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EFFECT OF SOWING DATES AND VARIETIES ON PHENOLOGY AND YIELD OF INDIAN MUSTARD (*Brassica juncea* L.)

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Abstract: *Field experiment was conducted during two consecutive seasons of rabi 2012-13 and 2013-14 at Research Farm, JNKVV, College of Agriculture, Tikamgarh (Madhya Pradesh) to study the influence of sowing dates and varieties on phenological development and yield of Indian mustard. The experiment was laid out in split-plot design with three replications consisted three sowing dates viz., October 20, November 4 and November 19 and five varieties viz., Pusa Agrani, Pusa Bold, Varuna, Pusa Jaikisan and Kranti as main plot and sub-plot treatments, respectively. Results showed that October 20 sowing took maximum days to attain maturity (132 d) followed by November 4 (128 d) and November 19 (122 d). Duration of reproductive phase was also longer in October 20 (83 d) sown crop followed by November 4 (72 d) and November 19 (62 d) sown crops. Number of siliquae plant^{-1}, 1000 seed weight, seed yield (kg ha^{-1}), biological yield (kg ha^{-1}) and harvest index was also significantly higher under October 20 sown crop followed by November 4 and November 19. Among varieties, Varuna took maximum days to attain maturity (132 d) followed by cvs. Kranti (131 d), Pusa Bold (130 d), Pusa Jaikisan (124 d) and Pusa Agrani (122 d). On the other hand, Pusa Jaikisan recorded significantly higher yield attributes (number of siliquae plant^{-1} and number of seeds siliqua^{-1}), seed yield, biological yield and harvest index among all varieties, being at par to Kranti. Longer reproductive phase in mustard ultimately elevated the seed yield as confirmed by significant and positive correlation of seed yield with duration of reproductive phase (r=0.75**).*
Key words: *Brassica juncea L., Indian mustard, phenology, sowing dates, varieties.*

Introduction: Indian mustard *(Brassica juncea* L.*)* is a winter season crop and grown in diverse agro-climatic conditions ranging from north-eastern/ north-western hills to down south under irrigated/ rainfed, timely/ late-sown, saline soils and mixed cropping. Its sowing gets delayed by mid to end November due to late harvesting of *kharif* crops. Growth and development of late sown mustard crop is more adversely affected by severe winter, foggy and frost conditions during vegetative stage and high temperature during reproductive (pod and seed filling) stages. Temperature is an important environmental factor that affects physiological as well as morphological developments during different phenological stages and yield [1]. Changes in seasonal temperature affect the grain yield mainly thorough bringing changes in phenological development processes. In general, it was observed that the mustard crop sown after October 30th resulted in lower yields [2-4]. Winter crops are especially vulnerable to high temperature during reproductive stages and differential response of temperature change (rise) to various crops has been noticed under different production environments [5]. Optimum sowing time plays an important role to fully exploit the genetic potentiality of mustard varieties as the productivity of varieties fluctuates due to their different responds to variation in the weather conditions such as temperature, light, humidity and rainfall, etc. Sowing time is also important in deciding the environmental conditions of crop, timing and rate of organ appearance while in crop growth analysis predicting of phenology is of prime importance. Since the temperature and solar radiation play an important role in partitioning of biomass between various organs of plant which is related to, and often governed by phenological phase of the plant and the way in which a crop develops can affect the yield and this therefore an aspect with which agronomists are much concerned. With the climatic vagaries there is ambient need of new varieties which could surpass the adverse effects of heat so that there should be minimum yield losses. There is good chance of finding promising source of heat tolerance in the available germplasm of Indian mustard. Keeping above facts in view, the present investigation was under taken.

Materials and Methods

The field experiment was conducted at Research Farm, J.N.K.V.V., College of Agriculture, Tikamgarh (24° 43' N latitude, 78° 49' E longitude at an altitude of 358 m above mean sea level), Madhya Pradesh, India during two consecutive *rabi* seasons of 2012-13 and 2013-14. The experimental site is of sub-tropical climate characterized by hot dry summers and cool dry winter lies in the Bundelkhand Zone (Agro-climatic Zone-VIII). The soil of experimental field was medium to deep black and clayey loam in texture having pH 7.0, EC 0.12 dS m^{-1}, organic carbon 0.5%, available N 265.1 kg ha^{-1}, available P_2O_5 25.3 kg ha^{-1} and available K_2O 255.2 kg ha^{-1}, respectively. The average annual rainfall of this region is about 1000 mm, which is mostly received between June to September and a little rainfall (90 mm) is also obtained during October to May. The average temperature ranges between 4.5 °C to 45 °C.

The experiment was conducted in split-plot design with three replications and comprised of three sowing dates *viz*., October 20, November 4 and November 19 as main plot treatments and five varieties *viz*., Pusa Bold, Pusa Agrani, Pusa Jai Kisan, Kranti and Varuna as sub-plot treatments. The mustard crop was sown in lines 30 cm apart using a seed rate of 5 kg ha^{-1}. The recommended doses of nitrogen (80 kg N ha^{-1}), phosphorus (40 kg P_2O_5 ha^{-1}) and potassium (20 kg K_2O ha^{-1}) along with sulphur (20 kg ha^{-1}) were applied. Full dose of phosphorus, potassium and sulphur and half dose of nitrogen were applied as basal just below the soil and the remaining half dose of nitrogen was applied after first irrigation. All other agronomic and plant protection measures were applied as per recommendations. The crop was critically observed at 2-3 days intervals to record different crop phenophases. Days taken to emergence were recorded by simple visual observation. After thinning at 20 days after sowing, 5 plants were selected randomly from each plot and tagged with metallic tags .The occurrence of various phenological stages from emergence to maturity were recorded from five tagged plants in each plot and the mean of these was calculated. All the observations regarding flowering and seed development were recorded only on main raceme. For seed development, the lower 2/3rd portion of main raceme containing siliquae was only taken into consideration for good result as there is a lot of variation in siliqua development on main raceme. Yield attributes were recorded from the five plants sample collected at the time of harvest. The crop harvested from net plot area was converted into seed yield (kg ha^{-1}) and biological yield (kg ha^{-1}).

Results and Discussion

Phenophases and Thermal Units: Duration of different phenophases during the entire growth period of mustard cultivars differed significantly with each 15 days successive delay in sowing from October 20 to November 4 and November 19 (Table 1). Days taken to different phenophases upto most seeds green stage were higher in November 19 sown crop followed by November 4 and October 20 sown crop. Thereafter, October 20 sown crop took maximum days to reach most seeds brown and physiological maturity. The October 20 sown crop took longer duration for maturity (132 days) than the later sown crops in all the varieties due to fulfillment of thermal unit requirements in more days as well as increased reproductive phase duration. The durations of different phenological events described above were within the range reported earlier for *Brassica* spp [6-8].

Table 1: Days taken to attain different growth stages in mustard and accumulated thermal unit as affected by various treatments (Pooled data over two years)

Treatments	Emergence	Fifth true leaf exposed	First flower opened	Lowest pod more than 2 cm long	Most seeds green	Most seeds brown	Physiological maturity	Vegetative phase	Reproductive phase
Sowing dates									
Oct 20	3.00 (60)	21.0 (397)	49.0 (755)	59.0 (871)	88.0 (1163)	124.0 (1532)	132.0 (1648)	49.0 (755)	83.0 (893)
Nov 04	4.00 (62)	24.0 (332)	56.0 (709)	63.0 (783)	93.0 (1059)	122.0 (1401)	128.0 (1506)	56.0 (709)	72.0 (797)
Nov 19	5.00 (63)	27.0 (345)	60.0 (676)	66.0 (729)	95.0 (1044)	118.0 (1359)	122.0 (1445)	60.0 (676)	62.0 (770)
S.Em±	0.38	0.53	0.49	0.65	0.64	0.85	1.48	0.49	1.58
CD at 5%	1.10	1.53	1.40	1.87	1.84	2.44	4.22	1.40	4.50

Varieties									
Pusa Bold	4.00 (62)	24.0 (355)	56 (725)	64.0 (814)	94.0 (1104)	122.0 (1443)	130.0 (1561)	56 (725)	74.0 (835)
Pusa Agrani	4.00 (62)	23.0 (341)	50 (663)	58.0 (741)	87.0 (1034)	114.0 (1333)	122.0 (1430)	50 (663)	71.0 (767)
Pusa Jai Kisan	4.00 (62)	24.0 (355)	51 (675)	60.0 (766)	89.0 (1058)	118.0 (1392)	124.0 (1462)	51 (675)	72.0 (790)
Kranti	4.00 (62)	25.0 (369)	57 (736)	64.0 (804)	93.0 (1095)	124.0 (1467)	131.0 (1568)	57 (736)	74.0 (732)
Varuna	4.00 (62)	25.0 (369)	60 (733)	68.0 (836)	98.0 (1155)	127.0 (1518)	132.0 (1645)	60 (733)	72.0 (879)
S.Em±	0.24	0.48	0.47	0.70	0.46	0.78	0.64	0.47	0.70
CD at 5%	NS	1.41	1.40	2.07	1.37	2.31	1.92	1.40	NS

Figure in parenthesis are accumulated thermal units in °C

The total accumulated thermal unit during the entire growth period of the crop decreased from 1648 °C under October 20 sowing to 1506 °C and 1445 °C under late sowings on November 4 and November 19, respectively (Table 1). October 20 sown crop accumulated higher thermal units for all the growth stages except emergence followed by November 4 and November 19 sowings. Fifteen-day successive delay in sowing from October 20 to November 4 and November 19 reduced the crop duration by 4 and 10 days, respectively and accumulated thermal units by 142 and 203 °C, respectively. Reported that higher temperatures during the reproductive phase reduced the duration of the late- sown *Brassica* crop [9-10]. Among varieties, Varuna had higher thermal unit requirement (1645 °C) due to comparatively longer duration of maturity (132 d) followed by *cvs*. Kranti (131 d), Pusa Bold (130 d), Pusa Jai Kisan (124 d) and Pusa Agrani (122 d). The varietal differences in mustard for phasic duration and thermal units were also reported [11, 9, 8].

Yield Attributes and Yield: Yield attributes and yield were significantly influenced due to different crop growing environments (Table 2). October 20 sown crop produced significantly more number of siliquae plant^{-1}, higher 1000 seed weight (g), seed yield (kg ha^{-1}), biological yield (kg ha^{-1}) and harvest index followed by November 4 and November 19 sown mustard crops. However, sowing dates were failed to significantly influence the number of seeds siliqua^{-1}. The maximum temperature during reproductive phase had negative correlation with number of siliquae, 1000 seed weight and seed yield. Exposure to higher temperatures leads to fast accumulation of GGD that means fulfilment of thermal requirement without producing sufficient biomass or economical yield [12]. The successive increased in temperature from 23.5 °C (October 20) to 24.0°C (November 4) and 25.7°C (November 19) during first flower opened to physiological maturity decreased the seed yield by 13.9% and 24.3%, respectively, number of siliqaue by 5.58% and 24.2%, respectively and 1000 seed weight by 6.12% and 10.5%, respectively. Significant negative correlation of maximum temperature during reproductive phase with seed yield (-0.65*), number of siliquae (-0.61*) and 1000-seed weight (-0.16*) confirmed the adverse effect of increased temperature on yield attributes and seed yield in the present investigation. Reported 40.6% reduction in seed yield under one month delay in sowing from mid of October in mustard [13]. Among varieties, Pusa Jai Kisan exhibited significantly more number of siliquae plant^{-1}, more number of seeds siliqua^{-1}, higher seed yield (kg ha^{-1}), biological yield (kg ha^{-1}) and harvest index followed by Kranti, Pusa Bold, Varuna and Pusa Agrani. However, 1000 seed weight was recorded significantly higher in *cv*. Pusa Bold followed by Pusa Jai Kisan, Varuna, Kranti and Pusa Agrani. Variety Pusa Jai Kisan exhibited 5.15%, 16.3%, 20.9% and 35.0% higher seed yield over *cvs*. Kranti, Pusa Bold, Varuna and Pusa Agrani, respectively. The varietal differences for yield attributes and yield in mustard was also reported [14-15].

Table 2: Mustard yield and its attributes as affected by various treatments (Pooled data over two years)

Treatments	Number of siliqaue plant^{-1}	Number of seeds siliqua^{-1}	1000 seed weight (g)	Seed yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Sowing dates						
Oct 20	215	13.4	6.21	2145	7300	29.4
Nov 04	203	13.0	5.83	1847	7125	26.1
Nov 19	163	12.9	5.56	1624	6686	24.1
S.Em±	4.5	0.27	0.01	66.	162	1.18
CD at 5%	13	NS	0.04	189	462	3.51
Varieties						

Pusa Bold	196	13.5	6.38	1854	6726	27.5
Pusa Agrani	160	11.7	4.98	1439	6466	22.3
Pusa Jai Kisan	218	13.9	6.23	2215	7830	28.4
Kranti	205	13.6	5.63	2101	7712	27.3
Varuna	187	12.7	6.11	1751	6452	27.2
S.Em±	4.7	0.41	0.06	70	225	1.01
CD at 5%	14	1.21	0.18	207	661	2.93

Correlation Studies: The correlation analysis between seed yield (kg ha^{-1}) and different phenological stages reveals that seed yield (kg ha^{-1}) was significantly and positively correlated with most seeds brown and physiological maturity (Table 3). Similarly, seed yield (kg ha^{-1}) was also found positively and significantly correlated with reproductive phases (r=0.75**).

Table 3: Correlation matrix of yield (kg ha^{-1}) and phenology of Indian mustard (pooled data)

Treatments	Seed yield (kg ha^{-1})	Vegetative phase	Reproductive phase	Most seeds brown	Physiological maturity
Seed yield (kg ha^{-1})	1.00				
Vegetative phase	0.35*	1.00			
Reproductive phase	0.75**	0.66**	1.00		
Most seeds brown	0.52*	0.25**	0.47*	1.00	
Fully ripened seeds	0.66**	0.67**	0.71**	0.85**	1.00

** Significant at P = 0.05 level of significant ** Significant at P = 0.01 level of significant*

Conclusion: The present study concluded that sowing of mustard on October 20 exhibited significantly higher yield due to optimal thermal requirements for various plant processes. The thermal unit requirements of mustard varieties decreased with delay in sowing beyond October 20. The maximum temperature during reproductive phase had negative correlation with yield attributes and seed yield.

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