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Physiological Traits Study to Identify Suitable Mustard Genotype for Late Sown Condition of Northern Part of India

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ABSTRACT

Background: Indian mustard (*Brassica juncea* L.) is a prominent seed crop grown in most of the northern part of India. It is also grown in different cropping systems where sowing time differs as per availability of vacant field prior to preceding crop. Being a *rabi* season (winter) crop its physiological as well as morphological developments are markedly influenced by temperature condition.

Methods: An investigation was carried out during *rabi* season of 2010-11 and 2011-2012 at Oilseeds Research Farm, Kanpur (UP) with 4 sowing dates (30th Sept. 11th 21st, 31st Oct.) and 5 genotypes (Kranti, Maya, PAC-437, PBR-357, Rohini) of mustard on sandy loam soil under irrigated condition to study different physiological and yield attributing characters.

Result: The results shown that among the sowing dates, 11th October registered the highest values of specific leaf weight (SLW), Crop Growth rate (CGR) estimated at 60-90 DAS, seed yield and oil content. The early sowing at 30th Sept. registered significantly lowest seed yield (1880 Kg ha^{-1}) and seed oil content (38%). In case of genotypes, PAC-437 registered highest values of SLW (29.60 mg cm^{-2}), NAR (113.3 mg dm^{-2} day^{-1}), RGR (26.7 mg g^{-1} day^{-1}), CGR (0.94g $plant^{-1}$ day) at 60-90 DAS, seed yield (2079 kg ha^{-1}). The interaction effect of sowing date × genotypes was found significant in most of the cases. Thus, the results concluded in Indian condition specially the northern part, 11th October proved to be the optimum sowing time of mustard. As far as the genotype is concerned, Kranti perform well of this date of sowing while PAC-437 proved its superiority over other genotypes as well as different sowings date of October month.

Key words: Genotype, Mustard, Sowing time, Seed quality, Yield.

INTRODUCTION

Indian mustard (*Brassica juncea* L.) is a prominent oil seed crop grown in most of the northern part of India. It is also grown in different cropping systems where sowing time differs as per availability of vacant field prior to preceding crop. Being a *rabi* season(winter) crop its physiological as well as morphological developments are markedly influenced by temperature condition. In different cropping systems, sowing of mustard varies from late September and goes up to November. Many times, early sowing of mustard failed due to high temperature while the delay in sowing shortens vegetative phase, advances flowering time, accelerates senescence, reduces seed development duration and dry matter accumulation (Dhaliwal *et al*., 2007). Sometime the late sowing also exposes vegetative phase to low temperature, resulting in poor and slow vegetative phase. The high temperature during grain developmental phase results poor biomass and seed yield. However, extent of influence of low as well as high atmospheric temperature varies in different genotypes of mustard. Thus, the seed yield of mustard is greatly influenced by prevailing temperature during crop period regardless of genotypes, though extent of influence varies in different genotypes.

Therefore, selection of suitable genotype for different sowing times is necessary to get the satisfactory yields under different sowing. It is why the present investigation was undertaken to study different physiological traits responsible for high temperature tolerance at grain filling stage.

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MATERIALS AND METHODS

A field experiment was conducted during winter season of 2010-2011 and 2011-2012 at Oil Seed Experiment Farm, Kalyanpur (26°N, 80°E) of C S Azad University of Agriculture and Technology (26°28′ North and 80°24′ East), Kanpur (U.P.), India. Experimental soil was sandy loam and slightly alkaline (pH 7.7) contained 0.44% OC, 268 Kg ha^{-1} available nitrogen, 18.3 Kg ha^{-1} available phosphorus and 268 kg ha^{-1} available potassium. The treatment included five genotypes of mustard *viz*. Kranti, Maya, PAC-437, PBR-357 and Rohini sown on four different dates *viz*. 30th Sept, 11th Oct. 21st Oct. and 31st October of year 2010-2011 and 2011-12. A total of 20 treatments were tested in spilt-plot design with sowing dates in main plots and genotypes in subplots the size of subplot is 4.05 × 6 m which replicated thrice. The crop was fertilized @150 Kg N+75 Kg P_2O_5 +75 Kg K_2O ha^{-1} uniformly

irrespective of treatment. Sowing of seed was done behind country plough in furrows 40 cm a part using 5 kg seed ha^{-1} for all genotypes and sowing times. The plant spacing with in row was maintained 15 cm by thinning extra plants at the stages of 15 days after sowing. The observations on growth parameters were recorded at successive periods of crop growth. The seed yield was estimated on individual plant basis (5 sample plants) on net plot area basis (kg ha^{-1}). Growth analysis parameters *viz*. specific leaf weight (SLW), relative growth rate (RGR), crop growth rate (CGR) and net assimilation rate (NAR) were calculated as per formula given below. Finally, the crop was harvested at physiological maturity in different sowings while threshing was done after complete sun drying of crop bundles. The oil content in seeds was estimated with the help of 'Soxhelt's extraction method'. All data obtained from different observations were statistically analyzed using the method suggested by Fisher (1921).

$$SLW\ (mgcm^{-2}) = \frac{\text{Leaf dry weight}}{\text{Leaf area}}$$

$$RGR\ (mg\ g^{-1}\ day^{-1}) = \frac{(\log_e W_2 - \log_e W_1)}{(t_2 - t_1)}$$

Where:
W_2 and W_1= Dry weight $plant^{-1}$ at time t_2 and t_1.
Log_e= Natural logarithm (Fisher,1921).

$$CGR\ (g\ plant^{-1}\ day^{-1}) = \frac{W_2 - W_1}{t_2 - t_1}$$

Where:
W_2 and W_1= Dry weight of plants at time t_2 and t_1, respectively (Watson, 1952).

$$NAR\ (mg\ d\ m^{-2}\ day^{-1}) = \frac{(W_2 - W_1)(\log_e L_2 - \log_e L_2)}{(t_2 - t_1)(L_2 - L_1)}$$

Where:
W_2 and W_1= Values of dry weight per plant at time t_2 and t_1, respectively.
L_2 and L_1= leaf area per plant at their respective time.
Log_e= Natural logarithm. (Gregory, 1926).

RESULTS AND DISCUSSION

Growth character

The early sown (30th Sept.) mustard varieties recorded significantly higher plant height while the other sowing date showednon significant effect on plant height as shown in (Table1). While on the other hand 30th Sept. sowing gave significantly lower values of branches $plant^{-1}$, leaf area and dry matter accumulation. On mean basis of both years, 11th Oct. sowing produced 5.3, 14.2 and 24.8% more branches $plant^{-1}$, 7.9, 17.9 and 41.1% higher leaf area $plant^{-1}$ and 6.3, 36.8 and 81.3% more dry matter $plant^{-1}$ over 21st, 31st Oct. and 30th Sept. sowings. The higher plant height attributed to higher temperature caused rapid cell division in meristematic tissues and led to taller plants (Ramesh, 2012). Maximum branches and other growth characters under 11th Oct. sowing might be attributed to the prevalence of optimum temperature during growth period. Reduced growth in later sowings beyond 11th October, might be subjected to relatively lesser time span available for plant growth. These results confirm the findings of Lallu and Dixit (2008). Among genotypes, Kranti produced significantly taller plants while other growth characters were higher in PAC-437. These are as per their genetic makeup and susceptibility to temperature adversities. These results may be supported by the findings of Awasthi *et al*. (2007).

Specific leaf weight (SLW)

The significant differencesin specific leaf weight was recorded with date of sowing and genotypes (Fig 1). Among sowing dates, significantly higher SLW was measured with 11th October followed by 21st October sowing whereas 30th September sowing registered lowest SLW at all stages of crop growth. However, the SLW increased with advancement of plant age, thus it maximized at last stage of 90 DAS during both years. At this stage, 11th October sowing registered 8.3, 17.7 and 18.9% higher SLW over 21st October, 31st October and 30th September sowings, respectively on mean basis of two years data. The maximum SLW at 11th October sowing could probably due to enhanced photosynthetic efficiency per unit leaf area under optimum sowing time. Prasad *et al*. (2009) also observed similar results.

Genotype PAC-437 closely followed by Kranti, recorded significantly higher SLW than all other genotypes which remained almost at par with each other. The genotype PAC-437 recorded 3.7, 6.5,7.4 and 8.0% higher SLW than Kranti, Maya, PBR-357 and Rohini genotypes, respectively at 90 DAS in mean data of 2 years.

These results corroborate with the findings of Kalubarne and Pandey (1979). The interaction effect of sowing date × genotypes was not found significant on SLW at any stage.

Net assimilation rate (NAR)

The net assimilation rate recorded at two stages *i.e*. 30-60 DAS and 60-90 DAS showed significant differences among the genotypes and with different date of sowing (Fig 2). The genotype PBR-357 and Rohini were at par and recorded significantly higher NAR values than other genotypes at 30-60 DAS at first two sowings dates *i.e.* 30th Sept. and 11th Oct. While at late sowing on 31st October difference between genotypes were non-significant. The genotype Rohini registered maximum and Kranti registered minimum NAR at 21st October sowing. At early sown (30th September) condition, genotype PAC-437 registered significantly higher NAR followed by Maya at 60-90 DAS stage. The sowings at 11th and 21st October, genotype PAC-437 recorded significantly higher NAR followed by Maya, while PBR-357 registered significantly lower NAR. These results may be explained as the resistance or susceptibility of genotypes to temperature exposure (Gregory, 1926). These results were supported by the findings of Pandey and Bose (2006).

Relative growth rate

Crop sown on 30th September recorded significantly higher RGR (Fig 3) while other sowing dates remained at par. At later stage of crop growth *i.e*. 60-90 DAS, treatment and their interaction influenced RGR significantly. In first and last sowings on 30th Sept. and 31st October, genotype PAC-437 registered significantly higher RGR while at 21st October sowing, Kranti recorded highest RGR. October, 11th sowing showed non-significant difference in RGR between genotypes. Almost similar trend in results was observed during both years of study. On mean basis, PAC-437 recorded highest RGR closely followed by Maya and Kranti genotypes. Among sowing dates, 21st Oct. sowing closely followed by 11th Oct. registered highest RGR value. It might

Table 1: Effect of sowing dates and genotypes of mustard on growth characters.

Treatments	Growth characters							
	Plant height (cm)		No. of branches plant^{-1}		Leaf area per plant (cm)		Dry matter palnt^{-1} (g)	
Sowing date	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
30th Sept.	187.6	189.5	16.86	18.23	702.5	711.40	33.4	34.10
11th Oct.	183.1	184.0	21.17	22.63	993.7	1001.4	61.4	61.00
21st Oct.	182.9	186.8	19.78	21.83	921.7	926.82	57.8	57.32
31st Oct.	183.0	184.8	18.33	20.02	842.0	850.94	44.5	45.02
S.Ed ±	0.3	0.7	0.37	0.09	4.9	5.9	0.3	0.4
C.D. (P=0.05)	0.8	1.7	0.91	0.22	11.9	15.0	0.8	1.0
Genotype								
Kranti	189.4	192.02	19.28	20.94	871.5	882.83	48.95	49.10
Maya	181.2	182.5	18.27	19.88	862.20	869.0	49.55	49.53
PAC-437	187.6	188.5	21.86	22.21	907.55	915.30	52.83	52.78
PBR-357	183.2	185.6	18.08	20.12	845.70	851.3	47.48	47.66
Rohini	179.5	182.6	17.68	20.24	837.72	844.76	47.73	47.74
S.Ed.±	0.6	0.7	0.36	0.21	4.9	13.3	0.3	0.5
C.D. (P=0.05)	1.2	1.4	0.74	0.43	10.1	27.0	0.6	0.9

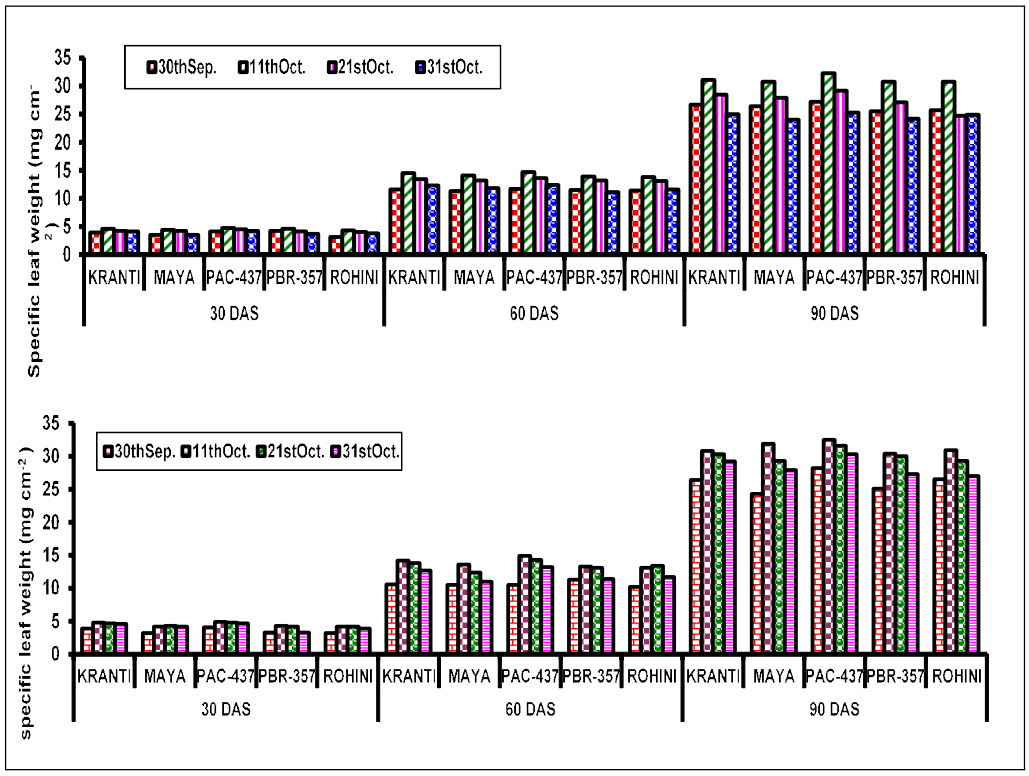

Fig 1: Effect of sowing dates on specific leaf weight (mg cm^{-2}) of mustard genotypes at successive periods of crop growth stage.

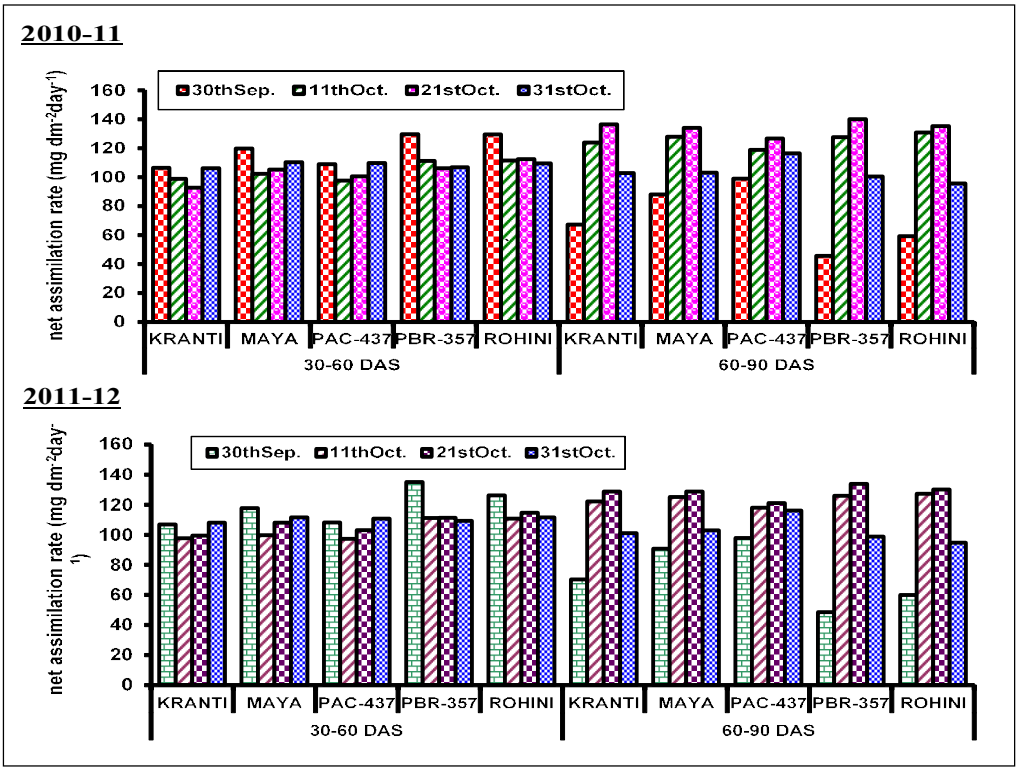

Fig 2: Effect of sowing dates on net assimilation rate (mg $dm^{-2}day^{-1}$) of mustard genotypes at successive periods of crop growth stage.

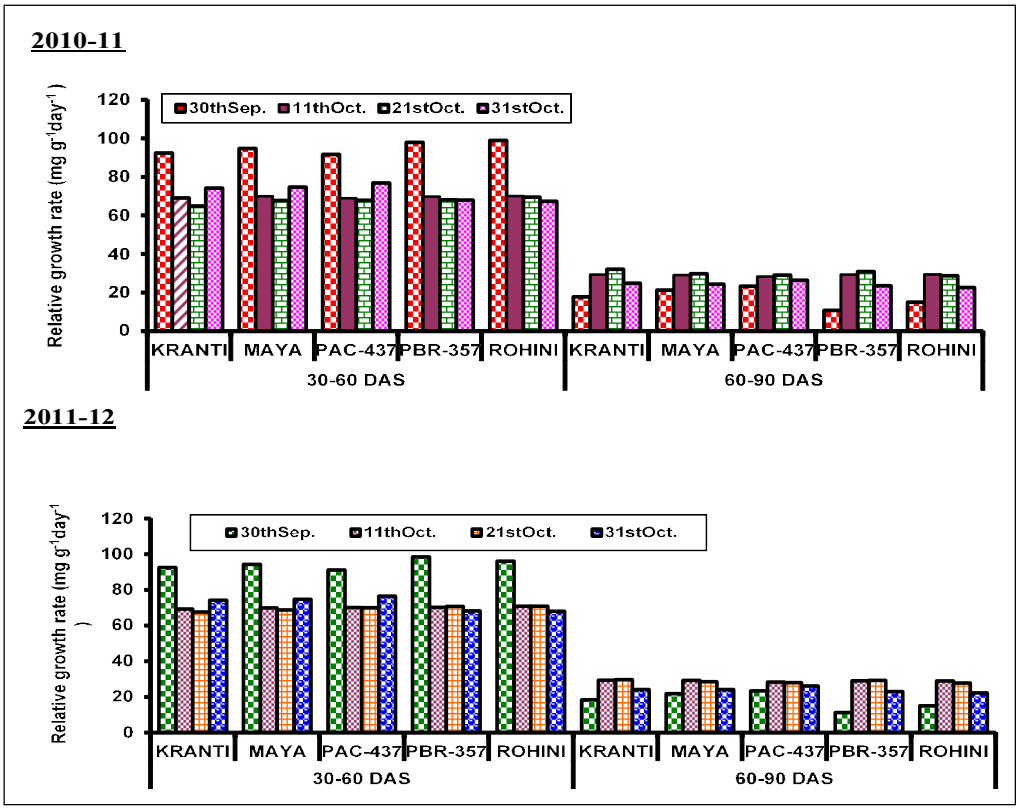

Fig 3: Effect of sowing dates on relative growth rate (mg $g^{-1}day^{-1}$) of mustard genotypes at successive periods of crop growth stages.

be the effect of soil and atmospheric temperatures experienced by crop during different growth phases under varied sowing dates. The higher RGR of PAC-437 might be associated with higher rate of photosynthesis particularly at the late stage beyond 60 DAS. The results confirm the findings of Gavit *et al*. (2008).

Crop growth rate

Sowing dates and genotypes significantly influenced the crop growth rate (CGR) at both stages but their interaction effect was found significant only at later stage of 60-90 DAS (Fig 4). Among different sowing dates, 11th Oct. recorded significantly higher CGR followed by 21st Oct sowing while 30th Sept. sowing registered significantly lowest CGR value during both the years at both stages. It might be attributed to favorable environment particularly temperature experienced at 11th Oct. Sowing which could utilize the available resources efficiently. In case of genotypes, PAC-437 registered significantly highest CGR at both stages during each year. It might be because of genetic makeup of genotype which differs in each other. These results are in agreement with the findings of Pradhan *et al*. (1997). The data regarding interaction effect indicated that first and last sowings on 30th Sept. and 31st Oct with genotype PAC-437 recorded highest CGR but in other sowings, difference in CGR between genotypes were non-significant. It showed that under favorable environment with timely sown, crop genotypes made no difference in CGR, while in adverse environment of earliest and last sowings, PAC-437 proved its superiority by showing resistance to adverse environment in respect to CGR. It may be supported by NAR and RGR values also.

Yield attributes

Yield attributes were significantly influenced by sowing dates and genotypes (Table 2). Number of siliquae plant^{-1}, siliqua length, seeds siliqua^{-1}, 1000-seed wt. and seed wt. plant^{-1} were comparatively higher in 11th October sowing and significantly lower in 30th Sept. sowing. The delay in sowing beyond 11th Oct. reduced all yield attributes significantly, might be because of less number of branches and lower leaf area plant^{-1}. More number of branches and larger leaf area might have increased the photosynthetic area which resulted in the accumulation of more photosynthates in different plant parts and their translocation from source to sink, thus yield attributes attained highest values under optimum time of sowing *i.e*. 11th October. These results corroborate with the findings of Archana Kumari *et al*. (2012). However, harvest index was not influenced by sowing dates. All sowings registered harvest index at par except 31st Oct. sowing which recorded significantly lowest harvest index. It might be because of lesser fruiting due to shortened reproductive phase of crop.

Among the genotypes, PAC-437 registered highest values of all yield attributes except 1000- seed weight and harvest index. Harvest index and 1000-seed weight were found significantly higher in genotype PBR-357 which is

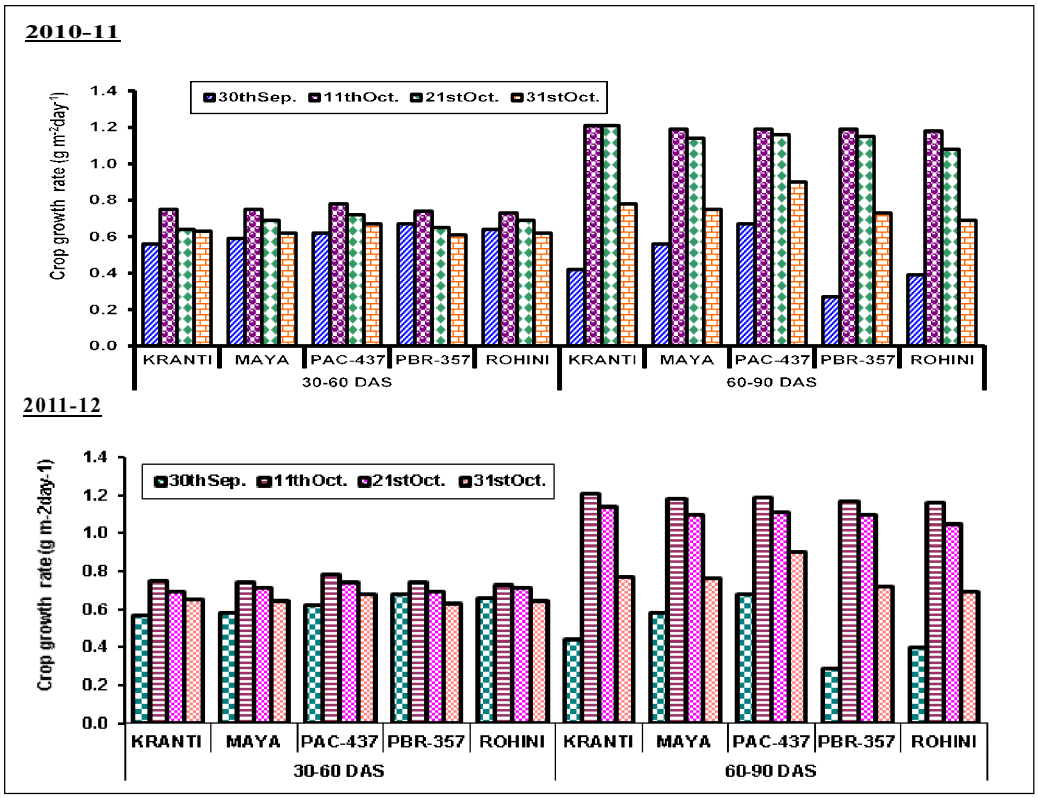

Fig 4: Effect of sowing dates on crop growth rate (g m^{-2} day^{-1}) of mustard genotypes at successive periods of crop growth stages.

purely a genetic character. These results are in agreement with those of Archana Kumari *et al*. (2012).

Yield

Sowing date and genotypes were significantly influenced seed yield (Table 3). The 11th Oct. sown crop produced significantly higher seed yield which reduced with delay in sowing. However, the earliest sown crop (30th Sept.) yielded significantly lowest biomass and seed yield. The similar trained was observed during both the years. On mean basis of 2-years data, 11th Oct. Sowing produced 2.3, 11.0 and 15.5% higher seed yield over 21st Oct., 31st Oct and 30th Sept. sowing respectively. Thus, the early sowing reduced mustard yields by greater margins over the optimum sowing date of 11th October. Such yield trends might be because of various growth and yield attributes which also behaved almost in the similar way. These results are in agreement to the findings of Pronay Bala *et al*. (2011).

It might be attributed to growth characters. Seed yield was also highest in genotype PAC-437 but it was significantly higher only over the seed yield of Rohini during 2010-11. However, the interaction of genotype with date of sowing showed that Kranti and Maya are good for early sowing (30th Sept) while PBR-357 is suitable for sowing at 21st while Oct 11th and 31st Oct. sowings are suitable for genotype PAC-437 and produced significantly higher seed yield. The similar results have also been observed by Archana Kumari *et al*. (2012). Most of the growth and yield characters were also influenced by significant interaction effect between sowing dates and genotypes. In such interactions, genotype Kranti performed better than others in 30th Sept. sowing while PAC-437on par with better performer in almost all sowing dates.

Oil content

The crop sown on 11th Oct. contained significantly higher seed oil content over the 30th Sept. sown crop. Seed oil

Table 2: Effect of sowing dates and genotypes on yield attributes of mustard.

Treatments	Yield attributes of mustard											
	No. of siliquae plant^{-1}		Siliqua length (cm)		Seeds siliqua^{-1}		1000 seed weight (g)		Seed wt plant^{-1} (g)		Harvest index	
Sowing dates	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
30th Sept.	716.3	709.8	5.7	5.9	10.5	10.3	4.7	4.5	18.2	18.4	23.2	24.1
11th Oct.	882.7	884.7	7.2	7.4	12.0	11.8	5.1	5.1	25.7	26.2	23.5	24.9
21st Oct.	839.8	833.0	6.6	6.8	11.4	11.3	4.9	4.7	24.7	25.0	23.4	24.3
31st Oct.	783.5	786.0	6.2	6.4	11.5	11.4	4.9	4.7	21.0	21.4	21.1	21.9
S.Ed±	4.6	6.4	0.07	0.12	0.02	0.06	0.03	0.02	0.23	0.44	0.22	0.42
C.D.(P=0.05)	11.3	15.6	0.18	0.28	0.06	0.16	0.08	0.05	0.56	1.09	0.53	1.02
Genotypes												
Kranti	838.9	832.6	6.6	6.8	11.5	11.3	4.8	4.7	22.9	23.3	22.2	23.0
Maya	780.3	775.0	6.5	6.6	11.2	11.1	5.0	4.4	21.2	21.7	22.0	23.1
PAC-437	888.7	890.8	6.9	7.0	12.0	11.8	4.9	4.8	24.3	24.6	22.3	23.0
PBR-357	765.4	769.5	6.2	6.4	11.2	11.1	5.1	5.0	22.3	22.5	24.3	25.4
Rohini	754.4	749.4	6.1	6.3	11.4	10.9	4.9	4.8	21.0	21.7	23.2	24.4
S.Ed.±	5.8	10.0	0.08	0.09	0.07	0.07	0.05	0.02	0.21	0.45	0.24	0.39
C.D.(P=0.05)	11.8	20.4	0.17	0.18	0.15	0.14	0.11	0.04	0.42	0.91	0.48	0.79

Table 3: Effect of sowing date on seed yield of mustard genotypes.

Treatment	Date of sowing									
	2010-2011					2011-2012				
	30th Sept.	11th Oct.	21st Oct.	31st Oct.	Mean	30th Sept.	11th Oct.	21st Oct.	31st Oct.	Mean
	Seed yield (Kg ha^{-1})									
Kranti	1959	2183	2093	1904	2034	1960	2185	2093	1908	2036
Maya	1958	2130	2090	1905	2020	1854	2134	2107	1909	2001
PAC-437	1852	2275	2103	2024	2063	1855	2278	2211	2027	2093
PBR-357	1852	2183	2209	1971	2053	1853	2185	2132	1973	2036
Rohini	1825	2077	2130	1969	2000	1829	2079	2053	1972	1983
Mean	1889	2170	2125	1955		1870	2172	2119	1957	
Factors	D	G	G × (D)			D	G	G × (D)		
S.Ed±	12	14	29			10	13	26		
C.D (P=0.05)	30	29	59			25	27	24		

content also reduced significantly with delay in sowing beyond 11th Oct. during both years. The 2 years mean data showed that seeds obtained from 11th October sowing contained 0.8, 2.4 and 5.2% higher oil content than those obtained from sowings. Yadav *et al*. (1996) also reported similar results. Among genotypes, seeds of PAC-437 contained 0.60, 1.05, 1.25 and 2.25% more oil than the seeds of Kranti, PBR- 357, Rohini and Maya genotypes, respectively. The finding was supported by Bisht (2004). These results have clearly indicated the influenced of sowing dates on oil content irrespective of the genotypes. Seed oil content was also significantly affected by sowing dates × genotypes interaction (Table 4). It showed that in earlier sowing of 30th Sept. genotype Kranti has registered significantly maximum seed oil content while in other sowings, the highest seed oil content was estimated in PAC-437 genotype. It might be attributed to better seed development of Kranti than PAC-437 in earlier sown crop on 30th Sept. as it is proved from 1000-seed weight. It is also associated with lesser heat susceptibility of Kranti genotype. These results are in agreement with the findings of Rajput *et al*. (1991).

Table 4: Effect of sowing dates on seed oil content (%) of mustard genotypes.

Treatment	Sowing dates						Significance	
Genotypes	30th Sept	11th Oct.	21st Oct.	31st Oct.	Mean	factors	S.Ed.±	C.D. (p=0.05)
				2010-2011				
Kranti	39.0	42.9	41.3	40.7	41.0			
Maya	35.3	41.3	40.7	39.9	39.3	D	0.2	0.5
PAC-437	37.20	43.8	43.5	41.7	41.6	G	0.2	0.5
PBR-357	36.4	42.9	42.8	39.9	40.5	G x D	0.5	1.0
Rohini	38.9	41.9	41.4	38.0	40.3			
Mean	37.4	42.6	41.9	40.2				
				2011-12				
Kranti	39.9	42.3	41.1	40.3	40.9			
Maya	34.2	41.3	40.2	39.7	39.3	D	0.2	0.5
PAC-437	36.7	43.8	43.1	41.5	41.5	G	0.2	0.5
PBR-357	35.9	42.9	42.8	39.7	40.5	G x D	0.5	1.0
Rohini	38.2	41.7	41.7	38.0	40.3			
Mean	37.0	42.1	41.3	39.8				

Table 5: Weather conditions of Kanpur during *Rabi* 2010-11 and 2011-12 seasons.

Months	Total rainfall (mm)	Atmospheric temperature (°C)			Relative humidity (%)			Evaporation rate monthly mean
		Max.	Min	Ave.	Max.	Min.	Avg.	Av. (mm/day)
				2010-2011				
September	204.70	34.40	25.40	29.9	92.3	77.4	84.85	5.4
October	18.0	32.30	20.70	26.5	88.2	51.7	69.95	5.0
November	41.90	27.50	16.20	21.85	83.7	46.0	64.85	2.1
December	01.20	24	08.90	16.45	91.9	60.4	76.15	3.7
January	00.00	19.4	06.70	13.05	89.4	51.8	70.6	1.1
February	8.80	25.10	11.30	18.2	88.7	46.8	67.75	2.3
March	00.00	31.90	16.10	24	75.7	45.5	60.6	4.9
Total	274.6	186.7	91.8	149.95	609.9	379.6	494.75	24.5
				2011-2012				
September	93.6	32.3	24.5	28.4	88.4	69.1	78.75	7.3
October	0.0	33.7	17.7	25.7	82.9	41.7	62.3	7.3
November	0.0	29.1	13.0	21.05	89.4	54.5	76.95	4.5
December	0.0	22.9	6.9	14.9	71.3	48.3	59.8	2.0
January	56.8	13.5	7.6	10.55	92.2	67.1	70.65	1.0
February	10.8	24.3	9.1	16.7	84.4	47.4	65.9	1.6
March	0.0	30.9	13.0	21.95	70.8	37.7	54.25	3.2
Total	67.6	186.7	91.8	139.25	579.4	365.8	468.6	26.9

CONCLUSION

The above study concluded that the early down mustard crop faced high temperature resulted in poor growth due to reduced growth parameters. The reduced vegetative growth affects yield attributes and seed yield. Similarly, the late sown crop faced high temperature at grain filling and seed yield. However, the genotype Kranti performed well under late sown condition. Thus, the sowing on 11th October observed as the optimum date for sowing in the northern part of India.

Conflict of interest

All Authors declare that they have no conflict of interest.

REFERENCES

Archana Kumari, Singh, R.P. and Yeshpal (2012). Productivity nutrient uptake and economics of mustard hybrid (*Brassica juncea*) under different planting time and row spacing. Indian Journal of Agronomy. 57(1): 61-67.

Dhaliwal, L.K., Hundal, S.S. and Chahal, S.K. (2007). Agroclimatic indices of Indian mustard (*brassica juncea)* under Punjab conditions. Indian Journal of Agriculture Science. 77: 88-91.

Awasthi, U.D., Singh, R.B. and Dubey, S.D. (2007). Effect of sowing date and moisture conservation practice on growth and yield of Indian mustard (*Brassica juncea*) varieties. Indian Journal of Agronomy. 52(2): 151-153.

Bisht, R. S. (2004). Nitrogen requirement of *Brassica juncea* genotypes. Thesis submitted to CCS Haryana Agricultural University, Hisar, India.

Fischer, R.A. (1921). Some remark on the methods analysis of plant growth. Annals of Applied Biology. 7: 367-372.

Gavit, A.F., Major, N.M., Patil, S.S. and Patil, T.R. (2008). Physiological analysis of growth and yield of pigeonpea [(*Cajanus cajan* (L.) Mill sp.)]. Advances in Plant Science. 21(2): 553-556.

Gregory, P.G. (1926). The effect of climatic conditions on the growth of barley. Annals of Botany. 40: 1-26.

Kalubarne, M.H. and Pandey, R.K. (1979). Note on the growth analysis of green gram genotypes. Indian Journal of Agricultural Science. 49: 975-977.

Lalluand Dixit R.K. (2008). High temperature effect at terminal stage in mustard genotypes. Indian Journal of Plant Physiology. 13(2) (N.S.): 151-158.

Pandey, D. and Bose B. (2006). Influence of pre sowing seed treatment with nitrate salt and different sowing dates on performance of mustard. Indian Journal of Plant Physiology. 11(3): 261-265.

Pradhan, A.C., Ghosh, D.C. and Sarkar S.K. (1997). Effect of late sowing time and management on growth and yield of rapeseed at tarai region of west Bengal. Indian Agriculture. 41(3): 123-129.

Prasad, R, Lallu and Kumar Saroj (2009). Effect of sowing date and environmental factors on incidence of sclerotinia rot and dry matter of mustard. Indian Phytopathology. 62(4): 526-529.

Pronayb Bala, Azad and Hossain, M.F. (2011). Yield Response of Mustard to Sowing Date. Libyan Agriculture Research Center Journal International. 2(3): 112-117.

Rajput, R.L., Sharma, M.M., Verma, O.P. and Chauhan, D.V.S. (1991). Response of rapeseed (*Brassica napus*) and mustard (*Brassica juncea*) varieties of sowing. Indian Journal of Agronomy. 36: 153-155.

Ramesh,V. (2012). Correlation analysis in different planting dates of rapeseed varieties. The Journal of Agriculture Science. (7): 2. doi: 10.4038/jas.v7i2.4407.

Watson, D.J. (1952). The physiological basis of variation in yield. Advanced Agronomy. 4: 101-145.

Yadav, K.S., Rajput, R.L., Verma, O.P. and Yadav, R.P. (1996). Effect of sowing date and irrigation levels on seed yield and quality of Indian mustard (*Brassica juncea*). Indian Journal of Agronomy. 41(2): 275-278.