RESEARCH ARTICLE

INFLUENCE OF THERMAL ENVIRONMENT ON PHENOLOGY, GROWTH, YIELD AND DEVELOPMENT OF MUSTARD (*BRASSICA JUNCEA* L.) VARIETIES

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Abstract: Among various important growth characters of these Mustard varieties, plant height was greatly influenced under different thermal environments. Maximum plant height was observed in variety Varuna E1 (29th November) and minimum height was recorded in E3 (19th December). First date of sowing had more duration from sowing to maturity as compared to delayed sowing. This shortening of duration was due to thermal stress at later sowing dates. From phenological development point of view, the thermal insensitivity of all the varieties was assessed based on the TSI and it was found that Vardan, Kranti and Varuna Mustard varieties were tolerant to thermal stress. Different Mustard varieties show non significant results under different thermal environments but the seed yield (kg/ha) showed significant results under different thermal regimes.

Keywords: Thermal environment, Phenology, Development, *Brassica juncea*

INTRODUCTION

Vegetable oils have become an indispensable part of present day civilized life being next to food grains in importance. Oilseeds are the second largest agricultural commodity after cereals. Oilseed constitutes a foremost group of crops next only to cereals. Oilseeds are vital source of energy, essential fatty acids and fat soluble vitamins. Besides being a plentiful source of edible oil and cooking media, these serves as an important raw material for various industrial products

Among all oilseed crops rapeseed and mustard is a major oilseed crop of the world being grown in fifty three (53) countries across the six (6) continents. It is yet used not only as media in cooking but also as condiment, medicine, in preparation of hair oil, soap manufacturing of mineral oil and grease for lubrication for softening of leather etc. Due to its varied uses it is a principal oilseed crop of world with edible as well as industrial importance.

The rapeseed and mustard crop had worldwide area of 6.33 million hectare and production of 6.69 million tons an average yield of 1057* kg ha^{-1}. (*Advance estimates as on 04.04.2007) In world China and Canada leads in total area and production, however UK ranks first in productivity of crops rapeseed and mustard. India is one of the major country in vegetable oil scenario of the world. At present time nearly four (4) million farmers are involved in oilseed production in the country. There was five time increased in oilseed production during the period 1950 to 2004 under predominantly rainfed agro-ecological conditions. Which is higher than corresponding production increase in total food grains. During 2003-2004 total production of rapeseed and Mustard was 5.83 million tones from an area of 5.06 million hectare with an average productivity of 935 kg/ha (Anonymous, 2005) currently. India is witnessing crop shifts in favour of oilseeds especially in non-traditional areas, owing to growing great demand in oil development of high yielding varieties suitable for an array of agro-ecological situations and favorable price structure in comparison with the traditional crops. Major oilseed crops grown in India are groundnut, rapeseed mustard, sesamum, soybean, safflower, sunflower and linseed. As much as ninety per cent (90%) of the total edible oil production in our country comes from two oilseed crop viz. groundnut and mustard.

MATERIAL AND METHOD

Experimental details

Different thermal environment and mustard varieties with different plant population were used. The treatment combinations of three dates of sowing and three varieties and two plant density of Mustard were laid out in Factorial Randomized Block Design with three replications.

Thermal sensitivity

The thermal stress is mainly expressed through the duration for maturity by any crop. For evaluation of thermal sensitivity of the genotypes the following index was used as developed by Sastri *et al.* (2001).

$$TSI = \frac{\text{Range of duration to maturity with different sowing dates}}{\text{Average duration}} \times 100$$

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On the basis of TSI (thermal sensitivity index) thermal sensitivity is categorized as follows

TSI	Thermal sensitivity	Genotypes
< 5	Tolerant	-
5.1 – 10	Moderately tolerant	-
10.1 – 15	Moderately susceptible	-
> 15	Susceptible	-

RESULT AND DISCUSSION

In Chhattisgarh, due to shorter winter span and temperature fluctuations the productivity of rapeseed and mustard fluctuates considerably. It is therefore, necessary to identify suitable high yielding varieties of mustard for late sown conditions under rice based cropping system which can tolerate the high temperature during reproductive and seed filling stages. Thermal units are used for describing the temperature responses to growth and different phenophases of the crop life cycle.

Phenological studies

The duration (days) taken for commencement of different phenological events *viz.*, emergence (P1), first flower appearance (P2), 50 % flowering (P3), start of seed filling (P4), end of seed filling (P5) and physiological maturity (P6) by different mustard varieties under different thermal environments. Also given values in parenthesis are the numbers of days taken to each particular phenophase (P1, P2, P3, P4, P5 and P6).

Data presented in Table 5 reveals that the duration for emergence enhanced by 1 day early sown varuna in (E2) under both the spacing S1 (30x10cm) and S2 (40x10cm). In general, 6 days were taken for emergence (P1) by 29th November (E1S1 and E1S2) and 19th December sown crop, while it was 5 days under 09th December sown crop (E2S1 and S2) in different varieties. On the other hand, the duration for first flower appearance (P2), 50 % flowering (P3), start of seed filling (P4), end of seed filling (P5) and physiological maturity (P6) were shortened in case of environment in E2S1 and S2 there after increased in E3S1 and S2 as the sowing was delayed from 29th November to 09th December and 19th December. The decreases in duration for different phenological events were different for different varieties. The decrease in first flower appearance (P2) stage was 1 day in case of variety Varuna and it was also 1 day in case of Kranti from 29th and 09th December sown crop. Similar results were also obtained by Saran & Giri (1987).

Similarly the duration for 50 % flowering (P3), start of seed filling (P4) and end of seed filling (P5) varies in different varieties when the sowing was delayed. All the varieties behaved differently in different phenological stages. The duration for 50 % flowering (P3) was reduced by 6 to 7 days thus the difference increased as the crop growth progressed towards start of seed filling (P4), end of seed filling (P5) and maturity (P6) stages. The decrease in duration for start of seed filling (P4) was only 1 day in case of variety Kranti. The decrease in duration (days) in 09th December and 19th December as compared to 29th November in different Mustard varieties is shown in Table 6.

It was recorded from the data given in Table 6 that the duration for maturity decreased by 3 days in E2S1 (30x10cm) and E2S2 (40x10cm) spacing varieties Vardan, 6 days in E3S1 (30x10cm) and E3S2 (40x10cm) spacing varieties Vardan as compared to E1 in different varieties which Varuna variety mature 5 days earlier in E2S1 and E2S2 and also mature 7 days earlier under E3S1 and S2 as compared to E1S1 and E1S2.

Where as in case of variety Kranti the duration from maturity decrease by 4 days from E1S1, E1S2 to E2S1, E2S2 and 6 days in case of E1 to E3 in both the spacing S1 and S2.Among the variety maturity of Varuna decreases in days from E1S1, E1S2 to E2S1, E2S2 and E1 to E2 and E1 to E3 are 5 and 7 days respectively. Decrease in days from E1 to E2 and E3 is mainly due to delayed sowing which result in early attainment of heat unit that enhance early maturity. The above finding is in conformity with the finding of Kar and Charkravarty (1999) in case of variety B.O.-54, Pusa Bold and T-9 under Delhi climatic (semi arid) condition.

Thermal sensitive

The thermal sensitive index (TSI) of different mustard varieties is shown in Table 1 and is assessed as per criteria as shown in Table 2. As mentioned earlier, Vardan, Kranti and Varuna was found insensitive thermal stress.

Table 1. Thermal Sensitive Index (TSI) values of different Mustard Varieties

Varieties	TSI values
Vardan	3.1
Kranti	2.3
Varuna	2.5

Table 2. Categorization of the effect of thermal stress based on TSI

TSI Value	Thermal Sensitive	Varieties
< 5	Insensitive	Vardan, Kranti and Varuna
5.1 to 10.0	Moderately insensitive	Nil
10.1 to 15.0	Moderately sensitive	Nil
> 15	Sensitive	Nil

Among different varieties i.e.Vardan, Kranti and Varuna TSI value is in between < 5 (3.1), (2.3) and (2.5), which is to be categorized as thermal insensitive. Similar result was also found by Kar and Chakravarty (1999) in case of *Brassica* species under semi arid environment.

Plant population

Variations in plant population in the three thermal environments studied are presented in Table 7 plant population showed statistically significant difference for different thermal environments. Maximum plant population of 36.0 /m^2 was recorded in 29th November sowing in S1 spacing (30x10cm) followed by 35.8 /m^2 for 09th December, 34.0 /m^2 19th December sowing. Highest plant population was recorded for variety Varuna(30.6 /m^2), statistically at par with Kranti (30.6 /m^2) and was lowest for cultivar Vardan (30.1 /m^2). It is clear that, only spacing (S) treatment thermal environments (E) showed significant variation for plant population.

As we compare the spacing, it is observed that the plant population is always higher in S1 (30x10cm) than S2 (40x10cm) spacing under all dates of sowing. The above findings is in close conformity with findings of Kumar *et al*., (1996)

Plant height

The plant height of the different mustard varieties were recorded at 10 day intervals from sowing to harvesting is given in Table 8.

It was observed that plant height increased with advancement in crop growth and reached to maximum at harvesting. The increase in plant height took place slowly up to 25 DAS. Maximum rate of increase in plant height was observed between 45- 55 DAS. Differences in plant height were significant due to dates of sowing (E) (*viz.,* at 25 DAS to harvest.). The Interaction between (VxS) and (V) differed significantly except at 25 DAS, 65 DAS. Whereas the (ExV), (ExS), (ExVxS) and (S) are the non-significant observed in 25 DAS to at harvest. In general, higher plant height was observed in E1 as compared to E2 and E3. Lowest plant height was recorded in E3 in all the varieties. At maturity stage, Varuna attained maximum height (161.9 cm) followed by Vardan (160.6 cm) Kranti attained the lowest height (159.5 cm). The minimum decrease in plant height was noticed in Kranti in E2 and E3 under both the spacing. Whereas, the Varuna attained maximum height in case of E2S2 (4.4) and E3S2 (5.7) in both the sowing dates i.e. (E2 and E3) are given in Table 8.

The decrease in plant height from E1 to E2 and E3 is lowest in case of *cv.* Kranti, which is mainly due to the effect of thermal stress. Similar result was also found by Thakur and Singh (1998). In order to quantify the thermal stress on plant height a criterion was development as shown in Table 8.

Table 3. Thermal stress status

Percentage decrease in plant height at maturity	Thermal stress status
< 5 per cent	Tolerant (T)
5.1-10.0 per cent	Moderately tolerant (MT)
10.1-1.5 per cent	Moderately susceptible (MS)
>15 per cent	Susceptible (S)

The decrease in height from E1 to E2 and E3 is lowest in case of Kranti, which is mainly due to the effect of thermal stress. Similar result was also indicated by Thakur and Singh (1998).

As per the above criterion, the thermal stress statuses of different varieties at E2 and E3 have been analyzed and the results are shown in Table 8.

Table 4. Categorization of thermal stress tolerance of Mustard varieties in different thermal environments

Variety	E2	E3
Vardan	1.86 (T)	3.05 (T)
Kranti	0.37 (T)	2.13 (T)
Varuna	2.18 (T)	2.49 (T)

From the above analysis it can be seen that in percentage decrease in height Vardan, Kranti and Varuna can be ranked as number one as it showed tolerance to thermal stress in E2 and E3.

Table 5. Effect of different thermal environments on different phenophases in *Brassica species*.

Varieties		P_1		P_2		P_3		P_4		P_5		P_6	
		S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
	E1	6	6	41	41	48	48	58	58	90	90	109	109
Vardan	E2	6	6	42	42	50	50	56	56	85	85	106	106
	E3	6	6	40	40	49	49	58	58	86	86	103	103
	E1	6	6	41	41	48	48	56	56	89	89	109	109
Kranti	E2	6	6	44	44	52	52	58	58	86	86	105	105
	E3	6	6	42	42	50	50	58	58	87	87	103	103
	E1	6	6	42	42	48	48	60	60	90	90	111	111
Varuna	E2	5	5	42	42	50	50	57	57	88	88	106	106
	E3	6	6	43	43	51	51	57	57	86	86	104	104

E1 -29.11.2007, E2 -09.12.2007, E3 -19.12.2007

P1 –Emergence, P2 –First flower appearance, P3 -50%Flowering

P4 –Start of seed filling, P5 –End filling and, P6 –Physiological maturity.

Table 6. Effect of different thermal environments on maturity duration of Mustard varieties (days)

S. No.	Variety	Decrease in days from E1 to E2 and E3					
		E1		E2		E3	
		S1	S2	S1	S2	S1	S2
1	Vardan	109	109	106 (3)	106 (3)	103 (6)	103 (6)
2	Kranti	109	109	105 (4)	105 (4)	103 (6)	103 (6)
3	Varuna	111	111	106 (5)	106 (5)	104 (7)	104 (7)

The values in parenthesis are difference in duration from E1.

E1 -29.11.2007, E2 -09.12.2007, E3 -19.12.2007

Table 7. Plant population / m^2 of Mustard varieties as influenced by different thermal environments

Varieties	Plant population /m^2						Mean
	E1		E2		E3		
	S1	S2	S1	S2	S1	S2	
Vardan	35.0	25.3	34.5	25.5	34.6	25.6	30.1
Kranti	36.4	26.0	36.5	25.0	34.3	25.1	30.6
Varuna	36.7	26.1	36.5	26.0	33.3	25.1	30.6
Mean	36.0	25.8	35.8	25.5	34.0	25.2	
	E	V	S	ExV	ExS	VxS	ExVxS
SEm±	0.36	0.36	0.29	0.62	0.51	0.51	0.88
CD (5%)	1.03	NS	0.84	NS	NS	NS	NS
CV (%)	4.99						

E1 -29.11.2007, E2 -09.12.2007, E3 -19.12.2007, NS – (Non significant).

Table 8. Decrease in plant height (cm) from E1 to E2 and E3 in different mustard varieties at maturity

Varieties	Decrease in plant height (cm) from E1 to E2 and E3						Mean
	E1		E2		E3		
	S1	S2	S1	S2	S1	S2	
Vardan	160.1	160.6	157.6 (2.5)	157.9 (2.7)	155.7 (4.4)	156.3 (4.3)	158.0
Kranti	159.1	159.5	158.5 (0.6)	157.2 (2.3)	155.5 (3.6)	156.8 (2.7)	157.8
Varuna	160.4	161.9	156.9 (3.5)	157.5 (4.4)	156.4 (4.0)	156.2 (5.7)	158.2
Mean	159.7	160.7	157.7	157.5	155.9	156.4	

The values in parenthesis are difference in height (cm) from E1

E1 -29.11.2007, E2 -09.12.2007, E3 -19.12.2007

Table 9. Grain yield (kg ha^{-1}) of Mustard varieties as influenced by different thermal environments

Varieties		Grain yield (kg/ha^{-1})						Mean
		E1		E2		E3		
Vardan	S1	1425.5		1199.8		1232.6		1286.0
	S2	1427.5		1317.4		1219.1		1321.3
Kranti	S1	1521.3		1296.3		1159.3		1325.6
	S2	1549.0		1039.7		1178.6		1255.8
Varuna	S1	1477.6		1213.3		1257.7		1316.2
	S2	1442.9		1246.1		1153.5		1280.8
Mean		1474.0		1218.8		1200.5		
		E	V	S	ExV	ExS	VxS	ExVxS
	SEm±	39.70	39.70	68.76	32.42	58.15	56.15	97.25
	CD (5%)	114.10	NS	NS	NS	NS	NS	NS
	CV (5%)	12.99						

E1 -29.11.2007, E2 -09.12.2007, E3 -19.12.2007, NS – (Non significant).

Grain yield (kg ha^{-1})

Grain yield of mustard as affected by various treatments are presented in Table 9. Data revealed that grain yield affected significantly due to different thermal environment. The higher grain yield was obtained 1474.0 kgha^{-1} in first thermal environment on 29th November under (E1) and lowest of 1200.5 kgha^{-1} in 19th December sown crop. Among the varieties Kranti (S1) production higher grain yield (1325.6 kgha^{-1}) closely followed by Vardan S1 (1321.3 kgha$^{-1)}$ and Varuna S2 (1280.8 kgha^{-1}).

The interaction between different thermal environments, varieties and spacing found to be non-significant. As we compare the spacing, it is observed that the grain yield is always higher in S1 (30x10cm) than S2 (40x10cm) under all the date of sowing. In case of varieties, they also produced higher seed yield in S1 spacing than S2 spacing. The higher yield was obtained in early sown crop than the late sown crop, which is due to the favorable effect of temperature and other weather parameters. Sharma *et. al.* (1992) also found that early sown crop produce higher seed yield kg ha^{-1} than the late sown crop which is in close agreement of the present findings.

CONCLUSION

The plant population showed statistically significant difference for deferent thermal environments. Maximum plant population of 36.0 /m^2 was recorded in 29th November sowing in S1 spacing (30x10cm) followed by 35.8 /m^2 for 09th December, 34.0 /m^2 19th December sowing. Differences in plant height were significant due to dates of sowing (E) (viz., at 25 DAS to harvest.). The Interaction between (VxS) and (V) differed significantly except at 25 DAS, 45 DAS. Whereas the (ExV), (ExS), (ExVxS) and (S) are the non-significant observed in 25 DAS to at harvest. In general, higher plant height was observed in E1 as compared to E2 and E3. Lowest plant height was recorded in E3 in all the varieties. However, Varuna attained maximum height (161.9 cm) followed by Vardan (160.6 cm) Kranti attained the lowest height of (159.5 cm). The phenological studied all Mustard varieties under different thermal environments. It was found that the first date of sowing took more number of days (111 days) from sowing to maturity as compared to delayed sowings. Maximum duration to attain maturity was found in Varuna (111 days) followed by Kranti (109 days) and Vardan both (109 days). In general, the duration of all varieties decreased due to delayed sowing. Thermal insensitivity of all the varieties was assessed based on the TSI (thermal sensitivity index) and it was found that all varieties of Mustard were tolerant. Different thermal environments significantly influenced Grain yield (Kgha^{-1}) in different varieties. Data revealed that grain yield affected significantly due to different thermal environment. The higher grain yield was obtained 1473.97 kgha^{-1} in first thermal environment on 29th November (E1S2) and lower of 1200.16 kgha^{-1} in 19th December sown crop as compare to S2 spacing. Among the varieties Kranti produce higher grain yield (1325.65 kg ha $^{-1}$) closely followed by Vardan (1321.32 kgha$^{-1)}$ and Varuna (1280.85 kgha^{-1}).

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