RESEARCH ARTICLE

THERMAL REQUIREMENT OF MUSTARD IN LATE SOWN CONDITION AFTER RICE CROP AT RAIPUR UNDER CHHATTISGARH PLAIN

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Abstract: The investigation of thermal requirement of mustard in late sown condition, after rice crop at Raipur under Chhattisgarh plain. It was found that cumulative GDD for emergence increased by different varieties under E1 as compared to E3. The PTU values were higher in 19th December sown crop as compared to 29th November and 9th December sowing. Lower PTU values were observed under 9th December sowing (E2) in Kranti while, the PTU values were in increasing trend for Vardan and varuna from29th November and 19th December. Different Mustard varieties show non significant results under different thermal environments but the seed yield (kg/ha) showed significant results under different thermal regimes. Highest seed yield was recorded in E1 (29th November) as compared to delayed sowings. Vardan was found out yielder in all temperature regimes as compared to other varieties. The radiation use efficiency was more in E1 sowing under S1 spacing. In early date of sowing (E1) both in case of S1and S2 the radiation use efficiency increase from 25 days to 75 days and then decreases up to at harvest. RUE is maximum in case of Varuna (3.06gMj^{-1}) under S1 spacing followed by Kranti (2.96gMj^{-1}) and lowest was recorded in variety Vardan (2.83gMj^{-1}) under S1 spacing. Heat use efficiency was observed that variety Kranti showed higher HUE for the entire thermal environment (different date of sowing) as compared to Varuna and Vardan It may be attributed to higher biomass.

Keywords: GDD, PTU, HTU, Heat use efficiency (HUE), Radiation use efficiency

INTRODUCTION

In India lot of works have been done on date of sowing. However, a very little work has been done in Chhattisgarh on radiation effect on *Brassica*. In Chhattisgarh, the shorter winter span and higher temperature particularly during reproductive and seed filling stages hasten the maturity which decreases the yield. Under such condition, thermal stress tolerant varieties play a vital role. *Brassica* species are thermosensitive and therefore phenological events of these crops are affected by dates of sowing. An attempt has been made in this section to review the effects of sowing dates on performance of rapeseed and mustard (*Brassica* spp.).

Kar and Chakarvarty (1999) reported reduction in yield of *Brassica* species (*viz.* B.O. 54, Pusa Bold T-9) in delayed sowing. RUE in the first crop season was found to be varied from 3.01 g MJ-1 in first sown crop of cultivar Pusa Bold to 2.13 g MJ-1 in second and third sowing of Toria-T9. In the second season, they found that the RUE range between 3.22 g Mj-1 in the first sowing of Pusa Bold and 2.28 g Mj-1 in the third sown Toria-T9.

Khichar *et al.* (2000) noted that Brassica crop sown on 20th October showed higher growth parameters (LAI, plant height and dry matter) and yield in comparison with other time sown crop (i.e. 10th November and 30th November). The radiation use efficiency (RUE) was highest from sowing to harvesting in the 20th October sowing and decreased with successive sowings. Brassica cultivars also differed significantly with respect to growth parameters. While in case of yield the difference was not significant. Also reported that plant spacing influenced growth parameters and yield of mustard crop, however, the influence on yield plant height was not significant.

Hundal *et al.* (2004) found that cultivars and sowing date effect on RUE and CGR in mustard (cv. Bio-902 and Pusa Bold). The peak CGR was 33.7 and 30.4 gm^{-2} day^{-1} for Bio-902 and Pusa Bold, respectively sown in first weak of November. The highest RUE of 2.44 MJ-1 of dry matter accumulation and 0.62 g MJ^{-1} for seed yield were recorded when the crop was sown in the third week of October. Significant linear regressions relationship (R^2 = 0.89) was observed between total dry matter accumulation and cumulative.

India is one of the major producers of rapeseed and mustard in the world. However, in terms of yield per hectare, its position is one of the lowest when compared to other oilseeds. Plants depend for growth and development on their genetic constituents and environmental conditions. The final yield of a crop is highly dependent on the genetic constitution and the weather condition, which its encounters during its

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growth and development. Out of several approaches through which the relationship between weather parameters and crop production can be understood, the crop phenology is an important aspect, since the biomass production and seed yield are greatly influenced by the prevailing environmental conditions during various crop phenophases. 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.

MATERIAL AND METHOD

Location of Experimental site:

The field experiment was carried out at the Research and Instructional farm of Indira Gandhi Krishi Vishwavidyalaya; Raipur situated in Eastern Central part of Chhattisgarh at latitudes of $21^0.16'$ N, longitude $81^0.36'$ E and altitude 289.5 m above mean sea level.

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.

Growing degree days

Growing Degree Days (GDD) concept assumes that there is a direct and linear relationship between growth and developments of plants and temperature and the growth is dependent on the total amount of heat to which it is subjected during its life time. The growing degree days was computed by using following formula:

$$\mathbf{GDD = \Sigma\ [(Tx + Tn)/2 - Base\ temperature]}$$

Where,

Tx = Daily maximum temperature

Tn = Daily minimum temperature

The base Temperature is defined as, "The temperature below which no plant physiological activity takes place" which is considered 5.0 for Rabi crops.

Photothermal Unit (PTU)

PTU is calculated by multiplying GDD with maximum possible sunshine hours (N).

$$\mathbf{PTU = GDD \times N}$$

Where,

N = maximum possible sunshine hour.

Heliothermal Unit (HTU)

HTU is calculated by multiplying GDD with actual sunshine hours (n) (Rajput, 1980).

$$\mathbf{HTU = GDD \times n}$$

Where,

n = actual sunshine hour.

Heat Use Efficiency (HUE)

Heat Use Efficiency (HUE) for total dry matter was obtained as under:

$$\text{HUE (g/m}^2 / {}^0\text{ day)} = \frac{\text{Biomass (g / m}^2)}{\text{GDD (}^o\text{ days)}}$$

Radiation Use Efficiency (RUE)

$$\text{RUE (gMJ}^{-1}) = \text{Biomass (g / m}^{-2}) / \text{IPAR (M J}^{-2})$$

Where,

IPAR is cumulative intercepted photo synthetically active radiation.

The photo synthetic active radiation can be calculated by using the following formula:

$$\text{PAR} = \text{Rs} \times 0.5$$

Where,

Rs = incoming solar radiation

The incoming solar radiation can be calculated by the formula

$$\text{Rs} = \text{Rs}_0\ (a + b \times n/N)$$

Where,

Rs_0 = Extra terrestrial radiation

n / N = Per cent sunshine hours

a = 0.2, b = 0.4

RESULT AND DISCUSSION

Growing degree-days

Growing degree-days is widely used for describing the temperature responses to growth and development of crops. Growing degree days (GDD) requirement for completion of different phenophases of mustard varieties were worked out and are presented in Table 1

Table 1 revealed that accumulated growing degree days for different varieties under different thermal environments varied considerably from sowing to maturity. The cumulative GDD required for first flower appearance (P2), end of seed filling (P5) and physiological maturity (P6) was maximum as compared to Emergence (P1), 50% flowering (P3) and start of seed filling(P4) in all thermal environment as well as in all varieties.

Different mustard varieties responded differently in terms of accumulated GDD at the time of maturity. Lower GDD values were observed under 9th December sowing (E2) in Kranti and varuna while, the GDD values were in increasing trend for Vardan from 29th November to 9th December and 19th December. The GDD values were higher in 19th December sown crop as compared to 29th November and 9th December sowing. Mustard crop required 1753.9 to 1808.5°C day from emergence to physiological maturity. Similar results were found by Singh *et. al.* (2004) which showed that maximum GDD was noticed in early sown crop which is similar with the present findings.

Photo thermal units

Table 2 revealed that accumulated photo thermal unit (PTU) for different varieties under different thermal environments varied considerably from sowing to maturity. The cumulative PTU required for first flower appearance (P2), end of seed filling (P5) and physiological maturity (P6) was maximum as compared to Emergence (P1), 50% flowering (P3) and start of seed filling(P4) in all thermal environment as well as in all varieties.

Lower PTU values were observed under 9th December sowing (E2) in Kranti while, the PTU values were in increasing trend for Vardan and varuna from29th November and 19th December. The PTU values were higher in 19th December sown crop as compared to 29th November and 9th December sowing. Mustard crop required 19808.9 to 20785.7°C day from emergence to physiological maturity.

Biomass production and heat use efficiency

Accumulated heat units to attain different crop growth stages from sowing to maturity for three cultivars and thermal environments are given in Table 3. It is observed from the table that the variety Vardan recorded higher GDD as compared to Varuna and Kranti reflecting longer duration variety in the different thermal environment. In all the thermal environment and variety 1808.5 to 1753.9 GDD were accumulated throughout the growing period.

Heat utilization efficiency (HUE) of three varieties to maximum biomass accumulation as influenced by sowing at different thermal environment are computed and presented in Table 3. It is observed that variety Kranti showed higher HUE for the entire thermal environment (different date of sowing) as compared to Varuna and Vardan It may be attributed to higher biomass. It is also noted that unlike Varuna and Vardan in the late sown condition. The reduction of HUE was not significant probably the biomass production was not affected due to E3.

Radiation Use Efficiency (RUE)

Radiation Use Efficiency of mustard varieties at 10 days intervals in different thermal environment (E1, E2 and E3) and in case of variety (V1, V2 and V3) has been presented in table 4. The radiation use efficiency was more in E1 sowing under S1 spacing. In early date of sowing (E1) both incase of S1and S2 the radiation use efficiency increase from 25 days to 75 days and then decreases up to at harvest. The same trend of RUE was also noticed in case of E2 and E3 in both the spacing (S1 and S2). In all the three dates of sowing i.e. E1, E2 and E3 RUE efficiency is more in case of S1 spacing than the S2 spacing. The increase in RUE in is more than S2 due to higher spacing in S1, which result less number of total plant population. Less number of plant populations under same unit area.

In case of different varieties (V1, V2 and V3) under S1 and S2 spacing the RUE increase from 25 days to 75 and then decreases up to at harvest. RUE is maximum in case of Varuna (3.06gMj^{-1}) under S1 spacing followed by Kranti (2.96gMj^{-1}) and lowest was recorded in variety Vardan (2.83gMj^{-1}) under S1 spacing. In case of variety also RUE is more in S1 spacing than S2 spacing. Variety Varuna have better RUE than the other two varieties i.e. Kranti and Vardan. Which may be due to variation in spacing and other environmental factor (temperature, cloudiness) and plant characteristics (leaf structure, plant anatomy and genotypes). The decrease in RUE from 75 days after sowing onwards is mainly due to the decrease in biomass production. Moreover at maturity stage (75 DAS) the chlorophyll content of leaf gets reduced to a lower level which in turns decreases the radiation use efficiency. Findings of Khichar *et al.* 2000 also conformity with findings of the present result.

Table 1. Accumulated growing degree days (GDD) required to attain various phenophase of Mustard Varieties under different thermal environments

Varieties (V)	Stages	Accumulated growing degree days			Mean
		E1	E2	E3	
Vardan	P1	87.7	90.7	88.9	89.0
	P2	625.5	657.3	629.0	637.3
	P3	737.6	780.9	749.3	755.9
	P4	900.0	855.2	883.0	879.4
	P5	1376.1	1317.7	1393.8	1362.5
	P6	1755.9	1777.0	1784.1	1772.3
Kranti	P1	87.7	90.7	88.9	89.1
	P2	625.5	692.4	651.1	656.3
	P3	737.6	803.0	766.4	769.0
	P4	868.4	884.9	883.0	878.8
	P5	1356.9	1337.5	1417.2	1370.5

	P6	1755.9	1753.9	1784.1	1764.6
Varuna	P1	87.7	75.1	88.9	83.9
	P2	640.6	657.3	666.8	654.9
	P3	737.6	780.9	781.7	766.7
	P4	922.8	867.6	870.5	887.0
	P5	1376.1	1375.6	1393.8	1381.8
	P6	1801.1	1777.0	1808.5	1795.5

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 2. Photo Thermal Unit required toattain various phenophase of Mustard Varieties under different thermal environments

Varieties (V)	Stages	Accumulated Photo thermal unit			Mean
		E1	E2	E3	
Vardan	P1	958.4	984.1	964.6	969.0
	P2	6807.1	7164.5	6871.0	6947.5
	P3	8035.8	8519.1	8228.1	8261.0
	P4	9815.7	9346.0	9771.6	9644.4
	P5	15266.6	14706.3	15794.8	15255.9
	P6	19808.9	20217.9	20477.8	20168.2
Kranti	P1	958.4	984.1	964.6	969.0
	P2	6807.1	7549.2	7113.2	7156.5
	P3	8035.8	8761.3	8425.5	8407.5
	P4	9469.3	9688.7	9771.6	9643.2
	P5	15266.6	14944.5	16075.6	15428.9
	P6	19808.9	19940.7	20477.8	20075.8
Varuna	P1	958.4	814.3	964.6	912.4
	P2	6972.6	7164.5	7285.3	7140.8
	P3	8035.8	8519.1	8602.6	8385.8
	P4	10066.1	9488.5	9626.8	9727.1
	P5	15266.6	15401.7	15794.8	15487.7
	P6	20351.9	20217.9	20785.7	20451.8

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 3. Heat utilization efficiency of three Mustard cultivars sown under different plant densities

Treatments	Thermal environment	Heat units at maximum biomass level (^0C)	Maximum biomass gram / m^2	HUE ($g/m^2/D^{-1}$)
Vardan	E1	1755.9	835.5	0.48
	E2	1777.0	825.3	0.46
	E3	1784.1	797.3	0.45
Kranti	E1	1755.9	863.6	0.49
	E2	1753.9	859.0	0.49
	E3	1784.1	839.5	0.47

Varuna	E1	1801.1	874.0	0.49
	E2	1777.0	857.7	0.48
	E3	1808.5	840.6	0.47

Table 4. Radiation Use Efficiency (gMj^{-1}) of mustard varieties at 10 days interval

Varieties		**Days after sowing (DAS)**													
		0-25		**25-35**		**35-45**		**45-55**		**55-65**		**65-75**		**75-at harvest**	
		S1	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
	E1	0.32	0.21	0.59	0.42	1.35	1.47	2.25	2.09	2.78	2.35	2.83	2.26	1.92	1.48
Vardan	**E2**	0.22	0.15	0.42	0.24	1.18	1.24	1.97	1.85	2.37	2.1	2.52	2.07	1.87	1.45
	E3	0.15	0.12	0.24	0.15	1.2	1.13	2.05	1.93	2.4	2.12	2.48	2.08	1.86	1.47
	E1	0.28	0.22	0.52	0.43	1.77	1.3	2.69	2	2.95	2.3	2.96	2.28	2.03	1.5
Kranti	**E2**	0.19	0.15	0.37	0.28	1.53	1.09	2.38	1.81	2.7	2.09	2.69	2.07	1.95	1.44
	E3	0.17	0.13	0.18	0.18	1.52	1.18	2.47	1.86	2.7	2.11	2.74	2.08	1.96	1.46
	E1	0.25	0.25	0.58	0.45	1.95	1.22	2.85	1.88	2.99	2.29	3.06	2.28	2	1.51
Varuna	**E2**	0.19	0.16	0.39	0.29	1.6	0.98	2.53	1.64	2.68	1.96	2.79	2.05	1.95	1.45
	E3	0.16	0.14	0.18	0.15	1.45	0.96	2.63	1.7	2.8	1.97	2.73	2.05	1.96	1.46

CONCLUSION

The accumulated growing degree days (GDD) for different Mustard varieties under different thermal environments varied considerably from sowing to maturity. Different Mustard varieties responded differently in terms of accumulated GDD at the time of maturity. Higher GDD was observed under 29th November sowing (E1) was observed in Vardan varieties higher GDD was recorded 29th November (E1). The radiation use efficiency was more in E1 sowing under S1 spacing. In early date of sowing (E1) both in case of S1and S2 the radiation use efficiency increase from 25 days to 75 days and then decreases up to at harvest. In case of different varieties (V1, V2 and V3) under S1 and S2 spacing the RUE increase from 25 days to 75 and then decreases up to at harvest. RUE is maximum in case of Varuna ($3.06 gMj^{-1}$) under S1 spacing followed by Kranti ($2.96 gMj^{-1}$) and lowest was recorded in variety Vardan ($2.83 gMj^{-1}$) under S1 spacing.

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