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Evaluating morpho-physiological and quality traits to compliment seed yield under changing climatic conditions in *Brassicas*

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Abstract

A study was conducted under irrigated conditions to test the performance of improved cultivars of Indian mustard (*B. juncea*), Gobhi sarson (*B. napus*) and African sarson (*B. carinata*) under changing climatic conditions. The effect of cultivar, environment and their interactions were significant in mustard and canola gobhi sarson. Environment had significant impact on all the studied traits except for leaf area index (LAI). Cultivar x Year (G x Y) interaction was significant for flowering behavior, days to maturity, SPAD, photosynthetic active radiations (PAR), growth parameters, yield components and yield except photosynthesis photochemical efficiency, relative water content (RWC) and LAI. Cultivar RLC1 surpassed other *B. juncea* cultivars for yield and had low erucic acid ('0') while GSL1 (non canola), Hyola PAC401 (hybrid canola) and GSC6 (canola) of *B. napus* were superior in performance for seed yield and possessed low erucic and glucosinolate content ('00'). Higher seed yield was associated with more number of total siliquae/plant, seed weight, biomass, seeds/siliqua, SPAD and RWC. Correlation coefficient revealed high positive association for seed yield with days to maturity (0.639**), plant height (0.982**), secondary branches (0.826**), total siliquae/plant (0.913**), seed weight (0.761**) and biomass (0.891**).

Key words

Brassicas, Fatty acid, Physiological traits, Yield attributes

Introduction

The oleiferous *Brassica* species, commonly known as rapeseed mustard are one of the economically important agricultural commodities grown in more than 50 countries in Asia, Europe, America and Australia (Singh *et al*., 2014). India is one of the largest rapeseed mustard growing countries in the world, occupying first position in area (20.2%) and second in production (10.7%) after China. *B. juncea, B. napus and B. carinata* are grown as oilseed crops in north-west India. Improved cultivars and good management are important tools which have geared production in many countries of the world. Cultivars with high yield potential and wide range of adaptability to edaphic and climatic conditions is essential for obtaining higher yield per unit area, ultimately boosting up total production (Mumtaz *et al.,* 2001; Gunasekera *et al.,* 2006). A large number of high yielding area specific cultivars have been developed but unfortunately, inspite of having cultivars with yield potential of 2.0 to 2.5 t ha^{-1}, our national average is revolving around 1.0 t ha^{-1}. Moreover, yield levels are also not sustainable and fluctuate year after year leading to fluctuations in production. Photosynthesis, a major determinant of total dry matter production,has often been related to yield (Lawlor,1995) .Further , a significant portion of total dry matter should be partitioned into the harvestable components (Congo and Vetty, 2001). An increased understanding of physiological basis for seed yield could enhance utilization of physiological traits as selection criteria for yield improvement. Although, correlations between yield and leaf net photosynthetic rate are rare but has been reported recently in *Brassicas* (Sharma, 2015). Under such situation, it becomes imperative to identify some already released and notified cultivars which can show steady performance over the years. The present investigation was carried out for two consecutive years to test the eight improved cultivars developed at Punjab Agricultural University for their performance in terms of morpho-physiological and quality traits associated with productivity. Further to investigate the effect of cultivar, environment and interactions in relation to crop growth and seed yield. Responsiveness and yield stability of different mustard and canola cultivars to varying environmental conditions were also investigated.

Materials and Methods

The experiment was conducted at experimental farm of Oilseeds Section in the Department of Plant Breeding and Genetics at Punjab Agricultural University, Ludhiana during winter (*rabi*) season of 2011-12 and 2012-13 under irrigated situations. The material for the present study consisted of eight popular cultivars of Brassicas *i.e.* PBR210, PBR91 and RLC1 of *B. juncea*, GSL1 (non-canola cultivar), GSC6, GSC5 (canola cultivars) and Hyola PAC401 (canola hybrid) of *B. napus* and PC5 of *B. carinata*. During both the years, crop was sown in first week of November and trials were laid out in randomized block design with 3 replications. Each cultivar consisted of 5 rows of 3m row length. Row to row and plant to plant distance was 30cm x 10 cm for *B. juncea* (Indian mustard, raya) and *B. carinata* (African sarson) while 45cm x 10cm for *B. napus* (Gobhi sarson). All the recommended agronomic and protection practices were followed to raise a healthy crop. Three plants per replication were randomly tagged and 3rd and 4th fully opened leaf was selected to record physiological traits. Rate of photosynthesis was recorded using a portable photosynthesis system with an infra red gas analyzer in a closed system with 1-L chamber (Model LI -6200, Licor, Inc., Lincoln, NE). Measurements were made in the morning between 11 a.m. to 2 p.m. All the leaves selected were fully dry without moisture or dew and were sunlit prior to photosynthetic rate measurements. The photosynthetic radiations were between 1400 and 1800 $\mu molm^{-2}$ $s^{-1.}$ Photochemical efficiency (Fv/Fm) was also measured with Os30p model by Opti Sciences as described by Sharma (2015). Chlorophyll content (SPAD) in leaves of intact plant was measured with Minolta SPAD502 at 90 days after sowing (DAS) taking care that midrib should not come under the sample area/sensor of the instrument. The mean of 10 readings was recorded as SPAD values. Relative water content at 100 DAS was determined following the method of Turner (1986). Leaf area index (LAI) and photosynthetic active radiations (PAR) were measured at 100 DAS using Digital Plant canopy imager (CI-110/CI-120). The observations were recorded on 14 characters viz; days to 50% flowering, days to 100% flowering, days to maturity, plant height (cm), main shoot length (cm), number of primary branches and secondary branches per plant, number of siliquae on main shoot, total siliquae/plant, siliqua length (cm), seeds/siliqua, 1000-seed weight (g), biomass and seed yield. Except days to 50% flowering, 100% flowering, maturity and biomass and seed yield where data were recorded on plot basis, data for rest of the morphological traits were recorded on randomly selected five competitive plants in middle 3 rows of each plot in all 3 replications. Biomass and seed yield was converted into kg ha^{-1}. The character means for each replication were subjected to analysis of variance (ANOVA) for factorial randomized block design (CPCS2008). Correlation coefficients among different characters were computed following standard methods. Fatty acids in oils were trans-esterified and analyzed by gas liquid chromatography (GLC) using standard method of transesterfication developed by Appleqvist (1968). Glucosinolates in de-oiled seed meal *i.e.,* in seed after oil extraction were estimated non-destructively on NIRS (Model Foss 6500). For this, intact seeds were filled in ring cup and NIR reflectance spectra in the wavelength range of 1100-2500 nm was measured and the content (μmol g^{-1} seed) was automatically calculated using mustard/ rape equation.

Results and Discussion

Weekly mean metrological data during two crop seasons is represented in Fig 1. Year 2011-12 was relatively dry year and rainfall of 63.2 mm was recorded in six rainy days during crop season with maximum rainfall of 38.0 mm received during 3rd SMW. During 2012-13, rainfall of 155.6 mm was recorded on 13 rainy days (wet year) with maximum rainfall of 33.4 mm received during 7th and 8th SMW in comparison to normal rainfall of 101.6 mm during same period in both the years. There was no major difference between mean daily maximum and minimum air temperature during the two growing seasons. No frost damage was observed in Indian mustard and canola oilseed rape cultivars.

Cultivars of *B. juncea* achieved flowering earlier than *B. napus* cultivars while PC5 took more days for 50% and 100% flowering. Average days to 50% flowering was 77.8 in RLC1, 98.5 in GSL1 and 109.5 in PC5 while 94.7 in PBR91, 106.2 in GSL1 and 121.8 in PC5 for 100% flowering. Environment played a pivotal role in flowering behavior of the cultivars. Mean days were higher by 6 days for 50% flowering and 3 days for full bloom during 2011-12. Cultivars took more days to mature in 2012-13 due to wet season. Mean days to mature were delayed by 11 days during 2nd year of study. Average days to maturity were lowest in

PBR210 and maximum in PC5. However, days to maturity were comparable in PBR91and GSC5, GSL1 and Hyola PAC401 and also in RLC1 and GSC6. High heritability has been reported for days to flowering initiation (Emrani *et al.,* 2012), half flowering (Dar *et al.,* 2010) and days for flowering completion (Khan *et al.,* 2008, Sadat *et al*., 2010) and also for all the above flowering traits by Nasim *et al*. (2013) in *B. napus*. Environment had a profound influence on the physiological traits in *Brassica* cultivars as differential variations existed within the cultivars and also over two crop seasons. Environment had inconspicuous impact on the rate of photosynthesis, with average maximum Pn in GSC6 (36.3

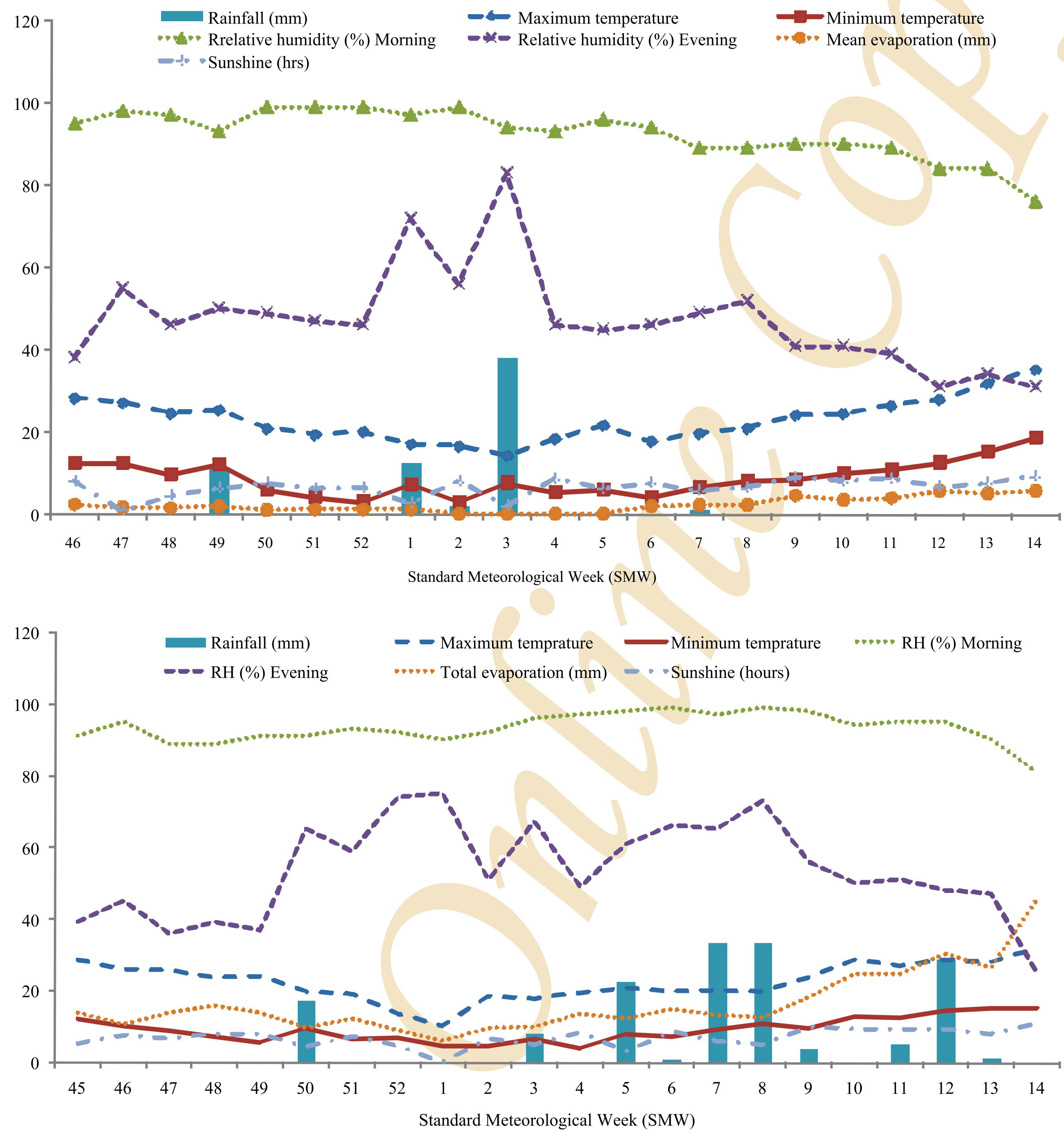

Fig. 1 : Weekly mean meterological data recorded during crop season (2011-12) and 2012-13 at School of Climate Change and Agricultural Meterology at PAU, Ludhiana

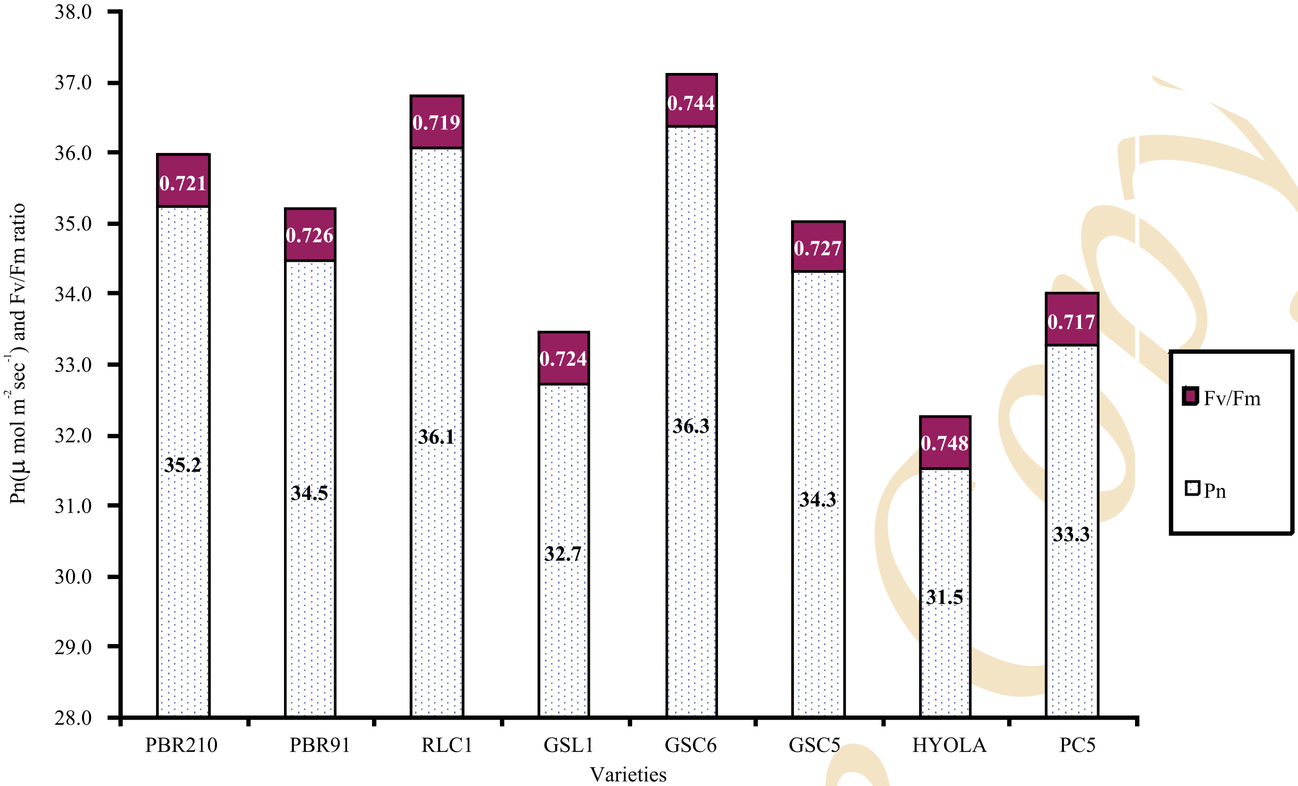

Fig 2 : Rate of photosynthesis and photochemical efficiency in different varieties of Brassica

Table 1 : Phenological stages, SPAD values, PAR interception, relative water content and leaf area index of *Brassica* as influenced by cultivars and seasons

Varieties	**50% Flowering**			**100% Flowering**			**Days to maturity**			**90 DAS**						**100 DAS**					
										SPAD			**PAR (%)**			**RWC (%)**			**LAI**		
	Y1	Y2	Mean	Y1	Y2	Mean	Y1	Y2	Mean	Y1	Y2	Mean	Y1	Y2	Mean	Y1	Y2	Mean	Y1	Y2	Mean
PBR210	75.0	75.0	75.0	85.3	86.7	86.0	141.0	157.7	149.3	41.3	39.1	40.2	77.2	58.3	67.7	74.5	85.9	80.2	2.4	0.93	1.7
PBR91	77.7	75.7	76.7	92.3	96.7	94.5	144.3	157.0	150.7	41.6	39.9	40.8	76.1	70.8	73.5	78.4	79.6	79.0	1.9	1.06	1.5
RLC1	80.3	75.3	77.8	90.0	89.3	89.7	145.3	157.0	151.2	42.0	39.9	41.0	78.1	57.1	67.6	75.4	82.7	79.1	2.3	1.88	2.1
GSL1	98.7	98.3	98.5	105.0	107.3	106.2	144.7	156.0	150.3	47.0	48.1	47.5	77.7	69.2	73.4	76.6	86.3	81.4	2.4	1.50	1.9
GSC6	83.3	85.0	84.2	97.0	90.7	93.8	148.3	155.3	151.8	45.8	47.4	46.6	71.3	49.3	60.3	83.2	81.2	82.2	2.1	0.72	1.4
GSC5	83.3	76.7	80.0	96.7	91.3	94.0	146.0	155.3	150.7	45.8	48.2	47.0	60.8	76.2	68.5	81.7	77.8	79.7	2.6	1.70	2.1
HYOLA	98.3	91.0	94.7	107.0	99.0	103.0	145.0	155.0	150.0	47.5	45.6	46.6	83.7	63.3	73.5	82.8	83.3	83.0	2.1	1.13	1.6
PC5	114.0	105.0	109.5	128.7	115.0	121.8	153.7	166.0	159.8	41.7	39.2	40.5	76.3	62.2	69.3	78.0	83.1	80.6	2.5	1.91	2.2
Mean	**88.8**	**82.4**		**100.3**	**97.0**		**146.0**	**157.4**		**44.1**	**43.4**		**75.2**	**63.3**		**78.8**	**82.5**		**2.3**	**1.4**	
CD@5%	G=1.35	Y=2.71		G=2.49	Y=4.99		G=1.1	Y=2.21		G=NS	Y=1.8		G=3.98	Y=7.96		G=1.8	Y=3.60		G=0.424	Y=NS	
	GxY=3.83			GxY=7.06			GxY=3.13			GxY=2.54			GxY=11.2			GxY=NS			GxY=NS		

Y1= 2011-12, Y2 =2012-13

umolm^{-2}s^{-1}) followed by RLC1 (36.1 umolm^{-2}s^{-1}) and PC5 (33.3 umolm^{-2}s^{-1}) at 100 DAS (Fig 2). This is in accordance with the findings of Uddin *et al*. (2012) where leaves were sources of photsynthates up to flowering when stem and siliquae became more significant exporters of assimilates. Earlier Raman and Ghldiyal (1997) reported that the role of leaf photosynthesis was mainly restricted to formation of pods in *B. campestris* and *B. juncea*, while in *B. nigra* and *B. carinata* it also contributed to seed development. SPAD chlorophyll values were higher in *B. juncea* cultivars during 1st year which increased only in GSL1, GSC6 and GSC5 in 2nd year. Cultivars differed non-significantly for chlorophyll pigments within the study period. However, SPAD values declined by 1.6%. Overall, cultivars PBR210 and PBR91 (*B.*

Table 2 : Growth and yield attributes of *Brassica* as influenced by cultivars and seasons

Varieties	Plant height (cm)			Main shoot length (cm)			Primary branches			Secondary branches			Siliquae on main shoot(SMS)			Total siliquae/ plant (TS)		
	Y1	Y2	Mean	Y1	Y2	Mean	Y1	Y2	Mean	Y1	Y2	Mean	Y1	Y2	Mean	Y1	Y2	Mean
PBR210	185.4	191.6	188.5	78.7	62.9	70.8	5.5	4.0	4.7	15.9	10.1	13.0	46.5	43.2	44.9	425.8	295.1	360.5
PBR91	197.1	197.0	197.0	77.2	52.0	64.6	6.4	5.4	5.9	16.6	14.1	15.3	49.8	49.8	49.8	499.3	469.3	484.3
RLC1	191.7	197.6	194.7	77.9	57.4	67.6	6.5	5.4	6.0	16.9	12.3	14.6	48.6	55.7	52.2	461.0	370.4	415.7
GSL1	161.8	175.0	168.4	68.9	48.0	58.5	7.7	7.7	7.7	15.4	5.3	10.3	52.3	61.8	57.1	358.2	335.5	346.8
GSC6	133.3	147.6	140.4	73.0	53.9	63.5	4.8	4.9	4.9	9.5	4.0	6.7	44.2	48.5	46.3	338.5	210.1	274.3
GSC5	133.1	154.5	143.8	75.6	56.5	66.1	5.3	5.6	5.5	11.1	6.1	8.6	53.3	62.8	58.1	425.0	273.7	349.4
HYOLA	153.1	159.7	156.4	77.5	56.8	67.1	4.7	5.0	4.8	8.7	4.2	6.5	50.9	61.5	56.2	275.1	248.1	261.6
PC5	221.5	226.1	223.8	44.5	35.6	40.0	14.1	12.4	13.2	43.6	58.9	51.2	21.1	23.5	22.3	482.7	608.8	545.8
Mean	172.1	181.1		71.6	52.8		6.8	6.2		17.2	14.3		45.8	50.8		408.2	351.4	
CD@5%	G=6.71 Y=13.4			G=NS Y=9.3			G=NS Y=0.797			G=0926 Y=1.85			G=2.55 Y=5.11			G=34.0 Y=68.1		
	GxY=18.9			GxY=13.1			GxY=1.12			GxY=2.61			GxY=7.23			GxY=96.3		

Y1= 2011-12, Y2 =2012-13

Table 3 : Yield attributes, biomass and seed yield of *Brassica* as influenced by cultivars and seasons

Varieties	Siliqua length (cm)			Seeds/siliqua			1000 seed weight			Biomass(q ha^{-1})			Seed yield (kg ha^{-1})		
	Y1	Y2	Mean	Y1	Y2	Mean	Y1	Y2	Mean	Y1	Y2	Mean	Y1	Y2	Mean
PBR210	4.8	4.9	4.8	12.0	12.0	12.0	4.4	4.6	4.5	315.90	94.2	205.0	2708.6	1151.1	1929.9
PBR91	6.3	4.6	5.4	14.0	10.8	12.4	5.3	4.3	4.8	288.6	103.3	195.9	3058.0	1216.5	2137.3
RLC1	4.5	4.7	4.6	13.8	13.0	13.4	5.0	4.2	4.6	327.2	84.0	205.6	3196.3	1124.4	2160.4
GSL1	7.3	7.1	7.2	22.6	21.1	21.9	3.4	2.6	3.0	327.2	72.8	200.0	2121.4	957.2	1539.3
GSC6	7.2	6.2	6.7	21.9	14.8	18.4	3.5	3.1	3.3	225.3	53.4	139.4	1779.6	685.6	1232.6
GSC5	7.4	7.6	7.5	26.1	19.1	22.6	3.2	2.8	3.0	213.0	53.6	133.3	1840.7	936.7	1388.7
HYOLA	7.2	7.3	7.3	29.9	19.3	24.6	3.1	2.3	2.7	274.1	50.2	162.2	2240.1	570.0	1405.1
PC5	6.6	5.9	6.2	15.3	13.4	14.3	4.2	3.9	4.0	370.4	128.6	249.5	2985.8	2312.2	2649.0
Mean	6.4	6.03		19.4	15.43		4.0	3.5		293.0	80.0		2491.3	948.8	
CD@5%	G=0.319 Y=0.639			G=1.09 Y=2.18		G=0.239 Y=0.479			G=2.97 Y=5.94		G=53.7 Y=107.4				
	GxY=0.904			GxY=3.08		GxY=0.677			GxY=8.4		GxY=151.9				

Y1= 2011-12, Y2 =2012-13

Table 4 : Fatty acid profile in different Brassica cultivars

Fatty acid composition	Gobhi sarson (*B. napus*)				Mustard			
					Raya (*B. juncea*)			African sarson (*B.carinata*)
	Canola			non-canola	Quality mustard	PBR210	PBR91	
	GSC6	GSC5	Hyola 401	GSL1	RLC1			PC5
Oil content (%)	39.1	38.7	39.2	44.5	37.8	38	37.6	38.1
Palmitic acid(16:0)	4.5	5.4	5	3.5	-		3.5	3.9
Stearic acid (18:0)	1.6	2.6	2.1	1.1	-		0.8	2.9
Oleic acid(18:1) (MUFA)	62.8	64	65.3	20.5	40.8	10.9	11.9	12.6
Linoleic acid(18:2)(PUFA)	20.2	15	17.8	16.9	32	16.1	17.6	11.9
Linolenic acid(18:3 (PUFA)	7.9	6.9	7	8.9	16.6	14.1	7.6	10.1
Eicosenic acid(20:1)	1.7	3.7	1.8	11.1	-	-	7	5.7
Erucic acid (22.1)	0.9	0.9	0.9	40.7	1.5	50.4	51.9	40.9
Glucosinolates (umoles g^{-1} deffated meal)	20.7	18.9	22.5	130	78	114	129	119

juncea) and PC5 (*B. carinata*) had comparable chlorophyll values at 90 DAS. SPAD values were higher in *B. napus* and comparable in GSL1 and GSC5 and also similar in GSC6 and Hyola PAC401.Genotypic variability in chlorophyll content in leaf was observed by Akbar *et al*. (2003), Chongo and McVetty (2001) and Uddin *et al.* (2012). Photosynthetic active radiations intercepted by the canopies of different cultivars showed variation over time. Hyola PAC401 intercepted higher radiations in 2011-12 which declined during 2nd crop season. PBR91 registered minimum decline in PAR over the years. Hyola PAC401 intercepted 83.7%, RLC1 78.1% while PBR91 and PC5 76% of light intensities. PAR interception was reduced by 20.3% during 2nd year due to variability in climate added by rainfall. PBR91 intercepted maximum (70.8%) and GSC6 minimum (49.3%) of incoming solar radiations. Relative water content was higher during 2nd year of study due to erratic rains. Cultivar average indicated highest RWC in Hyola PAC401 (83%) and GSC6 (82.2%) in *B. napus* and PBR210 (80.2%) in *B. juncea*. Relative water content were comparable in PBR91, RLC1 and GSC5. Mean RWC increased by 6.2% when compared with relative water content 1st year relative water content. Ghaffari *et al.* (2014) revealed that RWC and chlorophyll index had largest influence on seed yield and its components under well watered conditions. LAI varied significantly over two years of study. PC5 had highest LAI of 2.2 and was comparable in RLC1 and GSC5. A decrease in 39.1% in LAI was reported in 2nd year. Variation in LAI could be attributed to changes in number of leaves and rate of leaf expansion and abscission (Wei *et al*., 2007; Uddin *et al.,* 2012) in rapeseed mutants. Phenological variability is probably a most important trait related to G x E interaction (Zhang *et al.,* 2011)

Plant height and number of secondary branches per plant varied significantly within the cultivars and environment had significant impact on growth traits. Interactions between G x Y were also significant for all the growth traits. PC5 (*B. carinata*) was tallest followed by cultivars of *B. juncea*. Plant height was comparable in PBR91 and PC5 over two years of study. Average plant height was highest in PC5 (223.8 cm) followed by PBR91 (197 cm) and lowest in GSC6 (140.4 cm). Plant height differed significantly among the mustard cultivars as reported by Khaton (2004) and later by Rahman (2007). Non-significant variations were recorded for main shoot length during first year, whereas environment played a significant role as this trait declined in all the cultivars during 2nd crop season. However, main shoot length was comparable in PBR91, RLC1 and Hyola PAC401 during 1st crop season and GSC5 and Hyola PAC401 during 2nd year of study. PC5 possessed lowest average MSL (40 cm) and PBR210 (70.8 cm) highest. Significant variations in length of main shoot have been reported under rainfed and irrigated conditions in Indian mustard (*B. juncea*) by Zhang and Zhou (2006) and later by Yadava *et al.* (2010). Number of primary branches per plant did not vary significantly within the cultivars. Indian mustard and African sarson cultivars showed higher number of primary branches during 2011-12. GSL1 and GSC6 of *B. napus* possessed similar number of primary branches during both years. On an average, PC5 possessed higher number of primary branches followed by GSL1. Secondary

Table 5 : Correlation coefficient among characters recorded from the studied *Brassica* cultivar

Traits	50%F	100%F	M	Pl. ht	MSL	Pri. br	Sec. br	SMS	TS	SL	Seeds/ Siliqua	Seed wt.	BY	SY
50%F	1													
100%F	0.966**	1												
M	0.695**	0.794**	1											
Pl.ht	0.244	0.373	0.583**	1										
MSL	-0.843**	-0.919**	-0.936**	-0.526*	1									
Pri.br	0.786**	0.874**	0.922**	0.668**	-0.971**	1								
Sec.br	0.613**	0.733**	0.941**	0.799**	-0.885**	0.936**	1							
SMS	-0.489	-0.575	-0.887**	-0.693**	0.780**	-0.78	-0.911**	1						
TS	0.207	0.410	0.668*	0.891**	-0.620*	0.731**	0.822**	-0.660*	1					
SL	0.488	0.426	0.016	-0.649**	-0.194	0.044	-0.197	0.283	-0.466	1				
Seeds/Siliqua	0.341	0.220	-0.242	-0.746**	0.084	-0.195	-0.432	0.536*	-0.672**	0.919**	1			
Seedwt.	-0.441	-0.302	0.117	0.736**	0.037	0.098	0.332	-0.375	0.675**	-0.942**	-0.971**	1		
BY	0.458	0.532*	0.608**	0.947**	-0.635*	0.763**	0.797**	-0.665*	0.799**	-0.496	-0.583*	0.551*	1	
SY	0.195	0.344	0.639**	0.982**	-0.528*	0.663**	0.826**	-0.734**	0.913**	-0.664**	-0.773**	0.761**	0.891**	1

Significant at *P=0.05, **P=0.01, 50% F: 50% flowering, 100%F:100% flowering, M: days to maturity, Pl.ht: Plant height, MSL: main shoot length, Pri.br: primary branches, Sec.br: secondary branches, SMS: siliquae on main shoot, TS: total siliquae/plant, SL: siliqua length, BY: biological yield, SY: seed yield

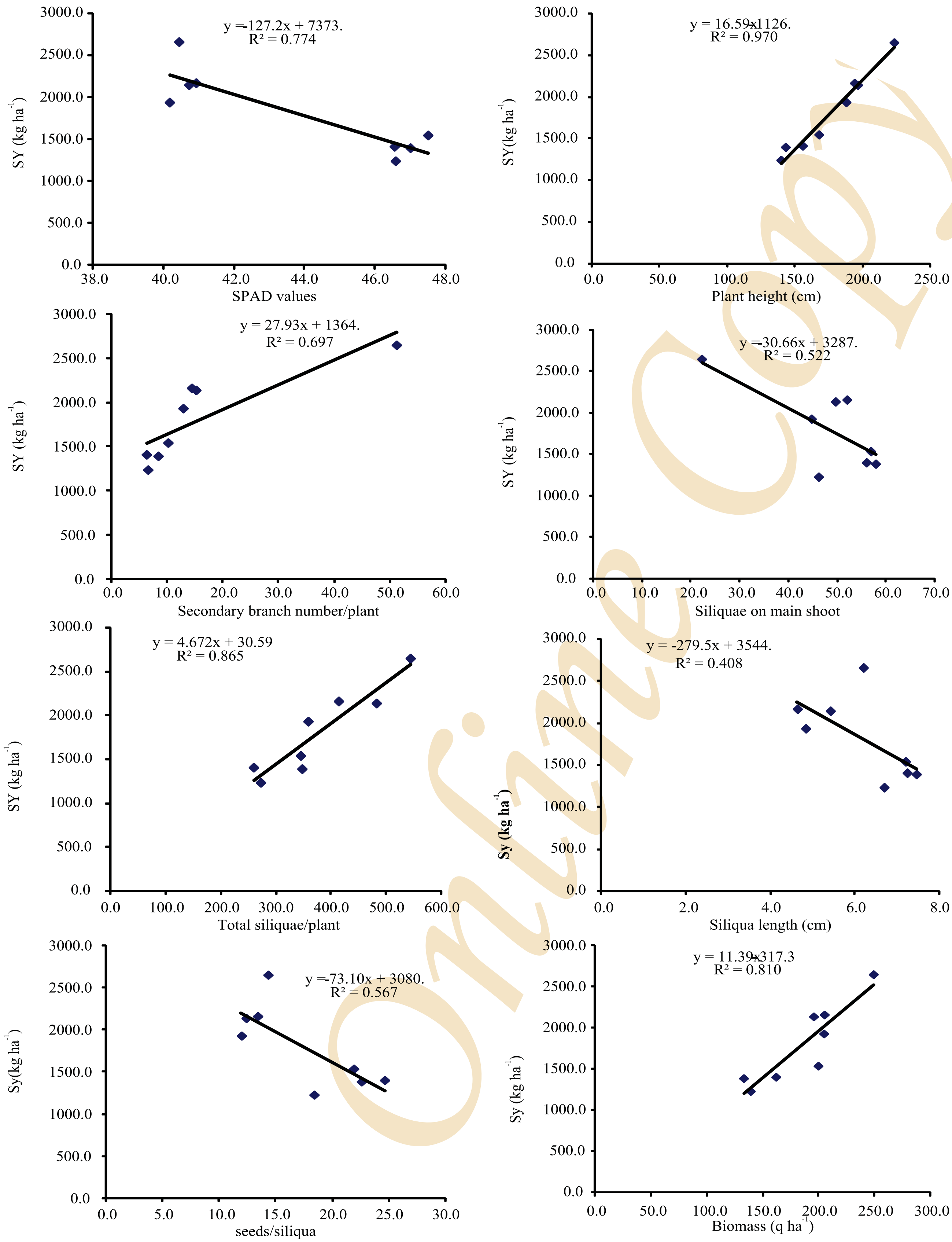

Fig 3: Relationship between seed yield, SPAD and yield attributes in *Brassicas*

branches/plant was higher during 2011-12 and PC5 possessed maximum number with mean of 51.2 followed by *B. juncea* cultivars. Photochemical efficiency of PSII was not affected much by environment and ranged from 0.719-0.726 with a mean of 0.721 in *B. juncea* and from 0.724-0.748 with a mean of 0.735 *in B. napus* cultivars. Least damage of PSII was in PBR91 and Hyola PAC401. Secondary branches were lower during 2012-13 except in PC5 (Table 2). Mean plant height was 5.2% higher while main shoot length, number of primary branches and secondary branches per plant were lower by 35.5%, 9.5% and 13.9% respectively over 2nd year of study. Findings of Mahmood *et al.* (2003) are in line. Results are in partial similarity with Dar *et al.* (2010) but in contrast to the findings of Khan *et al*. (2008).

Number of siliquae on main shoot was higher during 2nd crop season except in PBR210. Amongst *B. juncea* cultivars, RLC1 had higher mean number of siliquae on main shoot (52.2) whereas in *B. napus* GSC5 produced 58.1 and in African mustard PC5 produced 22.3 siliquae on main shoot. Number of siliquae on main shoot was comparable in PBR91 during two growth seasons while GSL1 and Hyola PAC401 had similar number during 2012-13. Khan *et al.* (2008) and Sadat *et al.* (2010) reported high heritability with pods on main raceme while the later reported it coupled with high genetic advance. Total number of siliquae per plant was higher during 1st year of study in *B. juncea* and *B. napus* while PC5 possessed 26.6% higher total siliquae/plant during 2nd crop season with an average of 545.8. Ozer *et al*. (1999) suggested that pod number could be a good selection criterion for assessing /increasing grain yield in rapeseed. Significant differences in number of pods per plant have been reported in 20 mustard/rapeseed cultivars by Khatun (2004) and between 16 rapeseed cultivars by Miri (2007). Siliqua length on an average was 5.4 cm in PBR91 and more than 7.2cm in GSL1, GSC5 and Hyola PAC401 while GSC6 had average siliqua length of 6.7cm. Wide range of variability in siliqua length has been reported by Modal *et al.* (2003) and Uddin *et al.* (2012). Siliqua length and seeds/siliqua were higher in *B. napus* cultivars followed by *B. carinata* and lowest in *B .juncea* cultivars. Seeds/siliqua was higher during 2011-12 in all the cultivars. Hyola PAC401 produced 24.6 and GSC5 produced 22.0 seeds/siliqua while PC5 produced 14.3 seeds/siliqua. Over the years, mean number of siliquae on main shoot was 10.2% higher during 2012-13, while total siliquae/plant were higher by 16.1%, siliqua length by 5.7% and seeds/siliqua by 25.7% in 2011-12, respectively. Variations in seeds per pod and pod length have been reported by Emrani *et al*. (2012), Khan *et al.* (2008a) and Shehzad and Farhatullah (2012). Cultivars varied significantly for yield attributes and the impact of environment was significant and also the interactions between G x Y were significant for yield components. All the cultivars registered higher seed weight during 1st crop season. On an average, seed weight was 4.8g in PBR91, 3.3g in GSC6 while PC5 had 4.0g. Yield losses during 2nd year of study was due to shattering along with erratic rains in *B. napus*. Similar findings were reported in *B. napus* (Zhang and Zhou, 2006; Nasim *et al*., 2013), mustard (Akbar *et al.,* 2007), winter rapeseed (Aytac and Kinaci, 2009), brown sarson (Dar *et al.,* 2010) and some F_2 : F_3 *Brassica* populations(Shahzad and Farhatullah, 2012). Biomass and seed yield were higher during 2011-12 which declined to the tune of 26.8% and 18.5%, respectively during 2nd year of study (Table 3). Average biomass was comparable in PBR210 and RLC1 cultivars of *B. juncea*. GSL1 (200 q ha^{-1}), a non canola cultivar registered highest biomass followed by canola hybrid Hyola PAC 401(162.2 q ha^{-1}) and canola cultivar GSC6 (139.4 q ha^{-1}). Average seed yield among. *B. juncea* cultivars was highest in RLC1 (2160.4 kg ha^{-1}) followed by PBR91 (2137.3 kg ha^{-1}). In *B. napus*, GSL1 registered highest seed yield of 1539.3 kg ha^{-1}. Hyola PAC401 (1405.1 kg ha^{-1}) amongst canola cultivars of *B. napus* had highest yield trailed by GSC6 (1388.7 kg ha^{-1}). PC5, a cultivar of *B. carinata* produced biomass of 249.5 q ha^{-1} and seed yield of 2649 kg ha^{-1}. This result is in consistent with the result of Rahman (2007), Uddin *et al*. (2012) and Nasim *et al.* (2013). Significant cultivar x environment interactions for days to maturity, plant height, primary and secondary branches/ plant, seed weight and seed yield/plant were reported by Gunasekera *et al*. (2006) and by Yadava *et al.* (2010).

Oil content was almost comparable in canola cultivars of *B. napus*. Canola cultivars possessed higher oleic acid (>60%), lower erucic acid (<1%) and glucosinolates (<30 μmol g^{-1} defatted meal) so referred as “00' cultivars. GSL1, a non canola cultivar, possessed higher oil content (44.5%), lower oleic acid (20.5%) but higher erucic and glucosinolates (Table 4). Among the mustard cultivars, RLC1 was low in erucic acid (referred as '0') but high in oleic acid (40.8%) and comparable glucosinolates (78 μmol g^{-1} defatted meal) with other *B. juncea* cultivars. PBR210 and PBR91 had erucic acid >50% but oleic acid was comparable in two mustard cultivars. PC5 had oil content of 38.1% and higher erucic and glucosinolates. Zhang and Zhou (2006) sowed that erucic acid and oil content of seeds from F_2 plants were lower but higher glucosinolate content than that of maternal plants.

Positive association existed between RWC and SPAD (0.632**) while seed yield showed positive association with SPAD (0.599**), PAR (0.487), RWC (0.544*) and LAI (0.421). Plant height was positively associated with days to maturity (0.583). Number of primary and secondary branches had positive association with 50%

flowering, 100% flowering and days to maturity but were negatively associated with main shoot length (Table 5). Siliqua on main shoot had positive association with main shoot length (0.780**)) only. Total siliquae / plant had positive association (0.668*) with days to maturity, plant height (0.891**), primary branches (0.731*) and secondary branches (0.822**). Seeds/siliqua was positively correlated with siliqua length (0.919**). Similar association has been recorded by Nasim *et al*. (2013) in *B. napus*. Seed weight had positive association with plant height (0.736**) and total siliquae/plant (0.674*) but negatively associated with siliqua length (-0.942**) and seeds/siliqua (-0.971**). Non-significant correlation for seeds/pod with seed weight (Puncture and Ciftci, 2007), primary branches/plant with plant height, seeds/pod, pod length (Khan *et al*., 2006a) and pods/main raceme with pod length (Aytac and Kinaci, 2009) have been reported. Biological yield was positively associated with 100% flowering (0.532*), days to maturity (0.608*), plant height (0.947**), primary branches (0.763*), secondary branches (0.797*), total siliquae/plant (0.799**) and seed weight (0.551*). Significant positive correlations were observed by Nasim *et al.* (2013) for plant height with main raceme length (r=0.48), pods/main raceme (r=0.67), seed weight (r=0.47). Anyaoha *et al*. (2015) reported highly positive association of 50% flowering with plant height in breeding lines of *B. juncea*. Linear regression equation indicated strong relationship between seed yield and SPAD, plant height, secondary branches, total siliquae/plant and biomass (Fig.3).

Our study demonstrates that cultivar, environment and their interactions have large effect on the morphological and physiological characters of mustard and canola gobhi sarson. Indian mustard (PBR91, RLC1) and Ethiopian mustard (PC5) cultivars showed relative stability for yield over the years, while cultivars of *B. napus* showed lower yields during second crop season due to erratic rains and shattering. Significant differences were observed during two years of study, indicating effect of environment in the expression of traits except rate of photosynthesis. RLC1 (*B.juncea*), GSL1 (non-canola), Hyola PAC401 (hybrid, canola), GSC6 (canola) cultivars of *B.napus* and PC5 (*B.carinata*) performed better under field trails over the years . Relatively higher photosynthetic rates (Pn) coupled with chlorophyll fluorescence i.e lower damage of PSII (Fv/Fm) , SPAD chlorophyll values , relative water content (RWC), plant height, total siliquae/plant, seed weight and seeds/siliqua were the contributing moropho-physiological traits for superior performance.

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