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Response of Indian mustard to different sowing environments and varieties in semi-arid of Haryana

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Abstract
A field experiment was conducted in Research Farm, Dept. of Agril. Meteorology, CCS HAU, Hisar (semi-arid of Haryana) during rabi season 2012-13 and 2013-14. The results indicated that plant height, LAI, dry matter, seed yield and quality were affected by different sowing environments. The experiment was conducted with split plot design replicated four times with three dates of sowing viz., 10th October, 25th October, 8th November in 2012-13 and 21st October, 30th October, 10th November in 2013-14 were kept as main plot and three varieties viz., RH 30, Laxmi and RH 0749 as sub plot. Plant height, dry matter accumulation, leaf area index, yield and quality parameters were decreased significantly with successive delay in sowing, whereas among the varieties, RH 0749 conceive higher values. Among the crop seasons, 2012-13 has higher yield as compare to 2013-14. The relationship between seed yield and biological yield (R^2=0.8743); seed yield and harvest index (R^2=0.8593); oil yield and seed yield (R^2=0.9215); oil yield and biological yield (R^2=0.9011) have positively significant.

Keywords: plant height, lai, dry matter, seed yield, oil yield, Indian mustard

Introduction
Triclosan (TCS) [5-chloro-2-(2, 4-dichlorophenoxy) phenol], is a typical chemical in Rapeseed-mustard contributed 20-22% in total oilseed production in the country, whereas Haryana alone contributed 10.2 % of total rapeseed-mustard production (Anonymous, 2016) [2]. In India it is cultivated on 6.65 million hectares with production of 7.10 mt and productivity of 1069 kg/ha in 2016-17. Indian mustard accounts for about 75-80 per cent of the total area under this crop in the country. Haryana is one of the major rapeseed and mustard growing state and crop occupied 5.4 lakh ha of area producing 7.5 lakh tonnes giving an average yield of 1404 kg/ha during 2016-17 (Anonymous, 2016) [2]. As sowing time is one of the most important non-monetary input affecting crop yield and other agronomic traits among them, optimization of sowing time for mustard is essential. Sowing either too early or too late has been reported unfavorable (Keerthi et al. 2017) [5]. The optimum time of sowing can provide congenial conditions to have maximum light interception, best utilization of moisture and nutrients from early growth stage to seed filling stage. Indian mustard is much sensitive to climatic variables, and climate change has significant effect on its production as well as productivity. One month delay in sowing from mid-October resulted in loss of 40.6 % in seed yield (Lallu *et al*., 2010) [8]. It suffers from exposure to low temperature during vegetative and early pod filling stage and relatively higher temperature during germination and maturity (Aggarwal *et al*., 2004) [1]. If sowing is delayed, there is also a great danger of attack of aphids on this crop. So, sowing time is a key input to increase the productivity of mustard.

Materials and Methods
The experiment was conducted at the Research farm of Department of Agril. Meteorology, Chaudhary Charan Singh Haryana Agricultural University, Hisar (India). Hisar is located in Indogangetic plains of North-West India at 215.2 meters above mean sea level with latitude of 29° 10’ N and longitude of 75° 36’ E. The weekly mean weather situation and soil properties (sandy loam) details are mention in the Fig.1 and Table 1, respectively. The experiment consisting of three dates of sowing *viz*. D_1: Oct. 10, 2012 and Oct. 21, 2013; D_2: Oct. 25, 2012 and Oct. 30, 2013; and D_3: Nov. 8, 2012 and Nov. 10, 2013 in main plots and three varieties *viz*. V_1: RH 30, V_2: Laxmi and V_3: RH 0749 in sub plots were laid out in split plot design with four replications.

The field experiment was carried out as per recommendations for Indian mustard by CCS HAU, Hisar during both the crop seasons (2012-13 & 2013-14).

Plant height (cm), dry matter (g/m^2) and leaf area index was measured at 30 days interval after sowing till physiological maturity on five tagged plants in each plot. The sampled plants were sun dried and oven dried (65 °C to 70°) thereafter. The biomass/dry matter accumulation in different plant parts was converted to weight per square meter. The green leaf area (cm^2) was recorded using leaf area meter (LI-3000 Area meter, LI-COR Biosciences, Nebroska, USA) and LAI by the following formula:

$$\text{LAI} = \frac{\text{Leaf Area (cm}^2\text{)}}{\text{Land area covered by plant (cm}^2\text{)}}$$

The total number of primary branches, secondary branches, siliqua length per plant, number of siliquae per plant, number of seed per siliqua, seed yield per plant produced per plant counted at harvest and mean value of five plants uprooted for biomass observation in all the treatments. The number of siliquae per square meter and seed yield per square meter were computed from the value of per plant. The 1000 seeds were counted manually from random sample and then weighed to record test weight in grams. The crop harvested from net plot and seeds yield and biological yield (seed yield and stover yield) together were expressed as quintal per hectare. The harvest index for each plot was calculated by dividing the total seed yield by the total biological yield of the same net plot and multiplied by 100 as given below:

$$\text{HI} = \frac{\text{Seed yield}}{\text{Biological yield}} * 100$$

Oil content of dried seeds was determined by Nuclear Magnetic Resonance (MK IIIA new port analyzer). Oil yield was calculated by using following formula:

$$\text{Oil yield (q/ha}^{-1}\text{)} = \frac{\text{Oil content (\%)}}{100} * \text{Seed yield (q/ha}^{-1}\text{)}$$

Results and Discussion

Plant height

The results of indicated that plant height increased with advancement of crop season during both the crop seasons. Among date of sowings, the plant height at different growth stages was recorded significantly higher in first sowing (D_1) than others in 2012-13 and 2013-14 (Tables 2). This was probably due to more heat units consumed by D_1 sown crop as compared to delayed sowing. Temperature stress on delayed sown crop during both the crop seasons might lead to this effect. In all the growth intervals, RH 0749 have observed highest plant height followed by Laxmi and lowest in RH 30 during both the crop seasons. These variations in plant height among different varieties were due to variation in their genetic constitution Weerakoon and Somaratne (2011) [19] also supported these findings.

Biomass Accumulation

The dry matter accumulation increased till physiological maturity among all the treatments during both crop seasons (Table 3). The increase in dry matter of plants was due to increase in plant height, growth and development of plant organs. The highest dry matter was accumulated in D_1 (10th Oct. and 21st Oct.) at all the growth intervals till physiological maturity, whereas the minimum dry matter accumulation was recorded in D_3 (8th Nov. and 10th Nov.) during both crop seasons. The crop of D_1 date of sowing has utilized more solar radiation at early vegetative phase as well as more congenial environment at reproductive phase and grand growth phase which resulted in higher biomass, LAI and better partitioning. However, D_3 late sown crop during vegetative phase suffered low temperature and consumed less radiation, whereas, at grand growth phase and reproductive phase due to higher temperature and terminal heat stress resulted into reduced reproductive phase and forced maturity too. The findings of Weerakoon and Somaratne (2011) [19] are also supported these results. Schwarte *et al*. (2005) also confirmed that delayed planting decrease the dry matter production. The highest biomass in earlier sown crop and variety RH 0749 might be due to maximum LAI and more PAR absorption by this variety. Among the varieties, the biomass accumulation in different plant parts of RH 0749 was significantly higher followed by Laxmi and RH 30 in irrespective of the growth intervals during both the years. The varieties performed same trend of biomass allocation as the sowing dates for the different growth intervals.

Leaf area index (LAI)

The LAI was highly influenced by different growing environments. Among three sowing dates, D_1 produced highest LAI followed by D_2 and D_3 sown crop during 2012-13 and 2013-14 (Fig. 2). The D_1 date of sowing has attained maximum value of LAI due to the elongated vegetative phase which added more foliage to the crop as compared to delayed sowing. Comparatively warmer temperature prevailed under delayed sowing induced force maturity by shortening duration of phenophases and ultimately life span of the crop. Among varieties, RH 0749 have produced maximum LAI followed by Laxmi and RH 30 in both the crop seasons. The PAR absorption was more in timely sown crop and RH 0749 due to elongated vegetative phase. Gill and Bains (2008) confirms that early sowing enhanced leaf area index and dry matter accumulation over late sown mustard. Nanda *et al*. (1996) [9], Kumari and Rao (2005) [7] and Tripathi (2005) [18] found that delayed sowing reduced leaf area.

Mustard yield and quality parameters

Stronger source is required to develop stronger sink. The high temperature during reproductive phase with lesser days available for occurrence of various phenophases induced forced maturity. It might be probable reason for reduced number of primary and secondary branches, number of seed per siliquae, siliquae length and siliquae per plant under late sowing (Weerakoon and Somaratne, 2011) [19]. Among the yield attributing characters were found highest in D_1 (10th Oct. and 21st Oct.) sowing treatment during both crop seasons (Table 4). This might be due to the fact that D_1 sown crop produced higher LAI and more biomass production as compared to other treatments. Similar finding were also observed by Robertson *et al*. (2002) [13], Poureisa and Nabipour (2007) [11] and Singh *et al*. (2002) in *B. napus*. Among sowing dates, D_1 (10th Oct. and 21st Oct.) recorded highest seed yield (33.6 and 29.2 q ha^{-1} in 2012-13 and 2013-14, respectively) and biological yield (151.3 and 147.7 q ha^{-1} in 2012-13 and 2013-14, respectively) (Table 5). Significantly, higher biomass production and harvest index in RH 0749 was due to comparatively longer crop maturity period and bulky biomass to economic sink, respectively. The reduction in yield might be due to delay in sowing resulted into less PAR interception, less accumulation of heat units and shorter seed filling period during both the crop seasons.

The results were revealed that yielding ability of a crop is dependent on investment of a greater proportion of biomass and yield to variation in their edaphic and environmental conditions, which was achieved through change in sowing dates (Poureisa and Nabipour, 2007; and Singh *et al*., 2002) [11, 16]. The oil content was significantly higher in RH 30, followed by RH 0749 and lowest in Laxmi, but the oil yield in mustard varieties was higher in RH 0749, followed by Laxmi which is found at par with RH 30, during 2013-14 (Table 6). The interaction effect of different sowing environment and varieties on seed yield in mustard is given is Table 7 and Fig. 3.

The higher biological yield and harvest index were found significantly associated with higher seed yield of mustard (R^2 = 0.874 and 0.859). Like the seed yield, oil yield was also significantly associated with higher seed yield (R^2 = 0.921) and biological yield (R^2 = 0.9011) (Fig. 4). This clearly shows that if any of above mention parameter increased by any input or management practice will automatically increase the seed yield and oil yield. Similar results have been reported by Singh *et al*., (2014) [15] and Keivanrad *et al*., (2012) [6].

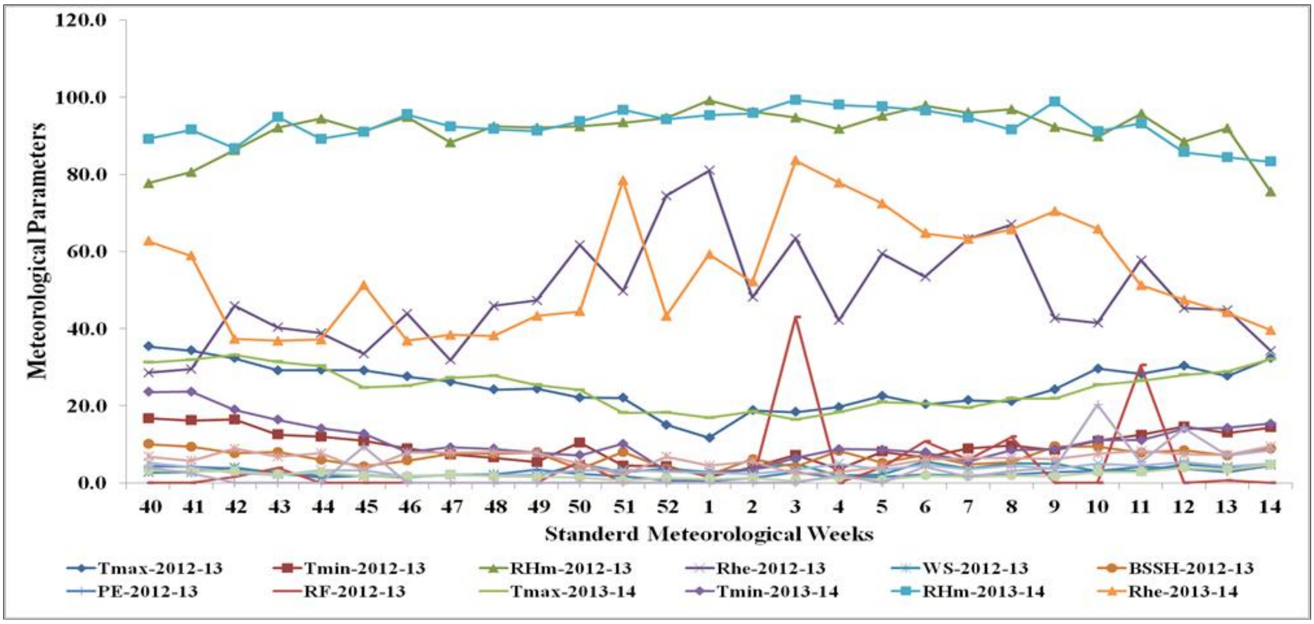

Fig 1: Weekly mean weather condition during Mustard crop season 2012-13 and 2013-14

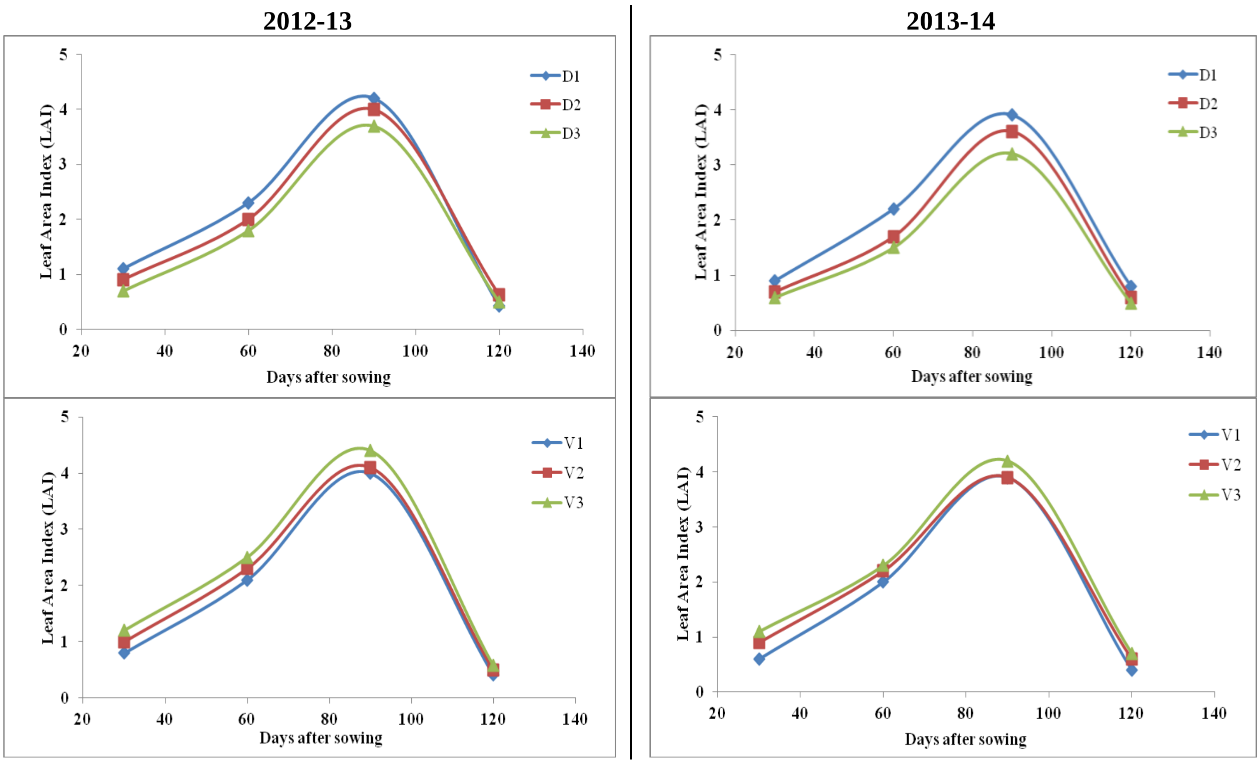

Fig 2: Effect of sowing time and varieties on LAI at various growth intervals for mustard during 2012-13 and 2013-14

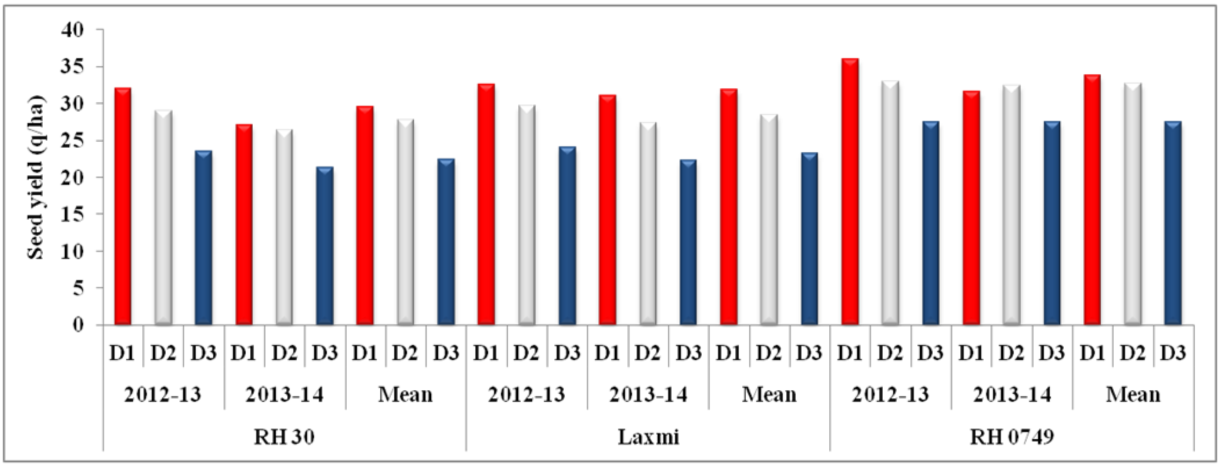

Fig 3: Effect of different sowing dates and varieties of Indian mustard on seed yield

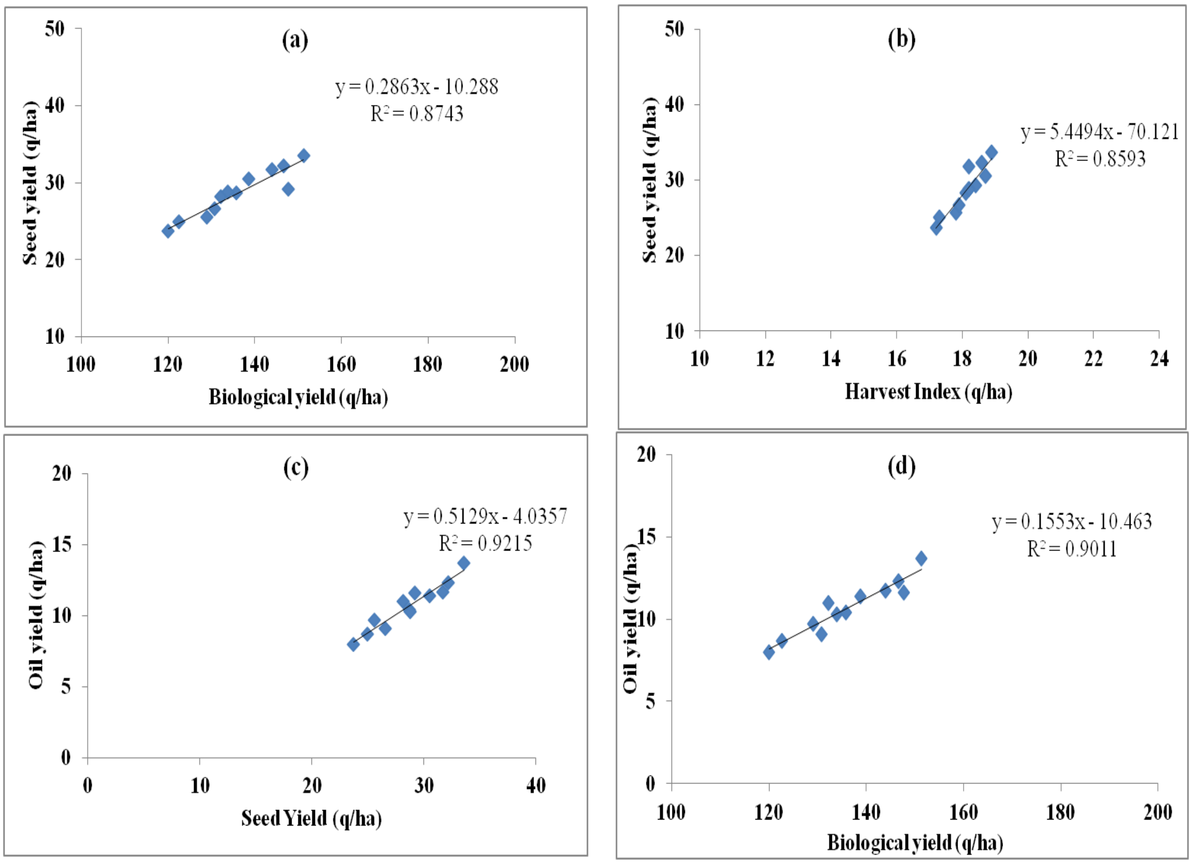

Fig 4: Regression line showing the relationship between (a) Seed yield and biological yield; (b) seed yield and harvest index; (c) oil yield and seed yield; (d) oil yield and biological yield

Table 1: Mechanical composition and chemical properties of experimental field

Mechanical composition			
Soil components		**Depth of soil profile (cm)**	
	0-30 cm	**30-60 cm**	**60-90 cm**
Sand (%)	57.38	56.56	56.42
Silt (%)	26.35	26.82	26.68
Clay (%)	16.27	16.62	16.90
Textural class	Sandy loam	Sandy loam	Sandy loam
Chemical properties			
Soil parameters	**Value recoded**	**Method of estimation**	
Soil pH (1:2 soil water suspension)	7.9	Glass electrode pH meter (Jackson, 1973)	
EC (dSm^{-1} at 25 °C) (1:2 soil water suspension)	0.93	Conductivity bridge method (Richards, 1954)	
Organic carbon (%)	0.39	Walkley and Black's wet oxidation method (Jackson, 1973)	
Available N (kg ha^{-1})	193	Alkaline permanganate method (Subhiah and Asija, 1956)	
Available P_2O_5 (kg ha^{-1})	17	Olsen's method (Olsen *et al.*, 1954)	
Available K_2O (kg ha^{-1})	356	Flame photometer method (Richards, 1954)	

Table 2: Plant height (cm) of mustard at various growth intervals under different sowing environments andvarieties during crop season 2012-13 and 2013-14.

Treatment	30 DAS		60 DAS		90 DAS		120 DAS		PM	
	Y1	Y2	Y1	Y2	Y1	Y2	Y1	Y2	Y1	Y2
D_1	41.9	39.8	93.1	103.4	158.4	149.3	185.8	177.6	195.1	186.0
D_2	36.7	34.8	81.4	90.8	147.9	130.8	177.7	153.1	186.4	172.5
D_3	30.1	28.6	65.5	74.2	133.7	107.3	165.9	125.4	174.7	134.4
CD at 5%	2.0	2.7	2.1	3.7	8.7	6.3	6.2	8.7	8.0	5.3
V_1	33.2	31.0	71.5	79.9	135.6	118.0	167.8	136.5	175.6	147.9
V_2	34.1	32.7	80.8	83.7	147.1	123.6	175.0	141.3	183.5	159.4
V_3	41.5	39.4	87.8	104.7	157.3	145.9	186.6	178.3	195.1	185.7
CD at 5%	2.1	1.9	1.9	4.9	8.2	4.7	6.0	8.0	9.1	7.6
CD at 5% (D x V)	1.56	2.0	1.75	3.83	6.42	5.21	5.48	6.14	7.23	5.83
CD at 5% (V x D)	1.63	1.63	1.20	3.10	4.23	4.31	5.21	5.31	6.10	4.78

Where, DAS- days after sowing, Y1 = 2012-13, Y2 = 2013-14

Table 3: Effect of sowing dates and varieties on the total biomass and its allocation (g/m^2) at various growth intervals in mustard during crop season 2012-13 and 2013-14

Treatment	30 DAS		60 DAS		90 DAS		120 DAS		PM	
	Y1	Y2	Y1	Y2	Y1	Y2	Y1	Y2	Y1	Y2
D_1	136.6	117.1	226.2	191.7	495.2	457.7	1467.6	1377.2	1516.3	1303.3
D_2	123.8	109.9	195.1	176.7	431.8	409.3	1232.7	1164.5	1250.6	1089.0
D_3	95.3	84.8	163.9	139.8	359.2	322.6	1081.3	982.4	1086.3	911.1
CD at 5%	6.4	4.6	10.7	15.8	27.1	24.1	23.8	22.7	23.4	33.0
V_1	108.1	95.1	169.0	159.2	374.7	363.6	1119.0	1046.2	1120.3	908.3
V_2	119.2	99.9	201.7	167.9	445.4	383.2	1267.7	1118.9	1278.9	1074.9
V_3	128.5	116.6	214.8	181.0	466.3	442.8	1395.0	1338.7	1454.1	1311.1
CD at 5%	6.5	5.1	11.5	12.5	25.9	25.2	21.0	28.5	28.4	30.7
CD at 5% (D x V)	4.6	5.6	9.5	14.2	22.2	22.8	18.9	24.5	26.7	29.6
CD at 5% (V x D)	3.5	4.7	7.2	13.8	17.9	18.7	16.4	22.0	28.1	28.2

Table 4: Effect of growing environments and varieties on yield attributes in mustard during crop season 2012-13 and 2013-14

Treatment	Number of primary branch		Number of secondary branch		Siliquae length (cm)		Number of siliquae per plant		Number of siliquae per m^2		Number of seed per siliquae	
	Y1	**Y2**	**Y1**	**Y2**	**Y1**	**Y2**	**Y1**	**Y2**	**Y1**	**Y2**	**Y1**	**Y2**
D_1	6.5	5.6	8.4	11.1	6.9	6.8	352.5	331.2	7832.6	7360.0	21.8	21.2
D_2	5.6	5.4	6.6	10.2	6.5	6.3	331.2	280.7	7360.4	6238.5	20.7	19.7
D_3	4.4	4.3	6.0	8.4	6.2	5.7	271.7	247.1	6038.2	5490.4	18.4	18.2
CD at 5%	0.2	0.9	1.0	2.1	0.1	0.1	19.2	18.6	34.0	30.8	0.4	1.0
V_1	5.3	5.0	6.3	9.3	6.2	6.0	305.2	258.6	6951.1	5745.9	19.9	18.8
V_2	5.4	5.0	7.0	10.0	6.4	6.2	312.8	288.6	6781.1	6413.9	19.9	19.2
V_3	5.6	5.4	7.6	10.5	7.0	6.7	337.5	311.8	7498.9	6929.2	21.3	21.1
CD at 5%	0.3	0.4	1.1	1.5	0.05	0.05	11.8	17.9	44.9	32.7	0.1	1.0
CD at 5% (D x V)	0.2	0.6	0.8	1.2	0.1	0.3	13.9	15.2	36.7	33.5	0.6	0.7
CD at 5% (V x D)	0.2	0.6	0.7	1.0	0.1	0.2	11.3	13.0	30.9	28.2	0.4	0.6

Table 5: Effect of growing environments and varieties on yield in mustard during crop season 2012-13 and 2013-14

Treatment	**Seed yield per plant (g)**		**Seed yield (g/m^2)**		**1000 –Seed weight (g)**		**Seed yield (q/ha)**		**Biological yield (q/ha)**		**HI (%)**	
	Y1	Y2	Y1	Y2	Y1	Y2	Y1	Y2	Y1	Y2	Y1	Y2
D_1	23.5	21.4	522.6	474.5	6.5	6.5	33.6	29.2	151.3	147.7	18.9	18.4
D_2	21.0	20.6	465.9	457.7	5.5	5.4	30.5	28.7	138.7	135.8	18.7	18.2
D_3	16.7	16.2	371.5	359.8	4.8	4.8	25.0	23.7	122.6	120.0	17.3	17.2
CD at 5%	0.8	2.4	16.8	25.7	0.2	0.2	2.4	0.9	13.1	13.1	1.2	0.2
V_1	18.2	18.1	353.0	332.5	5.5	5.5	28.2	25.6	132.2	129.0	18.1	17.8
V_2	19.0	19.6	435.8	421.8	5.1	5.0	28.8	26.6	133.8	130.7	18.2	17.9
V_3	24.1	20.4	485.2	454.3	6.4	6.3	32.2	31.7	146.6	143.9	18.6	18.2
CD at 5%	0.4	1.3	17.8	28.7	0.3	0.1	0.5	0.4	10.9	10.9	0.04	0.03
CD at 5% (D x V)	0.4	2.6	19.3	23.0	0.40	0.2	1.35	0.7	15.20	14.6	0.52	0.1
CD at 5% (V x D)	0.3	2.2	17.3	20.8	0.33	0.1	1.15	0.9	12.92	12.3	0.58	0.1

Table 6: Effect of growing environments and varieties on oil quality in mustard during crop season 2012-13 and 2013-14

Treatment	Oil content (%)		Oil yield (q/ha)	
	Y1	Y2	Y1	Y2
D_1	40.8	39.6	13.7	11.6
D_2	37.4	36.2	11.4	10.4
D_3	34.9	33.3	8.7	8.0
CD at 5%	2.7	0.6	1.2	1.1
V_1	39.1	37.8	11.0	9.7
V_2	35.7	34.3	10.3	9.1
V_3	38.3	37.0	12.3	11.7
CD at 5%	0.2	0.4	0.2	0.4
CD at 5% (D x V)	1.47	0.3	0.96	1.0
CD at 5% (V x D)	1.69	0.3	0.65	0.8

Table 7: Interaction effect of growing environment and varieties on mustard seed yield (q/ha) of mustard during 2012-13 and 2013-14

2012-13					2013-14			
Treatments	V_1	V_2	V_3	Mean	V_1	V_2	V_3	Mean
D_1	32.0	32.6	36.0	33.6	27.0	31.1	31.6	29.2
D_2	29.0	29.6	33.0	30.5	26.4	27.4	32.4	28.7
D_3	23.5	24.1	27.5	25.0	21.3	22.3	27.5	23.7
Mean	28.2	28.8	32.2	29.7	25.6	26.6	31.7	27.2
CD at 5% (D x V)	1.4				0.9			
CD at 5% (V x D)	1.2				0.9			

Conclusion

It may be concluded from the above discussed results that growth, productivity and quality of the mustard is influenced by both varieties as well as by the date of sowing. The October sown crop has more efficient results as compare to November. The first date of sowing of mustard with RH 0749 variety was found to be most suitable and realize better growth as well as yield and quality of oil during both crop seasons. The positively significant relationship were observed between seed yield and biological yield (R^2=0.8743); seed yield and harvest index (R^2=0.8593); oil yield and seed yield (R^2=0.9215); oil yield and biological yield (R^2=0.9011). The biological yield is contributing in the seed and oil yield

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