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Effect of growth and yield parameters on Indian-mustard genotypes under varying environmental conditions in western Haryana

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Abstract: An experiment was conducted in *Rabi* season of year 2014-15 at Research Farm,Department of Agril. Meteorology, CCSHAU Hisar, Haryana and field area was adjacent to agrometeorological observatory at 29^0 10' N latitude, 75^0 46' E longitude and altitude of 215.2 m with Split Plot Design as main plot treatments consisted of three date of sowing viz.26thOctober, 5thNovember, and 15th November and sub-plots consisted of three varieties (Kranti, RH 406 and RH 0749) with four replication. Various growth and yield parameters such as plant height, LAI, dry matter accumulation, partitioning and yield attributes were higher in 26thOctober sown crop as compared to 5th and 15th November at all the growth intervals. The crop sown on 26th October (1870.3 kg/ha) produced highest seed yield as compared to 5th (1525.5 kg/ha) and 15th November (1099.8 kg/ha).Among varieties,RH0749 recorded highest seed yield because LAI, biomass accumulates were performed better as compared to RH 406 and Kranti. There was significant interaction between growing environment and varieties with respect to growth and yield parameters. From the above study it was concluded that normal or early sowing of Indian mustard may be practisized for achieving higher seed yield and improved growth and yield attributes in western Haryana conditions.

Keywords: Growth intervals, Indian mustard, Sowing dates, Yield and yield attributes

INTRODUCTION

Indian mustard (*Brassica juncea*) is the second most important oilseed crop in India after groundnut sharing 27.8% in the India's oilseed production. The crop occupies an area of approximately 6.90 million hectare with a production of 8.18 million tonnes (Shekhawat*et al*. 2012).In India, the Haryana state contributes 10.2% to the total rapeseed-mustard production in the country. Likewise, area under mustard in Haryana has increased from 1.98 lakh ha in 1966-67 to 5.70 lakh ha in 2013-14. A considerable improvement in mustard productivity has also happened during the period with its increase from 405 kg/ha in 1966-67 to 1350 kg/ha in 2013-14 (Indiastat, 2014).

Growth and yield of *Brassica* species largely depends upon change in environment during crop growth this change in environment can occur through many practices including sowing dates and water availability. For getting higher yield, sowing time of crop needs to be adjusted with suitable agroclimatic environment (Saha and Khan, 2008). Pradhan *et al*. (2014) reported that there was significant interaction between date of sowing and cultivars with respect to seed yield of mustard. It was concluded that normal or early sowing of Pusa Jai Kisan or Pusa Bold cultivar may be practiced for achieving higher seed yield, radiation and water use efficiency in semi arid environment of north and north-western part of India. Indian-mustard is much sensitive to climatic variables; hence, climate change could have significant effect on its production. One month delay in sowing from mid of October resulted in 40.6% loss in seed yield (Lallu, *et al.,* 2010). Gill and Bains(2008) observed a linear and positive relation between leaf area development and photosynthetically active radiation (PAR) interception, which leads to higher dry matter production. LAI plays an important role for crop growth based on its interception and utilization of PAR for producing dry matter (Kumar *et al*., 2007) and with the delay in planting date, the higher mean temperature was experienced during flowering which led to accelerate the decrease in LAI and reduction in the flowering period. Neog*et al*. (2005) revealed that as growing degree days (GDD) increased from 1270 to 1684 ºC day in PusaJaikisan and Varuna, the seed yield also increased and with the further increase in GDD accumulation, there was a decline in seed yield. At the value of 1606 ºC day, the yield was found to be highest. Adak *et al*. (2011) reported that change in sowing dates led to change in thermal environments of the cultivars with respect to different growth and development stages leading to variation in completion of life cycle. Roy *et al*. (2005) attributed the reduction

in seed yields to the relatively higher temperature prevailing during the pod filling stage especially if the crop is sown beyond the sowing window (October 1st to 22st) in 2004-05.

Planting window and mustard cultivars is the most important element for realizing potential yield of crop. Hence keeping these in view, the study was undertaken to investigate the effect of growing environment on growth and yield parameters of three mustard varieties under western Haryana condition.

MATERIALS AND METHODS

Climate and weather conditions of experiment location in brief: Experiment was conducted in *Rabi* season 2014-15 at Research Farm of Department of Agril. Meteorology, CCSHAU Hisar, Haryana, India at 29^0 10' N latitude, 75^0 46' E longitude and altitude of 215.2 min the tract of semi-arid and sub-tropical monsoonal climate. In winter only 2-3 rainy showers are received due to western disturbances followed by low temperature. The occurrence of frost on certain days is also not an unusual feature here. The average annual rainfall in the tract is around 450 mm, most of which is received during south-west monsoon season.

Soil analysis of the experimental field: The soils of Hisar are derived from Indo-Gangetic alluvium, which are very deep and sandy loam in texture and have some amount of calcium carbonate in the soil profile. Physico-chemical analysis of the soil was done by taking random soil samples from 0-30, 30-60 and 60-90 cm soil profile depths before sowing of the experiment field.

Soil chemical analysis

Mechanical composition of soil: Composite soil samples were analyzed by International Pipette Method of Piper (1966) and the results are presented in table 1.

Chemical composition of soil: The chemical analyses of the soil were carried out with standard methods based on composite soil sample of 0-30 cm depth. The values of Nitrogen, Phosphorus, potassium, organic matter, pH and electrical conductivity given in table 2 were determined with standard techniques and the above analyses indicated that the soil of experimental site was low in organic carbon and nitrogen, medium in phosphorus and rich in potassium and slightly alkaline in reaction.

Experimental details: The data was taken at Hisar station from experiment which was conducted during *Rabi* 2014-15using split plot design comprising threedate of sowing (26th October, 5th November and 15th November) as main plots and varieties (Kranti, RH 406 and RH 0749) in sub plots with four replications. The package and practices for Indian mustard cultivation was followed as per the recommendation of CCS Haryana Agricultural University (CCSHAU, Hisar).

Plant height: Plant height was measured at 30 days interval till harvesting on five tagged plants in each plot. The height was measured from the base of the plant to the tip of the main stem of randomly tagged plants and expressed in centimeters (cm) and their mean values were calculated.

Leaf area index: The plant leaves separated from samples taken for dry matter were used for determining leaf area from each plot at 30 days interval after sowing. The green leaf area (cm^2) was recorded using leaf area meter (LI-3000 Area meter, LI-COR Biosciences, Nebraska, USA). The leaf area measured with the help of leaf area meter was used to compute the leaf area index by the following formula.

LAI = Leaf area (cm^2)/ Land area covered by plant (cm^2)

Dry matter accumulation and partitioning: The five randomly selected plants from destructive sampling were used to record the dry matter production at 30 days interval after sowing. The sampled plants were separated into roots, stems, leaves and reproductive parts (flowers, buds and siliquae) and sun dried. Further, the samples were oven dried at 65 ºC to 70 ºC to a constant weight. The biomass/ dry matter accumulation in different plant parts was the converted to weight per square meter.

Yield and yield attributes

Number of primary and secondary branches at harvest: The numbers of primary and secondary branches per plant were calculated at harvest by average values of five plants uprooted for biomass observation in all the treatments.

Seed yield (kg ha^{-1}): The crop harvested from net plot was threshed after sun drying, cleaned and weighed. The seed yield obtained was converted to kg per hectare.

Biological yield (kg ha^{-1}): Biological yield from net plot was calculated and expressed as kg per hectare. It was taken as the seed yield and stover yield together.

Harvest index (HI, %) The harvest index for each plot was calculated by dividing the total grain yield by the total biological yield (seed + stover yield) of the same net plot and multiplied by 100 as given below:

HI = (Grain yield / Biological yield) x 100

Statistical analysis: The data were statistically analyzed using analysis of variance (ANOVA) as applicable to split plot design (Gomez and Gomez, 1984). The significance of the treatment effects was determined using F-test at 5 % significance level.

RESULTS AND DISCUSSION

Weather: In the present study weekly weather parameters during the *Rabi* season 2014-15 (43th to 15th standard meteorological weeks - SMW) are presented in the table 3.

Growth studies:

Plant height: The plant height recorded at different growth intervals in mustard varieties under different

dates of sowing are presented in table 4. The plant height reduced significantly at 5% level of significance with delay in sowing. Among varieties, RH 0749 (195.8 cm) were tallest and RH 406 (190.5 cm) second in plant height then Kranti (175.5 cm).The interaction between sowing environment and varieties was observed to be significant at all growth intervals.

Leaf area index: LAI of mustard varieties under different dates of sowing were recorded at various growth intervals and are presented in table 5.Leaf area index reached maxima at 90 DAS, the LAI reduced significantly at 5% level of significance with the delay in sowing irrespective of the varieties, at all growth intervals and recorded maximum in 26thOctober followed by 5th and 15thNovember. Among varieties, RH 0749 were highest LAI followed by RH 406 and Kranti. The interaction between sowing environment and varieties found significant in 5% level of

Table 1. Mechanical composition of soil (per cent fraction).

Soil depth (cm)	Sand (%)	Silt (%)	Clay (%)
0-30	57.38	26.35	16.27
30-60	56.56	26.82	16.62
60-90	56.42	26.68	16.90

Textural class: Sandy loam

Table 2. Chemical composition of soil (0-30 cm).

Particulars	Values	Methods
pH (1:2)	7.9	Glass Electrode pH Meter (Piper, 1950)
EC (dSm^{-1} at 25°C)	0.93	Conductivity Bridge Meter (Richards, 1954)
Organic Carbon (%)	0.39	Walkley, Black's and Wat's Oxidation Method (Piper, 1950)
Available N (kg ha^{-1})	193	Alkaline Permanganate Method (Subbiah and Asija, 1956)
Available P (kg ha^{-1})	17	Oleson *et al.* 1954
Available K (kg ha^{-1})	356	Flame Photometer Method (Richards, 1954)

Table 3. Weekly weather parameters during the crop season 2014-15 (43th to 15th standard meteorological weeks - SMW)

WEEKLY WEATHER DATA – 2014-15
CCS HAU, HISAR

SMW	Max. Temp. (°C)	Min. Temp (°C)	G min Temp (°C)	AVP (mm of Hg) M	AVP (mm of Hg) E	RH (%) M	RH (%) E	AVG WS (Km/h)	BSS (Hrs.)	PAN Evap. (mm)	Rainfall (mm)
43	32.4	19.0	-	16.6	16.4	85	47	3.5	7.0	2.9	0.0
44	30.7	14.6	-	12.7	11.1	88	35	3.1	6.4	2.7	1.0
45	29.9	14.3	-	12.4	11.2	87	36	2.9	6.7	2.8	0.0
46	27.1	7.7	-	7.8	7.5	79	28	1.9	7.1	2.4	0.0
47	26.6	6.9	-	7.9	7.4	88	29	1.5	7.8	2.9	0.0
48	28.1	9.9	0.9	9.1	9.2	81	32	2.5	7.7	3.0	0.0
49	26.9	7.9	2.6	8.6	8.9	91	35	2.2	7.8	1.9	0.0
50	20.5	6.8	2.9	8.3	8.7	94	56	3.6	5.2	1.5	9.0
51	13.8	5.0	1.9	7.3	9.0	100	88	2.4	1.6	0.3	0.0
52	15.0	3.9	0.4	6.9	8.6	100	71	2.7	4.0	0.5	0.0
1	16.9	2.4	-1.9	6.1	8.1	95	59	2.7	4.4	1.0	0.0
2	18.5	3.3	-0.8	6.4	8.1	96	52	2.3	5.5	1.2	0.0
3	16.4	6.5	3.7	8.3	10.8	99	84	3.4	2.3	0.5	0.0
4	18.3	8.8	5.3	9.4	12.1	98	78	5.0	2.8	1.4	2.0
5	21.0	8.6	6.0	9.2	12.4	98	72	3.4	4.2	0.8	0.0
6	20.6	7.9	3.7	9.3	10.9	97	65	4.7	6.0	1.9	4.1
7	19.5	5.5	1.0	7.5	10.5	95	63	3.6	6.5	1.6	1.5
8	21.9	8.5	4.0	9.0	12.5	92	66	4.5	6.4	1.9	3.1
9	21.9	8.7	5.1	10.0	13.5	99	70	3.7	6.1	1.7	3.8
10	22.5	9.0	-	10.4	13.4	96	64	3.1	5.7	2.3	11.3
11	24.9	11.0	-	10.9	14.5	92	66	6.2	7.9	2.6	13.3
12	28.3	12.3	-	12.0	12.2	89	42	3.6	8.8	3.2	1.1
13	28.0	15.7	-	13.5	14.5	86	54	5.2	5.5	3.7	21.3
14	31.2	14.3	-	13.9	12.7	88.1	38.1	5.0	9.1	4.4	8.5
15	33.3	16.4	-	13.4	12.1	72.0	31.1	5.7	9.5	6.2	0.0

Table 4. Plant height (cm) of mustard varieties at different growth intervals under different growing environments in 2014-15.

	30 DAS*				60 DAS				90 DAS				120 DAS				Maturity			
Treatment	**Kranti**	**RH 406**	**RH 0749**	**Mean**	**Kranti**	**RH 406**	**RH 0749**	**Mean**	**Kranti**	**RH 406**	**RH 0749**	**Mean**	**Kranti**	**RH 406**	**RH 0749**	**Mean**	**Kranti**	**RH 406**	**RH 0749**	**Mean**
26 October	21.7	23.4	24.7	23.2	97.5	101.2	102.8	100.5	149.6	154.6	157.6	153.9	165.2	170.1	189.7	175.1	182.2	191.0	199.2	190.5
5 November	20.6	21.9	22.5	21.6	83.6	86.7	98.8	91.0	136.8	141.7	152.5	143.2	156.1	162.1	173.9	164.0	179.5	190.1	195.1	188.2
15 November	16.8	17.0	21.5	18.4	76.7	79.5	92.5	82.8	126.5	130.1	151.4	135.9	148.1	152.2	163.7	160.9	167.7	181.4	184.2	178.1
Mean	19.7	20.8	22.8		86.1	89.1	99.3		141.9	145.7	153.8		159.1	165.0	175.8		175.5	190.5	195.8	
CD at 5% (D)		0.5				2.0				2.2				1.7				0.8		
CD at 5% (V)		0.2				0.9				0.9				1.0				0.9		
D*V		0.4				1.7				1.7				1.9				1.7		
V*D		0.6				2.3				2.5				2.2				1.5		

Table 5. Leaf area index (LAI) of mustard varieties at various growth intervals under different growing environments in 2014-15.

	30 DAS*				60 DAS				90 DAS				120 DAS				Maturity			
Treatment	**Kranti**	**RH 406**	**RH 0749**	**Mean**	**Kranti**	**RH 406**	**RH 0749**	**Mean**	**Kranti**	**RH 406**	**RH 0749**	**Mean**	**Kranti**	**RH 406**	**RH 0749**	**Mean**	**Kranti**	**RH 406**	**RH 0749**	**Mean**
26 October	1.59	1.89	2.60	2.02	2.99	3.25	3.52	3.24	4.62	5.65	6.64	5.63	3.85	4.33	4.85	4.34	1.60	1.73	1.88	1.73
5 November	1.27	1.61	2.35	1.75	1.95	2.78	3.32	2.68	4.32	4.45	4.61	4.45	3.50	3.75	3.98	3.74	1.27	1.35	1.58	1.40
15 November	0.98	1.33	1.63	1.31	1.77	1.93	2.16	1.96	3.59	3.86	3.99	3.81	3.02	3.33	3.61	3.32	1.00	1.18	1.33	1.17
Mean	1.21	1.62	2.20		2.22	2.65	3.01		4.17	4.65	5.08		3.46	3.81	4.14		1.29	1.42	1.60	
CD at 5% (D)		0.46				0.24				0.33				0.45				0.16		
CD at 5% (V)		0.21				0.20				0.24				0.15				0.21		
D*V		NS				0.37				0.44				NS				NS		
V*D		NS				0.38				0.47				NS				NS		

Table 6. Dry matter (g/plant) of mustard varieties at various growth intervals under different growing environments in 2014-15.

	30 DAS*				60 DAS				90 DAS				120 DAS				Maturity			
Treatment	**Kranti**	**RH 406**	**RH 0749**	**Mean**	**Kranti**	**RH 406**	**RH 0749**	**Mean**	**Kranti**	**RH 406**	**RH 0749**	**Mean**	**Kranti**	**RH 406**	**RH 0749**	**Mean**	**Kranti**	**RH 406**	**RH 0749**	**Mean**
26 October	5.35	5.70	6.41	5.82	30.45	34.38	41.18	35.33	69.81	73.13	77.85	73.59	72.95	84.43	93.15	83.51	112.12	122.83	137.32	124.08
5 November	2.13	2.48	3.38	2.66	14.73	20.48	32.81	22.67	62.25	66.32	70.45	66.33	67.18	72.68	85.95	75.27	97.75	108.15	120.01	108.63
15 November	1.53	1.73	2.22	1.82	16.35	18.43	19.93	18.72	60.62	62.98	67.25	63.61	62.08	67.65	71.85	67.19	59.45	73.83	78.93	70.73
Mean	3.00	3.31	3.99		20.51	24.93	31.27		64.22	67.47	71.85		67.40	74.92	83.65		89.77	101.62	112.15	
CD at 5% (D)		0.2				1.6				1.7				1.9				16.5		
CD at 5% (V)		0.1				1.7				1.2				1.3				7.1		
D*V		0.2				3.0				NS				2.3				NS		
V*D		0.2				2.7				NS				2.5				NS		

*DAS – Days after sowing.*where D-date of sowing, V–variety, D*V, V*D-interaction between date of sowing and variety.

Table 7. Dry matter partitioning (g/plant) of mustardcrop at various growth intervals under different growing environments in 2014-15.

	30 DAS*				60 DAS					90 DAS				
Treatment	**Leaf**	**Stem**	**Root**	**Total dry matter**	**Leaf**	**Stem**	**Root**	**Siliquae**	**Total dry matter**	**Leaf**	**Stem**	**Root**	**Siliquae**	**Total dry matter**
26 October	3.3 (55.8)*	1.9 (32.7)	0.7 (11.1)	5.8	19.4 (54.8)	10.2 (28.9)	4.5 (12.6)	1.3 (3.7)	35.3	29.1 (39.5)	30.3 (41.1)	7.1 (9.6)	7.2 (9.8)	73.6
5 November	1.5 (57.8)	0.8 (31.1)	0.3 (10.6)	2.7	12.9 (57.0)	6.3 (27.8)	2.7 (11.8)	0.8 (3.2)	22.7	26.7 (40.3)	27.3 (41.2)	6.2 (9.4)	6.0 (9.1)	66.3
15 November	1.1 (62.5)	0.5 (29.2)	0.2 (8.3)	1.8	11.1 (59.4)	5.0 (26.7)	2. (10.7)	0.6 (3.2)	18.7	27.2 (42.8)	24.5 (38.6)	6.1 (9.6)	5.7 (9.0)	63.6
Kranti	1.8 (60.9)	0.9 (28.9)	0.3 (12.6)	3.0	12.0 (58.7)	5.7 (27.7)	2.0 (9.8)	0.8 (3.8)	20.5	26.9 (41.9)	25.3 (39.4)	5.7 (8.9)	6.3 (9.8)	64.2
RH 406	2.0 (60.3)	1.0 (29.4)	0.3 (10.1)	3.3	14.7 (59.1)	6.5 (26.2)	2.8 (11.1)	0.9 (3.6)	24.9	27.1 (40.2)	26.3 (39.0)	7.6 (11.3)	6.4 (9.5)	67.5
RH 0749	2.3 (58.1)	1.2 (30.9)	0.5 (11.2)	4.0	18.8 (60.0)	8.2 (26.1)	3.5 (11.2)	0.8 (2.7)	31.3	29.9 (41.6)	28.5 (39.6)	7.2 (10.0)	6.4 (8.8)	71.8
CD at 5% (D)	0.8	0.1	0.2	0.2	2.2	2.4	0.6	0.9	1.6	1.3	2.6	0.4	0.7	1.7
CD at 5% (V)	0.5	0.1	0.5	0.1	2.1	1.3	0.9	0.2	1.7	1.5	1.9	1.2	0.5	1.3
D*V	0.2	0.2	0.3	0.2	1.8	2.5	1.4	2.0	1.8	1.1	2.4	NS	1.2	1.9
V*D	0.7	1.3	0.4	1.1	3.6	2.2	1.4	0.5	2.6	2.1	2.3	NS	0.6	2.4

*The values in parenthesis are percent fraction of total biomass partitioned to respective plant part.

Cont.

Table 7. *Cont.*

	120 DAS					Maturity				
Treatment	**Leaf**	**Stem**	**Root**	**Siliquae**	**Total dry matter**	**Leaf**	**Stem**	**Root**	**Siliquae**	**Total dry matter**
26 October	1.5 (1.8)	36.7 (43.9)	6.5 (7.8)	38.8 (46.4)	83.5	0.3 (0.2)	50.4 (40.6)	6.3 (5.1)	67.1 (54.1)	124.1
5 November	1.7 (2.2)	34.3 (45.6)	5.6 (7.4)	33.7 (44.8)	75.3	0.4 (0.4)	46.6 (42.9)	5.1 (4.7)	56.5 (52.0)	108.6
15 November	2.4 (3.6)	28.1 (41.8)	5.2 (7.8)	31.5 (46.8)	67.2	0.4 (0.5)	28.7 (40.5)	3.4 (4.8)	38.3 (54.2)	70.7
Kranti	1.2 (1.8)	31.7 (47.1)	4.3 (6.4)	30.2 (44.7)	67.4	0.3 (0.3)	40.7 (45.3)	3.0 (3.3)	45.9 (51.1)	89.8
RH 406	1.8 (2.4)	33.0 (44.1)	5.7 (7.6)	34.4 (45.9)	74.9	0.4 (0.4)	40.4 (39.8)	5.0 (4.9)	55.8 (54.9)	101.6
RH 0749	3.5 (4.2)	35.2 (42.1)	7.1 (8.5)	37.8 (45.2)	83.7	0.6 (0.5)	46.4 (41.4)	6.3 (5.6)	58.8 (52.5)	112.1
CD at 5% (D)	0.6	2.3	0.3	2.1	1.9	**0.7**	**7.6**	**0.8**	**7.9**	**16.5**
CD at 5% (V)	0.8	2.5	1.0	3.2	1.3	**0.1**	**2**	**1.1**	**3.8**	**7.1**
D*V	1.5	1.6	0.8	1.8	1.6	**NS**	**8.9**	**1.6**	**7.2**	**18.9**
V*D	1.8	1.9	1.4	3.6	2.2	**NS**	**1.5**	**2.1**	**4.6**	**6.3**

Table 8. Effect of varying environmental conditions on yield attributes of mustard varieties in 2014-15.

	Number of branches at harvest								Seed yield (kg/ha)				Biological yield (kg/ha)				HI (%)			
	Primary				Secondary															
Treatment	**Kranti**	**RH 406**	**RH 0749**	**Mean**	**Kranti**	**RH 406**	**RH 0749**	**Mean**	**Kranti**	**RH 406**	**RH 0749**	**Mean**	**Kranti**	**RH 406**	**RH 0749**	**Mean**	**Kranti**	**RH 406**	**RH 0749**	**Mean**
26 October	6.0	7.6	9.7	7.7	10.2	12.3	15.0	12.53	1,679.9	1,793.5	2,137.5	1,870.3	11,080.9	11,154.0	14,481.8	12,238.9	13.4	14.0	16.4	14.6
5 November	4.6	6.5	8.0	6.4	9.2	10.1	13.0	10.78	1,410.0	1,480.8	1,685.7	1,525.5	9,448.4	10,347.3	12,847.0	10,880.9	12.3	13.3	15.2	13.6
15 November	4.1	6.0	6.8	5.6	7.2	8.2	10.5	8.65	865.9	1,163.3	1,270.6	1,099.9	5,400.0	6,550.0	6,775.0	6,241.7	11.2	12.6	13.6	12.5
Mean	4.9	6.7	8.1		8.9	10.2	12.9		1,318.6	1,479.2	1,697.9		8,667.5	9,326.0	11,367.9		12.3	13.3	15.1	
CD at 5% (D)		0.3				0.6				38.8				518.8						
CD at 5% (V)		0.3				0.2				45.6				365.5						
D*V		0.5				0.4				81.8				680.5						
V*D		0.5				0.7				75.1				729.9						

*DAS – Days after sowing. *where D-date of sowing, V-variety, D*V, V*D-interaction between date of sowing and variety.

significance at 60 and 90 DAS sowing only. Thereafter with advancement in growth stages up to maturity, interaction effect was observed non-significant.

Dry matter accumulation: The dry matter production by three mustard varieties under various growing environments is given in Table 6. Among the sowing dates, 26thOctober (124.1 g/m^2) was found to accumulate higher biomass as compared to other dates of sowing. Among the varieties, RH 0749 (112.2 g/m^2) showed highest value of dry matter per plant followed by RH 406 (101.6 g/m^2) and Kranti (89.8 g/m^2) in at all growth intervals. The interaction between varieties and dates of sowing was also found significant except 90 DAS and maturity. RH 0749 accumulate more biomass in 26th October at 30 DAS (6.41), 60 DAS (41.18), 90 DAS (77.85), and 120 DAS (93.15) and maturity (199.2 cm).These results are in unison with those obtained by Srivastava *et al*. (2011) in *Brassica*.

Dry matter partitioning: The dry matter partitioning by three mustard varieties under various growing environments is given in Table 7. During the initial flowering period (30 DAS) the percent allocation of biomass was highest to leaves (%) followed by stem (%) and root (%). At 120 DAS the highest percentage of biomass was allocated to stem. At maturity stage, the highest percent of biomass was allocated to siliqua (reproductive parts of the crop) in all treatment. Higher total dry matter production was produced in 26th October followed by 5th and 15th November. Among varieties, RH 0749 were the higher followed by RH 406 and Kranti. Subsequent delay in sowing recorded significantly lower biomass accumulation in different plant parts at all growth stages.

Yield and its attributes: Effect of varying environmental conditions on yield attributes of mustard varieties in 2014-15 are presented in Table 8.

Number of primary and secondary branches at harvest: The numbers of primary and secondary branches of mustard crop under different sowing environment were recorded at the time of harvesting period. The interaction effect of different sowing environment with varieties revealed that RH 0749 sown on 26th October resulted in highest number of primary (9.7) and secondary (15.0) branches at harvest as compared to RH 406 and Kranti. Among the sowing environment, higher numbers of primary and secondary branches were recorded in26th October followed by 5th and 15th November at harvesting time.

Seed yield (kg/ha): The result showed that seed yield showed significant difference among sowing dates. The highest seed yield in 26th October sown crop was also due to significantly improved yield attributes as compared to crop sown on other dates. Maximum seed yield was recorded in 26th October (1870.3 kg/ha) as compared to 5th (1525.5 kg/ha) and 15th November (1099.9 kg/ha). Among varieties, RH 0749 (1697.9) recorded highest seed yield as compared to RH 406 (1479.2) and Kranti (1318.6). These results confirmed the findings Pradhan *et al*. (2014) in mustard crop at IARI, Delhi.

Biological yield (kg/ha): Among varieties, RH 0749 (11367 kg/ha) was significantly higher biological yield as compared to RH 406 (9326.0) and Kranti (8667.5). Interaction effect also shows that RH 0749 sown on 26th October (12238.9 kg/ha) produced significantly highest biological yield as compared 5th November (10880.9 kg/ha) and 15th November (6241.7 kg/ha). Similar results reported that Kumar *et al*. (2007) also reported that less amount of above ground biomass yield were recorded from sowing to maturity in *Brassica* as planting was delayed.

Harvest index (%): The 26th October (14.6) sown crop recorded highest harvest index as compared to 5th (13.6) and 15 November (12.5) sowing. Among varieties, RH 0749 (15.1) showed significantly higher harvest index as compared to RH 406 (13.3) and Kranti (12.3).

Conclusion

There was significant interaction between date of sowing and varieties with respect to plant height, LAI, dry matter accumulation, partitioning and yield attributes of mustard. The crop sown on 26thOctober performed significantly better in respect of growth and yield parameters as compared to mustard sown on 5thand 15th-November during the year 2014-15. From the above study, it was concluded that normal or early sowing of RH 0749, RH 406 and Kranti cultivar may be practiced for achieving good yield in the semi arid environment of north-western part of India.

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