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EFFECT OF INCREASING TEMPERATURE ON PHENOLOGICAL AND MORPHOLOGICAL FEATURES OF MUNGBEAN (*VIGNA RADIATA* L. WILCZEK)

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ABSTRACT

Climate change-related temperature increases will have a negative impact on a variety of crops. Mungbean (*Vigna radiata* L.) is grown as a summer crop in various regions of the world. The optimal temperature for mungbean growth is 28-30°C; temperatures over these thresholds, particularly during reproductive growth are predicted to reduce the crop's potential. As a result, a research investigation was done to assess the impact of high temperatures during reproductive growth on mungbean performance and to investigate the reasons underlying reproductive failure. We examined how twenty mungbean genotypes respond to heat stress in outdoor situations. Twenty mungbean cultivars Pusa BM-3, Pusa BM-9, Pusa 1971, Pusa 9531, Pusa M.19-111, TCA-DM-19-1, MH-1703, SML-1933, MML-2560, PM-1601, PM-1520, PM-504-20-27, IPM-1604-1, IPM-604-16, IPMD-401-7, IPMD-604-1-7, Virat, Phule chetak, Phule Vaibhav, BM-2003-2 were cultivated in field condition with three sowing dates: S_1-Early Summer (February, 15th), S_2- Summer (March, 15th), S_3-Late Summer (April, 15th). The experiment was set up in a factorial randomized block design (FRBD) with two replicates. The phenological parameters such as days to flower initiation, days to physiological maturity and the morphological parameters such as plant height at harvest and number of branches per plant at harvest. The results reveals significant variations genotypes under different sowing dates. Days to flower initiation, days to physiological maturity, plant height and number of branches plant^{-1} showed significantly dropped in S_3-Late Summer (April, 15th). The genotype PM-504-20-27 (6.9) and Phule chetak was found thermal stress tolerant genotype with higher days to flower initiation, days to physiological maturity, plant height, number of branches plant^{-1}. Whereas, MML-2560 (5.17) was identified as a thermal stress susceptible genotype.

Key words : Thermal, Heat stress, Temperature, Summer, Tolerance, Susceptible, Different sowing dates.

Introduction

Mungbean [*Vigna radiata* (L.) Wilczek] is a short-duration, warm-season legume crop planted in the Northern portion of the country. According to Lambrides *et al.* (2007), India is the greatest producer of mungbean, accounting for around 65% of the average and 54% of global production. Mungbean is a primary protein source for vegetarian diets. Mungbean can be planted as an intercrop, green manure or cover crop. Farmers love this pulse crop as it earns high market prices. Mungbean crops planted in warm seasons experience high temperatures during different growth phases. In addition to ensuring enough nourishment; the urgent issue of the day is addressing acute protein malnutrition in the rapidly growing population. Mungbean [*Vigna radiata* (L.) Wilczek], a valuable food and feed legume crop that is both commercially and nutritionally significant, is a good fit for this situation. Since, the crop fixes atmospheric nitrogen to fulfill its own nitrogen needs, increasing the yield of grain legumes high in protein, such as mungbean, seems like a suitable substitute. Despite being referred to as "poor men's protein" (Mian, 1976). The changing climate is expected to have a direct influence on agriculture because of higher mean seasonal temperatures, which will shorten the growing season and have a negative effect on final yield. According to Wahid *et al*. (2007), heat stress has a negative impact on plants at multiple levels, which causes a sharp decline in growth rates and yield characteristics. A few degrees of temperature increase during flowering can result in the loss of entire grain growing cycles because reproductive tissues and their roles are extremely susceptible to heat stress (Wheeler *et al*., 2000; Hatfield *et al*., 2011; Asseng *et al*., 2011). During the reproductive stage, flowers work to achieve pod set, which is hampered by heat stress. The primary causes of this disruption are pollen germination loss, anther dehiscence issues, pollen landing on the stigma surface and subsequent germination through style (Kaur *et al*., 2015). Higher temperatures (>40°C) are exposed to mungbean grown in this season, particularly during its reproductive development stage. This is adverse to the productivity of both vegetative and reproductive growth (Sharma *et al*., 2016). Mungbean is comparatively more vulnerable to other abiotic stresses like salt and high temperature than it is to water shortage stress (Sangakkara *et al*., 2000; Yimram *et al*., 2009).

In view of this, we have undertaken research to assess mungbean lines for heat tolerance at the whole plant level, including during the vegetative and reproductive stages, in order to record phenological, morphological and yield responses. The objective is to find out more about the mechanism underlying heat tolerance in this crucial legume crop.

Materials and Methods

The field investigation was carried out throughout the summer season of 2021-2022 on the farm of Agriculture Botany, Post Graduate Institute, Mahatma Phule Krushi Vidyapeeth Rahuri, Ahmednagar, Maharashtra (India). The investigation was set up in a Factorial Randomized Block Design (FRBD) with two replications. Three sowing dates were identified as major factors, namely, S_1-Early summer (February, 15th), S_2-Summer (March, 15th), S_3- Late summer (April, 15th) and 20 genotypes as a sub factor. The genotypes are G_1: Pusa BM-3, G_2: Pusa BM-9, G_3: Pusa 1971, G_4: Pusa 9531, G_5: Pusa M.19-111, G_6: TCA-DM-19-1, G_7: MH-1703, G_8: SML-1933, G_9: MML-2560, G_{10}: PM-1601, G_{11}: PM-1520, G_{12}: PM-504-20-27, G_{13}: IPM-1604-1, G_{14}: IPM-604-16, G_{15}: IPMD-401-7, G_{16}: IPMD-604-1-7, G_{17}: Virat, G_{18}: Phule chetak, G_{19}: Phule Vaibhav, G_{20}: BM-2003-2. The twenty green gram genotypes used in this study were sourced from ARS, Oilseeds and Pulses Research Station Jalgaon, Maharashtra. The plot measured 3.0×1.2 m^2. The recommended fertilizer dose for green gram crops is $N:P_2O_5:K_2O$ @ 15:30:10 kg ha^{-1}. On February 15, 2022, the seed of green gram variety genotypes was spread on flat beds using the dibbling method. Sowing was done at a distance of 30 cm between rows and 10 cm between plants. To promote proper germination, the land was watered immediately following sowing.

Phenological studies

Estimation of days to flower initiation : Daily evaluations were made in every plot and replication at the time of flower beginning. The day to flower initiation was defined as the day on which 50% of plants or more began to flower. Days to flower initiation are the total number of days from the date of sowing to the day of flower initiation, calculated and recorded.

Estimation of days to physiological maturity : After 90 days, the plant reached physiological maturity as evidenced by indications such as fading leaves, withering of older leaves and a transformation in pod colour from green to pale yellow. Days to maturity is a count of the total number of days from seeding to maturity.

Morphological studies

Estimation of plant height (cm) at harvest : When the plants were harvested, their height was measured in centimetres from the ground's surface to the terminals of the plants and the average heights were computed.

Estimation of number of branches plant^{-1} at harvest : The total number of branches plant^{-1}, comprising the primary shoot, was taken into account at physiological maturity and average figures were derived.

Results and Discussion

Days to flower initiation

Table 1 and Fig. 1 shows the data for days to flower initiations as impacted by genotypes, sowing dates and their interactions. For days of flowering initiation, the genotype, sowing dates and interactions all show statistically significant differences.

Table 1 : Days to flower initiation and days to physiological maturity influence by different sowing conditions under thermal stress in summer green gram.

Genotypes	Days to flower initiation			Mean (G)	Days to physiological maturity			Mean (G)
	S_1	S_2	S_3		S_1	S_2	S_3	
1) Pusa BM-3	41.5	40.0	37.0	**39.50**	69.5	68.0	59.0	**65.50**
2) Pusa BM-9	43.0	41.5	38.0	**40.83**	70.5	68.5	59.0	**66.00**
3) Pusa 1971	44.5	43.0	39.0	**42.17**	70.0	67.5	57.5	**65.00**
4) Pusa 9531	41.5	40.5	36.5	**39.50**	67.0	65.0	56.0	**62.67**
5) Pusa M.19-111	43.0	41.5	37.5	**40.67**	68.0	64.5	55.5	**62.67**
6) TCA-DM-19-1	42.5	40.5	35.5	**39.50**	67.5	66.0	58.0	**63.83**
7) MH-1703	42.5	41.5	36.5	**40.17**	67.5	66.0	56.0	**63.17**
8) SML-1933	43.5	42.5	37.5	**41.17**	69.0	67.5	58.0	**64.83**
9) MML-2560	44.5	44.0	39.5	**42.67**	71.5	70.0	61.0	**67.50**
10) PM-1601	43.0	41.5	38.5	**41.00**	68.0	66.0	58.5	**64.17**
11) PM-1520	43.5	42.5	36.5	**40.83**	69.0	67.5	56.0	**64.17**
12) PM-504-20-27	43.0	41.5	36.0	**40.17**	66.5	64.5	55.0	**62.00**
13) IPM-1604-1	42.0	40.5	37.5	**40.00**	67.0	66.0	58.5	**63.83**
14) IPM-604-16	45.0	43.5	38.5	**42.33**	69.0	66.5	57.0	**64.17**
15) IPMD-401-7	43.5	41.0	36.0	**40.17**	72.0	67.5	59.5	**66.33**
16) IPMD-604-1-7	45.0	41.5	35.5	**40.67**	70.0	66.0	56.0	**64.00**
17) Virat	44.5	43.5	38.5	**42.17**	71.2	69.0	59.5	**66.57**
18) Phule chetak	41.5	40.5	37.5	**39.83**	67.5	64.5	54.5	**62.17**
19) Vaibhav	44.0	41.5	35.5	**40.33**	70.0	66.0	55.5	**63.83**
20) BM-2003-2	42.0	40.5	35.5	**39.33**	66.5	64.5	54.5	**61.83**
Mean (S)	**43.2**	**41.7**	**37.1**		**68.9**	**66.6**	**57.2**	
	Sowing Dates (S)		**Genotypes (G)**	**S × G**	**Sowing Dates (S)**		**Genotypes (G)**	**S × G**
SE(±)	0.022		0.149	0.446	0.044		0.291	0.874
CD @ 5%	0.063		0.420	1.261	0.124		0.825	2.474

Note : S: Sowing dates, NS: Non-significant, S_1: Early summer: February, 15th, S_2: Summer: March, 15th, S_3: Late summer : April, 15th

Different planting dates had a significant impact on flower initiation. When comparing the maximum days of flowering initiation (43.2 days) among the sowing circumstances, S_1 outperformed S_2 (41.7 days) and S_3 (37.1 days). BM-2003-2 (39.33 days) flowered substantially earlier than the other genotypes, while MML-2560 (42.67 days) genotype flowered significantly later despite planting variance.

While, Pusa BM-3, Pusa 9531 and Phule chetak (41.5) genotypes took significantly fewer days than all other genotypes to flower induction under S_1 conditions, IPMD-604-16 and IPMD-604-1-7 genotypes took much longer. The Pusa BM-3 genotype required 40 days to flower initiation, much fewer days than any other genotype, whereas the MML-2560 genotype took 44 days under S_2 conditions. The MML-2560 genotype required 39.5 days to induce flowers under S_3 conditions, but the TCA-DM-19-1, IPM-604-1-7, Vaibhav and BM-2003-2 genotypes required 35.5 days, which was significantly shorter than the days required by all other genotypes.

Similar to this, higher temperatures caused the first flowering to occur in a considerably shorter period of time (34, 35). This could be because higher temperatures lessen the vegetative phase, which in turn causes increased enzymatic activities of peroxidase, catalase and superoxide dismutase. Huxley *et al.* (1976), Gibson and

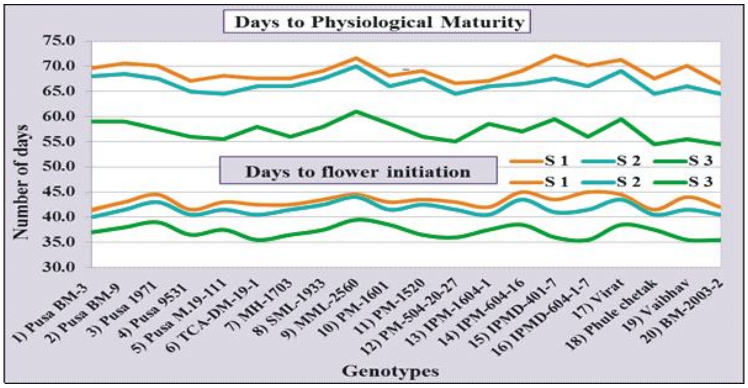

Fig. 1 : Days to physiological maturity and days to flower initiation influence by different sowing conditions under thermal stress in summer green gram.

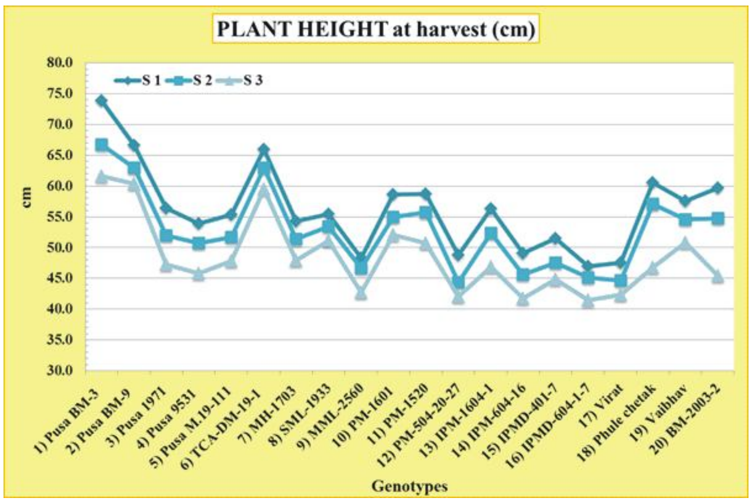

Fig. 2 : Plant height at harvest influence by different sowing conditions under thermal stress in summer green gram.

Mullen (1996) observed equivalent results in soybean.

Days to physiological maturity

Table 1 and Fig. 1 displays the data on days to physiological maturity influenced by genotypes, sowing dates and the impacts of their interactions. For days to physiological maturity, the genotype, sowing date and interaction differences are statistically relevant. Changing sowing dates have a significant impact on physiological maturity. When comparing the maximum days to physiological maturity (68.9 days) among the sowing circumstances, S_1 outperformed S_2 (66.6 days) and S_3 (57.2 days). BM-2003-2 (61.83 days) matured substantially earlier than the other genotypes, while MML-2560 (67.50 days) genotype matured significantly later despite sowing variance.

In the S_1 condition, IPMD-401-7 (72 days) and MML-2560 (71.5 days) genotypes, in S_2 conditions, MML-2560 (70 days) and Virat (69.0 days) genotypes and in S_3 conditions, MML-2560 (61 days), IPMD-401-7 and Virat (59.5 days) required considerably more days to reach physiological maturity over the other genotypes, however the genotypes PM-504-20-27 and BM-2003-2 (66.5 days) in S_1 condition Pusa M.19-111, PM-504-20-27, Phule chetak and BM-2003-2 (64.5 days) in S_2 condition and Phule chetak and BM-2003-2 (54.5 days) in S_3 condition required significantly fewer days for maturityas compared to any genotypes.

Early-seeded crops needed the most days to reach maturity; as crops grew older, this number decreased gradually. Similar results were noted by Kumar *et al.* (2012) following multiple sowings. Likewise, a considerable reduction in the days required to reach physiological maturity was observed with the rise in temperature (99.74). An earlier start in days to first and 50% flowering, as well as an increase in mitochondrial respiratory activity, are the causes of this. These results are in line with those of Gibson and Mullen (1996) in soybean.

Plant height (cm) at harvest

Table 2 and Fig. 2 displays the information about plant height as it relates to genotypes, sowing dates and their interactions. For plant height, the variations in genotype, sowing dates and interactions are significantly different. Alternate sowing dates have a significant impact on plant height. S_1 considerably outperformed S_2 and S_3 in terms of maximum height (56.3 cm) within the sowing circumstances. In comparison to the other genotypes, the height of the Pusa BM-3 (67.37 cm) genotype greatly rose, whereas the IPMD-604-1-7 (44.53 cm) genotype dramatically decreased despite the planting variance.

In the S_1 condition, genotypes Pusa BM-3 (73.8 cm) and Pusa BM-9 (66.6 cm), in S_2 conditions, genotypes Pusa BM-3 (66.7 cm), Pusa BM-9 and TCA-DM-19-1 (63 cm) and in S_3 conditions, genotypes Pusa BM-3 (61.6 cm) and Pusa BM-9 (60.4 cm) took substantially longer to reach their greatest height than the rest of the genotypes, however the genotypes IPMD-604-1-7 (47 cm) and Virat (47.5 cm) in S_1 condition Virat (44.6 cm) and PM-504-20-27 (44.4 cm) in S_2 condition and IPMD-604-1-7 (41.5 cm) and IPM-604-16 (41.8 cm) in S_3 condition needed notably longer to reach the minimum height over the remaining genotypes.

The results agree with those of Karim *et al.* (2003), Vijaylami and Bhattacharya (2007). Photosynthesis is commonly recognized as the primary factor controlling agricultural plant dry matter output. The production of dry matter and subsequently translation into economic

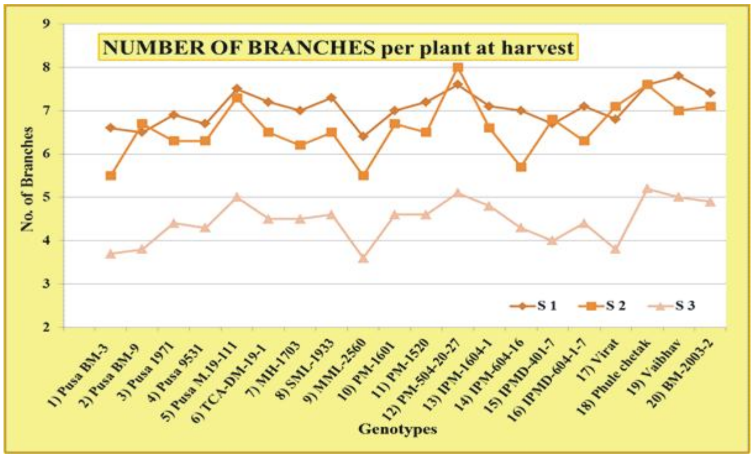

Fig. 3 : Number of branches at harvest influence by different sowing conditions under thermal stress in summer green gram.

output is the result of a complex physiological process that occurs throughout plants.

Number of branches plant^{-1} at harvest

Table 2 and Fig. 3 shows the results on the number of branches plant^{-1} as influenced by genotypes, sowing dates, and their interaction effects. Regarding the number of branches plant^{-1}, the genotype, sowing dates and interactions all show variations that are statistically significant. Varying sowing dates significantly altered the number of branches plant^{-1}. Among the sowing circumstances, S_1 had considerably more branches (7.07) than S_2 (6.61) and S_3 (4.46). Regarding the seeding variation, PM-504-20-27 (6.9) and Phule

Table 2 : Plant height and number of branches plant^{-1}at harvest influence by different sowing conditions under thermal stress in summer green gram.

Genotypes	Plant height at harvest			Mean (G)	Number of branchesplant^{-1} at harvest			Mean (G)
	S_1	S_2	S_3		S_1	S_2	S_3	
1) Pusa BM-3	73.8	66.7	61.6	**67.37**	6.60	5.50	3.70	**5.27**
2) Pusa BM-9	66.6	63.0	60.4	**63.33**	6.50	6.70	3.80	**5.67**
3) Pusa 1971	56.4	52.0	47.2	**51.87**	6.90	6.30	4.40	**5.87**
4) Pusa 9531	53.9	50.7	45.8	**50.13**	6.70	6.30	4.30	**5.77**
5) Pusa M.19-111	55.3	51.7	47.8	**51.60**	7.50	7.30	5.00	**6.60**
6) TCA-DM-19-1	65.9	63.0	59.5	**62.80**	7.20	6.50	4.50	**6.07**
7) MH-1703	54.3	51.4	47.9	**51.20**	7.00	6.20	4.50	**5.90**
8) SML-1933	55.4	53.4	51.1	**53.30**	7.30	6.50	4.60	**6.13**
9) MML-2560	48.3	46.7	42.7	**45.90**	6.40	5.50	3.60	**5.17**
10) PM-1601	58.6	55.0	52.1	**55.23**	7.00	6.70	4.60	**6.10**
11) PM-1520	58.7	55.7	50.7	**55.03**	7.20	6.50	4.60	**6.10**
12) PM-504-20-27	48.8	44.4	42.0	**45.07**	7.60	8.00	5.10	**6.90**
13) IPM-1604-1	56.3	52.4	46.9	**51.87**	7.10	6.60	4.80	**6.17**
14) IPM-604-16	49.1	45.6	41.8	**45.50**	7.00	5.70	4.30	**5.67**
15) IPMD-401-7	51.5	47.5	44.8	**47.93**	6.70	6.80	4.00	**5.83**
16) IPMD-604-1-7	47.0	45.1	41.5	**44.53**	7.10	6.30	4.40	**5.93**
17) Virat	47.5	44.6	42.3	**44.80**	6.80	7.10	3.80	**5.90**
18) Phule chetak	60.5	57.1	46.8	**54.80**	7.60	7.60	5.20	**6.80**
19) Vaibhav	57.6	54.6	50.8	**54.33**	7.80	7.00	5.00	**6.60**
20) BM-2003-2	59.7	54.8	45.4	**53.30**	7.40	7.10	4.90	**6.47**
Mean (G)	**56.3**	**52.8**	**48.5**		**7.07**	**6.61**	**4.46**	
	Sowing Dates (S)		**Genotypes (G)**	**S × G**	**Sowing Dates (S)**		**Genotypes (G)**	**S × G**
SE(±)	0.102		0.678	2.035	0.034		0.229	0.686
CD @ 5%	0.288		1.919	5.757	0.097		0.647	1.942

Note : S: Sowing dates, NS: Non-significant, S_1: Early summer: February, 15th, S_2: Summer: March, 15th, S_3: Late summer : April, 15th

chetak (6.8) genotype branches gained significantly, whereas MML-2560 (5.17) genotype branches decreased significantly when contrasting with the remaining genotypes.

In the S_1 condition, Vaibhav (7.8), PM-504-20-27 and Phule chetak (7.6) genotypes, in S_2 conditions, PM-504-20-27 (8.0) and Phule chetak (7.6) genotypes and in S_3 conditions, Phule chetak (5.2) produced the largest number of branches, whereas MML-2560 genotypes generated the fewest number of branches as compared to any genotypes in S_1(6.4), S_2 (5.5) and S_3(3.6) condition.

In mungbean genotypes, having more branches correlates with increased yield (Goswami *et al.*, 2010). The findings were consistent with those reported by Haqqani and Pandey (1994), Jahan and Adam (2012) and Awasarmal *et al.* (2015).

Conclusion

Our research showed that mungbean crops grown at varied planting dates experienced significantly decreased flower production, which in turn produced fewer pods and seeds during the vegetative and reproductive growth stages. The elite genotypes examined here varied significantly in terms of their ability to withstand heat. Based on the number of branches at harvest, plant height at harvest, days to physiological maturity and days of flowering commencement, genotypes Pusa BM-3, Pusa BM-9, Pusa 1971, Pusa 9531, Pusa M.19-111, TCA-DM-19-1, MH-1703, SML-1933, MML-2560, PM-1601, PM-1520, PM-504-20-27, IPM-1604-1, IPM-604-16, IPMD-401-7, IPMD-604-1-7, Virat, Phule chetak, Phule Vaibhav and BM-2003-2 were determined to be heat tolerant. Not only would these genotypes be valuable donors for upcoming breeding initiatives, but they would also make excellent base plants from which to learn more about the effects of heat stress on cell metabolism.

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