.211	1	0.788**	0.073
PAR	0.561*	0.535*	0.568*	-0.066	0.553*	0.529*	0.537*	-0.567	-0.588*	0.564*	-0.149	0.018	1	0.086
SY	-0.448	-0.455	-0.462	-0.319	-0.451	-0.430	-0.462	0.436	0.426	-0.458	0.540*	0.701**	-0.346	1

*I.F = Initiation of flowering, 50% F = 50% flowering, 100% F = 100% flowering, F.D = Flowering duration, I.S = Initiation of siliqua, 50% S = 50% siliquae formation, 100% S = 100% siliquae formation, S.D = Siliquae duration, R.P = Reproductive phase, M = Maturity, SPAD = SPAD-chlorophyll values, LAI = Leaf area index, PAR = Photosynthetic active radiation, *and** indicated significant at 5% and 1% level of probability*

Physiological traits

The effects of planting dates and the cultivars differing for growth habits were significant ($p < 0.05$) for the physiological features at 100% flowering. Cultivars possessed higher SPAD values, LAI and also intercepted more radiations when sown on 15 October. However, reduction was recorded with delayed sowings. BJC-13-4 possessed maximum SPAD-chlorophyll values at three planting dates. Genotypic mean for SPAD values were highest in BJC-13-4 (39.5) and statistically similar in BJC-13-2 (37.2), BJC-13-3 (37.5) and PC-5 (37.4). Delayed sowing reduced SPAD-chlorophyll values by 5.7% (5 November) and 12.7% (25 November) over 15 October sowing. These results are confirmatory with the findings of Chauhan *et al.* (2014) and Fariduddin *et al.* (2014) in Indian mustard (*B. juncea*).BJC-13-2 registered highest LAI of 1.84 followed by PC-5 (1.73) when planted at first (15 October) date. At second sowing date, PC-5 had LAI of 1.65 and was statistically similar (1.42) in BJC-13-4 and PC-5 at third date. Genotypic mean indicated highest LAI of 1.60 in PC-5 and comparable in BJC-13-2, BJC-13-3 (1.51) and BJC-13-4 (1.55). LAI declined by 5.4% and 13.1% with late planting on 5 November and 25 November, respectively. Delayed sowing reduced LAI as reported by Singh and Singh (2014) and Chauhan *et al.* (2014) in *B. juncea*. Low temperature during delayed sowing reduced LAI (Patel *et al.* 2013) and in *B. rapa* by Akhter *et al.* (2014) and again by Akhter *et al.* (2015).Early planted (15 October) cultivars intercepted maximum photosynthetic active radiations and therefore possessed higher LAI and chlorophyll values. Delayed planting reduced plant growth resulting in reduced PAR interception, LAI and chlorophyll and ultimately seed yield. Genotypic mean recorded highest PAR interception by PC-5 (86.2%) and was statistically similar in BJC-13-2 (84.1%) and BJC-13-3 (84.2%). Average of planting time indicated decline of 8.9% and 20.3% in PAR at second (5 November) and third planting date (25 November).

Seed yield

Overall mean, BJC-13-2 possessed maximum seed yield at three sowing dates. BJC-13-1 had the least seed yield with first date and third date whereas BJC-13-4 with second date (Table 3). Seed yield varied from 0.215 g m^{-2} (BJC-13-1) to 0.258 gm^{-2} (BJC-13-2) as indicated by genotypic mean. Seed yield was reduced by 41.4% and 61.7% with delayed sowings compared to first date. Seed yield in rapeseed-mustard varieties was achieved by first date of sowing (20th October) (Dinda *et al* 2015). The seed yield in Indian mustard (*B. juncea*.) was significantly higher in 20th October (2049.73 $kgha^{-1}$) than 10th November (1437.3 $kgha^{-1}$) and 30th November (915.08 kg ha^{-1}) sowing dates (Yogesh *et al* 2011). Higher seed yield was obtained with first sowing date of 30th August as compared to second sowing date in 27thJanuary as reported by Rafiei *et al* (2011). Seed yield successively decreased with delay in sowing from 14 November to 29 November (Singh *et al* 2014; Singh and Singh 2014)

Table 3: Effect of planting time and plant grwoth habits on seed yield in *B.carinata*

Genotypes	Seed Yield (g m^{-2}) Mean of two years			
	D1	D2	D3	MEAN
BJC-13-1	0.335 ±0.08	0.192±0.03	0.117±0.01	0.215
BJC-13-2	0.378 ±0.06	0.24±0.05	0.156±0.02	0.258
BJC-13-3	0.368 ±0.04	0.194±0.05	0.13±0.01	0.230
BJC-13-4	0.369±0.05	0.168±0.04	0.147±0.01	0.228
PC 5	0.343±0.05	0.235±0.04	0.12±0.01	0.233
MEAN	**0.35**±0.02	**0.205**±0.02	**0.134**±0.01	
CD(p=0.05)	Y = NS, DOS = 0.019 G = NS, Y x DOS = 0.027 Yx G= NS, DOSxG = NS Y x DOS xG = NS			

Correlations studies

50% flowering and initiation of flowering (0.99**) were significantly correlated. Positive and highly significant correlation existed between 100% flowering, initiation of flowering (0.99**) and 50% flowering (0.99**). Similar results have been reported by Belete (2011). Positive association was found between siliquae and flowering duration (0.645**), reproductive phase with flowering duration (0.652**) and reproductive phase and siliquing duration (0.998**). Highly significant positive correlation occurred between days to maturity and all the phenological traits except flowering duration (-0.624**), siliquae duration (-0.999**) and reproductive phase (-0.997**). SPAD-values were positively associated with siliquae duration and reproductive phase however the magnitude of association was low. PAR had positive correlation with all the studied traits except with flowering duration (-0.066), siliquae duration (-0.567), reproductive phase (-0.588) and SPAD values (-0.149). Seed yield had positive correlation with siliquae duration (0.436), reproductive phase (0.426), SPAD values (0.540*) and LAI (0.701**) indicating more the length of siliquing duration and reproductive phase along with higher SPAD-chlorophyll values and leaf area index ultimately contributing to seed yield (Table 4). These results are in confirmation to the findings of Belete (2011).Positive significant correlation existed between different phenological and physiological traits at second planting date (15 November) except for SPAD with different phases of flowering, siliquing and maturity.

Table 5: Correlation coefficients among 14 traits in five genotypes Ethiopian mustard genotypes tested for 2 years

	I.F	50% F	100% F	F.D	I.S	50% S	100% S	S.D	R.P	M	SPAD	LAI	PAR	SY
I.F	1													
50% F	0.998**	1												
100% F	0.985**	0.983**	1											
F.D	-0.859**	-0.861**	-0.758**	1										
I.S	0.993**	0.995**	0.965**	-0.890**	1									
50% S	0.986**	0.992**	0.984**	-0.815**	0.978**	1								
100% S	0.569*	0.539*	0.639*	-0.252	0.466	0.553*	1							
S.D	-0.423	-0.386	-0.396	0.386	-0.435	-0.287	-0.179	1						
R.P	-0.748**	-0.713**	-0.736**	0.619*	-0.727**	-0.638**	-0.561*	0.883*	1					
M	0.986**	0.992**	0.984**	-0.815**	0.978**	0.999**	0.553*	-0.287	-0.639**	1				
SPAD	0.0278	0.0457	-0.0268	-0.175	0.135	0.012	-0.712**	-0.432	-0.114	0.011	1			
LAI	0.444	0.480	0.396	-0.515*	0.542*	0.477	-0.448	-0.202	-0.143	0.477	0.813**	1		
PAR	0.464	0.466	0.527*	-0.183	0.495	0.457	0.028	-0.618**	-0.546*	0.457	0.619**	0.619**	1	
SY	-0.504*	-0.496	-0.381	0.772**	-0.501*	-0.452	-0.304	0.058	0.316	-0.452	0.277	0.021	0.433	1

*I.F = Initiation of flowering, 50% F = 50% flowering, 100% F = 100% flowering, F.D = Flowering duration, I.S = Initiation of siliqua, 50% S = 50% siliquae formation, 100% S = 100% siliquae formation, S.D = Siliquae duration, R.P = Reproductive phase, M = Maturity, SPAD = SPAD-chlorophyll values, LAI = Leaf area index, PAR = Photosynthetic active radiation , *and** indicated significant at 5% and 1% level of probability*

Reproductive phase had positive correlation with flowering duration (0.62**) and siliquing duration (0.88**). LAI was positively correlated with initiation of siliquing (0.54*) and highly significant with SPAD values (0.81**). Association between PAR and 100% flowering (0.53*), SPAD (0.62*) and LAI (0.62*) was positive and significant. Seed yield was highly but significantly correlated with flowering duration (0.77**) at third planting date (25 November) (Table 5). Under late plantings flowering duration and LAI seems to be correlated with higher seed yield. Although in planting date studies of rapeseed and other *Brassica* species, correlation among the yield and associated traits were noticed but in few studies the variations of correlations among the traits were stressed (Molazem *et al.* 2013).

Phenological and physiological traits were significantly affected by the cultivars differing for plant growth habits and also with planting dates. The interactive effects of planting date and the cultivars (DOS x G) were significant for the studied traits indicating the variability and differential behavior resulting not only due to planting dates but greatly due to inflorescence types. Delayed planting drastically reduced both phenological and physiological traits consequently influencing seed yield. Amongst different dates of sowing and cultivars, first sowing (5 October) and cultivar BJC-13-2 realized significantly higher seed yield due to positive association with siliquae duration, reproductive phase, SPAD-chlorophyll and LAI

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