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Influence of Salicylic Acid and Thiourea on Morphological and Physiological parameters of Mustard (*Brassica juncea* (L.) Czern & Coss) Genotypes under High Temperature Stress

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ABSTRACT: The study investigates the effects of salicylic acid (SA) and thiourea on the morphological and physiological parameters of mustard (*Brassica juncea* (L.) Czern & Coss) genotypes under high-temperature stress. Two consecutive years (2017-18 and 2018-19) were considered for the assessment. Morphological parameters such as plant height, number of primary branches plant^{-1}, and number of secondary branches plant^{-1} were evaluated along with physiological parameters including relative water content (%) and chlorophyll stability index. Results revealed significant variations in plant height, branch numbers, and physiological parameters under different treatments. Notably, foliar application of thiourea exhibited the highest enhancement in plant height and branch numbers compared to SA treatments and controls. Moreover, variations in relative water content and chlorophyll stability index were observed across treatments, suggesting a potential role of foliar application in mitigating high-temperature stress effects on mustard genotypes. The study evaluated the influence of sowing time, variety and foliar spray on morphological and physiological traits of mustard. Normal sowing of variety Pusa Mustard-26 with foliar application of thiourea led to superior plant growth, branches, water content and chlorophyll stability compared to late sowing and other treatments. Timely cultivation practices can help boost productivity.

Keywords: Mustard, Salicylic acid, Thiourea, High-temperature stress, Morphological parameters, Physiological parameters, Chlorophyll stability.

INTRODUCTION

Mustard (*Brassica juncea* (L.) Czern & Coss) is an important oilseed crop belonging to family Brassicaceae. Indian mustard or brown mustard is natural amphidiploids having chromosome no. (2n=36). It is self-pollinated but certain amount (2-15%) pollination occurs due to insects and other factors. The origin place of mustard is China, North Eastern India from where it has extended upto Afghanistan via Punjab (Vaughan, 1997).

Mustard is a cool season crop, which requires temperature range of 6-26°C. Mustard follows C_3 pathway of carbon assimilation, therefore, it has efficient photosynthetic response at 15-20°C temperature. At this temperature plant achieves maximum CO_2 assimilation. Mustard is generally grown as rainfed crop and moderately tolerant to soil acidity, it required well drained soil having pH near to neutral. It has low water requirement (240-400mm) which fits well under rainfed cropping system. India is one of the largest producers of rapeseed and mustard in the world. In India, rapeseed and mustard is grown in about 6.5 million ha with total production of about 7.7 million tones and an average productivity of 1179 kg ha^{-1} (Anonymous, 2011). Rajasthan ranks first both in area and production of rapeseed and mustard in the country.

High temperatures can induce heat stress in plants, negatively impacting their growth, development, and productivity. Mustard is an important oilseed crop grown widely across temperate regions, but its yield and quality can suffer under high heat conditions. High temperature negatively affects plant growth and survival and hence crop yield (Boyer, 1982). According to a study (Lobell and Asner 2003) each degree centigrade increase in average growing season temperature may reduce crop yields up to 17%. High temperature stress directly or indirectly affects the plant photosynthetic functions by changing the structural organisation and physic chemical properties of thylakoid membranes (Lichtenthaler *et al.,* 2005). Plant growth regulators (PGRs) show potential in reducing the impact of high temperature stress on crops. These regulators have the ability to assist plants in dealing with heat by increasing antioxidant activity, optimizing stomatal function, and improving stress signaling. Salicylic acid and thiourea are compounds known to help mitigate abiotic stresses in plants. Salicylic acid is a natural plant hormone that plays a key role in plant defense responses. Thiourea contains sulfur, which is involved in antioxidant reactions that can scavenge harmful reactive oxygen species produced during stress (Meena *et al.,* 2023). Exogenous application of these compounds may confer thermotolerance in plants exposed to high temperatures. The morphological and physiological responses of different mustard genotypes when treated exogenously with salicylic acid and thiourea under high temperature stress. The key morphological parameters examined include plant height, leaf area, number of leaves, number of branches, and yield attributes like number of pods and seeds (Sahoo *et al.,* 2022). Physiological parameters include photosynthetic efficiency, transpiration rate, stomatal conductance, chlorophyll content, proline and sugar accumulation, and antioxidant enzyme activities. Comparing the effects of salicylic acid and thiourea on heat tolerance across diverse mustard genotypes can help identify thermotolerant varieties and beneficial management practices to mitigate high temperature stress in mustard crops. Enhanced thermotolerance will help maintain mustard productivity and quality despite rising temperatures due to climate change.

METHODOLOGY

A field experiment was undertaken during *rabi* season, 2017-18 and 2018-19 at the year at the Department of Plant Physiology, Banaras Hindu University, Varanasi, with the objective of evaluating two varieties under various treatment conditions. The experiment utilized a split plot design with 16 treatments and 03 replications. The main plots were assigned the two varieties, while the treatments were allocated to the sub-plots. Standard agronomic practices were adhered to throughout the crop cultivation process, ensuring uniformity and reliability in the study. Proper layout and labeling were meticulously maintained to uphold the integrity of the split plot design with the treatment and variety details viz., T_1: Normal Sown; T_2: Late Sown; V_1: Pusa Mustard-26; V_2: RGN-145; P_1: Control; P_2: SA 0.5 mM; P_3: SA 1.0 mM; P_4: Thiourea. Based on the study the following parameters were recorded to assess the morphological and physiological characteristics of mustard crop. The Morphological parameters: Plant height (cm), Number of primary branches per plant and Number of secondary branches per plant. Physiological parameters: Relative water content (%) and Chlorophyll stability index.

Plant height (cm). Plant height was measured by taking three random plants from each plot. Plant was uprooted and height was measured from the base of the plant to the tip of the main stem. The height was determined with the help of meter scale and mean values were calculated.

Number of primary and secondary branches per plant. Three plant samples were randomly selected from each plot. The number of primary branches and secondary branches were recorded.

Relative water content (RWC) (%). Method of Weatherly (1950) was used for measuring leaf relative water content (RWC). RWC was measured at 50% flowering stage in first fully expanded leaf from top of plant. Leaves were brought to the lab, surface cleaned with cotton and cut into small pieces with a sharp blade. Weighed amount of leaflets were immersed in de-ionised water at room temperature in low light for 4 h to attain full turgidity. The turgid leaf weight was measured after removing adhered water carefully and then oven-dried at 65°C for 48 h for dry weight determination. The relative water content (RWC) was calculated by the formula given by Weatherly (1950).

RWC (%) = 100 × [(fresh weight - dry weight)/[(turgid weight - dry weight)].

RESULT

A. Morphological parameters

(i) Plant height (cm). The data on plant height of mustard crop as influenced by sowing time with variety and foliar application of chemicals at both the years are presented in Table 1.

Sowing time with variety. It is apparent in Table 1 that the significantly maximum plant height was found in this year (2017-18) in treatment T_1V_2 (Normal Sown+ RGN-145) (198.45cm) which was followed by the treatment T_2V_2 (Late Sown+ RGN-145) (170.54cm) and T_1V_1 (Normal Sown + Pusa Mustard-26) (120.69 cm). Significantly minimum plant height (94.53 cm) was observed in treatment T_2V_1 (Late Sown + Pusa Mustard-26).

It is apparent in Table 1 that the significantly maximum plant height was found in this year (2018-19) in treatment T_1V_2 (Normal Sown + RGN-145) (195.18cm) which was followed by the treatment T_2V_2 (Late Sown+ RGN-145) (159.51cm) and T_1V_1 (Normal Sown + Pusa Mustard-26) (121.31cm). Significantly minimum plant height (88.32cm) was observed in treatment T_2V_1 (Late Sown + Pusa Mustard-26). These results emphasize the importance of selecting appropriate sowing time and variety to maximize plant height and overall crop productivity. Taller plant height is advantageous for mustard crops as it allows the plants to better compete for sunlight by accessing rays high above the canopy, helps reduce lodging risks through stronger stalks, accommodates more branching and pods to increase potential yield, facilitates more uniform drying down of leaves and pods across the plant, and makes mechanical harvesting easier. These outcomes are consistent with findings of Mahto *et al*. (2023).

Foliar application. The data pertaining in Table 1 clearly showed that the significantly maximum plant height was found in this year (2017-18) in treatment P_4 (Thiourea) (170.38cm) which was followed by the treatment P_3 (SA 1.0 mM) (150.00cm) and P_2 (SA 0.5 mM) (140.23cm). Significantly minimum plant height (123.61cm) was observed in treatment P_1 (Control).

The data pertaining in Table 1 clearly showed that the significantly maximum plant height was found in this year (2018-19) in treatment P_4 (Thiourea) (167.28cm) which was followed by the treatment P_3 (SA 1.0 mM) (143.64cm) and P_2 (SA 0.5 mM) (132.72cm).

Significantly minimum plant height (120.70 cm) was observed in treatment P_1 (Control). Based on the data, it can be concluded that the application of Thiourea (Treatment P4) consistently resulted in the tallest plants in both years. This suggests that Thiourea positively influences plant height and promotes growth. The treatments with SA (salicylic acid) also had positive effects on plant height, although to a lesser extent. Also, similar results were reported by Meena *et al*. (2020).

(ii) Number of primary branches plant^{-1}. The data on number of primary branches plant^{-1} of mustard crop as influenced by sowing time with variety and foliar application of chemicals at both the years are presented in Table 2.

Sowing time with variety. Among the data in Table 2 that the significantly maximum number of primary branches plant^{-1} was found in this year (2017-18) in treatment T_1V_1 (Normal Sown + Pusa Mustard-26) (7.30) which was followed by the treatment T_2V_1 (Late Sown+ RGN-145) (6.42) and T_1V_2 (Normal Sown+ RGN-145) (6.06). Significantly minimum number of primary branches plant^{-1} (4.81) was observed in treatment T_2V_2 (Late Sown+ RGN-145).

Among the data in Table 2 that the significantly maximum number of primary branches plant^{-1} was found in this year (2018-19) in treatment T_1V_1 (Normal Sown + Pusa Mustard-26) (6.68) which was followed by the treatment T_2V_1 (Late Sown + Pusa Mustard-26) (5.87) and T_1V_2 (Normal Sown + RGN-145) (5.43). Significantly minimum number of primary branches plant^{-1} (4.40) was observed in treatment T_2V_2 (Late Sown+ RGN-145). Based on the data, it can be concluded that in both years, the treatment involving normal sowing time and the variety Pusa Mustard-26 (T1V1) consistently resulted in the highest number of primary branches per plant. Late sowing time combined with the variety RGN-145 (T2V2) generally led to a lower number of branches per plant. These observations indicate that sowing time and variety selection significantly influence the branching pattern of mustard plants.

Foliar application. A perusal of data recorded in Table 2 clearly showed that the significantly maximum number of primary branches plant^{-1} was found in this year (2017-18) in treatment P_4 (Thiourea) (6.75) which was at par with the treatment P_3 (SA 1.0 mM) (6.65). While significantly minimum number of primary branches plant^{-1} (5.28) was observed in treatment P_1 (Control).

A perusal of data recorded in Table 2 clearly showed that the significantly maximum number of branches plant^{-1} was found in this year (2018-19) in treatment P_4 (Thiourea) (6.11) which was at par with the treatment P_3 (SA 1.0 mM) (6.02). While significantly minimum number of branches plant^{-1} (4.91) was observed in treatment P_1 (Control). The results imply that the application of Thiourea treatment P_4 and SA_3 (salicylic acid) in both years had a positive impact on the number of primary branches per plant. These chemicals likely stimulate branching and promote lateral shoot development. In contrast, the control treatment (P_1) without any chemical application resulted in a lower number of branches per plant. Similar results were reported by EI-Yazeid (2011).

(iii) Number of secondary branches plant^{-1}. The data on number of secondary branches plant^{-1} of mustard crop as influenced by sowing time with variety and foliar application of chemicals at both the years are presented in Table 3.

Sowing time with variety. It is noticed from the data presented in Table 3 that the significantly maximum number of secondary branches plant^{-1} was found in this year (2017-18) in treatment T_1V_1 (Normal Sown + Pusa Mustard-26) (10.72) which was followed by the treatment T_2V_1 (Late Sown + RGN-145) (9.91) and T_1V_2 (Normal Sown + RGN-145) (8.14). Significantly minimum number of secondary branches plant^{-1}(6.80) was observed in treatment T_2V_2 (Late Sown+ RGN-145).

It is obvious from the data presented in Table 3 that the significantly maximum number of secondary branches plant^{-1}was found in this year (2018-19) in treatment T_1V_1 (Normal Sown + Pusa Mustard-26) (9.72) which was followed by the treatment T_2V_1 (Late Sown+ Pusa Mustard-26) (8.55) and T_1V_2 (Normal Sown+ RGN-145) (7.89). Significantly minimum number of secondary branches plant^{-1} (6.39) was observed in treatment T_2V_2 (Late Sown + RGN-145). The significant variation in the number of secondary branches per plant in the mustard crop, influenced by sowing time and variety, of chemicals can be attributed to the interplay of environmental conditions, genetic factors, and treatment effects. These factors collectively affect the branching patterns and growth of mustard plants, leading to the observed differences in secondary branch numbers across treatments and years. The finding of present study is in accordance with those of Mahto *et al*. (2023).

Foliar application. It is noticed from the data presented in Table 3 that the significantly maximum number of secondary branches plant^{-1}was found in this year (2017-18) in treatment P_4 (Thiourea) (9.70) which was followed by the treatment P_3 (SA 1.0 mM) (9.28) and P_2 (SA 0.5 mM) (9.00). While significantly minimum number of secondary branches plant^{-1}(7.60) was observed in treatment P_1 (Control).

It is obvious from the data presented in Table 3 that the significantly maximum number of secondary branches plant^{-1} was found in this year (2018-19) in treatment P_4 (Thiourea) (8.91) which was at par with the treatment P_3 (SA 1.0 mM) (8.71). While significantly minimum number of secondary branches plant^{-1} (7.16) was observed in treatment P_1 (Control). The variation in the number of secondary branches per plant in the mustard crop due to foliar application of chemicals can be attributed to the physiological effects of these chemicals on plant growth. Thiourea and SA treatments likely promoted branching by influencing hormone regulation and nutrient uptake. These chemicals may have stimulated lateral bud development, resulting in increased secondary branches. In contrast, the control group lacked these stimulatory effects, leading to a lower number of secondary branches.

B. Physiological parameters

(i) Relative water content (%) (Weatherly, 1950). The data on relative water content (%) of mustard crop as influenced by sowing time with variety and foliar application of chemicals at both the years are presented in Table 4.

Sowing time with variety. It is obvious from in Table 4 that the significantly maximum relative water content was found in this year (2017-18) in treatment T_1V_1 (Normal Sown + Pusa Mustard-26) (89.21%) which was followed by the treatment T_1V_2 (Normal Sown+ RGN-145) (85.39%) and T_2V_1 (Late Sown+ Pusa Mustard-26) (83.27%). Significantly minimum relative water content (76.28%) was observed in treatment T_2V_2 (Late Sown + RGN-145).

The data presented in Table 4 clearly indicated that the significantly maximum relative water content was found in this year (2018-19) in treatment T_1V_1 (Normal Sown + Pusa Mustard-26) (84.71%) which was at par with the treatment T_2V_1 (Late Sown + Pusa Mustard-26) (81.50%). Significantly minimum relative water content (73.24) was observed in treatment T_2V_2 (Late Sown+ RGN-145). Sowing time refers to the timing of planting seeds in the field. Normal sowing is typically done during the optimal planting window for a particular crop, while late sowing refers to planting seeds after the optimal window has passed. The results indicate that normal sowing resulted in higher relative water content compared to late sowing. Variety selection is another important factor that can influence crop performance. In this case, the variety Pusa Mustard-26 exhibited higher relative water content compared to the variety RGN-145. Relative water content is a measure of the water content in plant tissues relative to their maximum water-holding capacity. Similar results were also observed by Hafez and Fariq (2019).

Foliar application. As per the data flashed in Table 4 it is clear that the significantly maximum relative water content was found in this year (2017-18) in treatment) P_4 (Thiourea) (85.68%) which was at par with the treatment P_3 (SA 1.0 mM) (84.99%). While significantly minimum relative water content (81.08%) was observed in treatment P_1 (Control).

Based on the data presented in Table 4 it is clearly showed that the significantly maximum relative water content was found in this year (2018-19) in treatment P_4 (Thiourea) (84.41%) which was at per with the treatment P_3 (SA 1.0 mM) (82.06%). While significantly minimum relative water content (74.48%) was observed in treatment P_1 (Control). Foliar application refers to the application of substances directly to the leaves of plants. It is a common agricultural practice used to provide nutrients, enhance plant growth, and improve plant health. In this case, the foliar application treatments involving Thiourea and SA at a concentration of 1.0 mM led to increased relative water content in the plants. Thiourea is a compound that has been reported to have various effects on plant growth and development, including improving water uptake and water-use efficiency. Salicylic Acid (SA) is a plant hormone that is involved in various physiological processes, including responses to stress. Both Thiourea and SA have been studied for their potential to enhance plant water status and mitigate water stress. The finding of present study is in accordance with those of Tripathi *et al*. (2020).

(ii) Chlorophyll stability index. The data on chlorophyll stability index of mustard crop as influenced by sowing time with variety and foliar application of chemicals at both the years are presented in Table 5.

Sowing time with variety. The data displayed in Table 5 it is clearly showed that the significantly maximum chlorophyll stability index was found in this year (2017-18) in treatment T_1V_1 (Normal Sown + Pusa Mustard-26) (46.26) which was followed by the treatment T_1V_2 (Normal Sown+ RGN-145) (42.42) and T_2V_1 (Late Sown + Pusa Mustard-26) (40.89). Significantly minimum chlorophyll stability index (35.76) was observed in treatment T_2V_2 (Late Sown+ RGN-145).

The data depicted in Table 5 that the significantly maximum chlorophyll stability index was found in this year (2018-19) in treatment T_1V_1 (Normal Sown + Pusa Mustard-26) (43.74) which was followed by the treatment T_1V_2 (Normal Sown + RGN-145) (40.43) and T_2V_1 (Late Sown + Pusa Mustard-26) (41.54). Significantly minimum chlorophyll stability index (36.63) was observed in treatment T_2V_2 (Late Sown + RGN-145). It is also worth considering that late sowing and the variety RGN-145 exhibited lower chlorophyll-A content values, indicating a potential decrease in photosynthetic activity and productivity. Normal sowing of Pusa Mustard-26 variety resulted in significantly higher chlorophyll stability index compared to late sowing of RGN-145 variety in both years. This indicates that Pusa Mustard-26 was able to retain more stable chlorophyll pigments under normal sowing conditions, leading to better photosynthetic activity and productivity. The delayed sowing and RGN-145 variety showed lower chlorophyll stability, suggesting decreased photosynthetic performance. This effect was consistent across the two years of study. The ability of Pusa Mustard-26 to maintain higher chlorophyll levels under normal sowing can be attributed to its genetic makeup and physiological efficiency in that growing environment. These outcomes are consistent with findings of Fardus *et al*. (2020).

Foliar application. Among the data presented in Table 5 that the significantly maximum chlorophyll stability index was found in this year (2017-18) in treatment) P_4 (Thiourea) (44.12) which was followed by the treatment P_3 (SA 1.0 mM) (42.47) and P_2 (SA 0.5 mM) (40.28). While significantly minimum chlorophyll stability index (38.45) was observed in treatment P_1 (Control).

Based on the data presented in Table 5 it is clearly showed that the significantly maximum chlorophyll stability index was found in this year (2018-19) in treatment P_4 (Thiourea) (43.57) which was followed by the treatment P_3 (SA 1.0 mM) (41.85) and P_2 (SA 0.5 mM) (39.61). While significantly minimum chlorophyll stability index (37.31) was observed in treatment P_1 (Control). Additionally, the optimal concentrations and timing of foliar application need to be determined to maximize the desired effects on chlorophyll-A content and overall crop productivity. Among the foliar application treatments, thiourea resulted in significantly higher chlorophyll stability index compared to control in both years. This suggests that thiourea was most effective in improving chlorophyll retention and photosynthetic efficiency. SA at 1.0 mM also showed benefits over control. The positive effects of thiourea and SA indicate their potential to enhance chlorophyll levels and productivity through foliar application. However, optimal concentrations and timing need to be standardized to maximize the benefits. Overall, the foliar application results demonstrate that plant growth regulators like thiourea and SA can improve chlorophyll stability and photosynthetic performance in mustard crop. Also, similar results were reported by Sohrab *et al*. (2018).

Table 1: Plant height (cm) of mustard genotypes as influenced by Salicylic acid and Thiourea under high temperature stress at harvest stage.

	2017-18					2018-19				
	P_1	P_2	P_3	P_4	Mean	P_1	P_2	P_3	P_4	Mean
T_1V_1	98.24	114.98	124.67	144.87	**120.69**	101.67	113.81	123.14	146.62	**121.31**
T_1V_2	176.11	192.62	202.18	222.87	**198.45**	174.65	186.57	197.79	221.72	**195.18**
T_2V_1	71.84	88.69	98.84	118.77	**94.53**	67.45	79.69	91.47	114.68	**88.32**
T_2V_2	148.24	164.62	174.30	195.00	**170.54**	139.02	150.81	162.14	186.09	**159.51**
Mean	**123.61**	**140.23**	**150.00**	**170.38**		**120.70**	**132.72**	**143.64**	**167.28**	

	2017-18 SEm±	2017-18 LSD (P=0.05)	2018-19 SEm±	2018-19 LSD (P=0.05)
T	4.33	14.99	3.48	12.03
V	4.33	14.99	3.48	12.03
P	4.45	12.99	3.76	10.98
T×V	7.07	24.47	5.68	19.65
T×P	10.14	32.27	8.36	26.50
V×P	8.28	26.35	6.83	21.64
T×V×P	14.34	45.64	11.83	37.48

T_1: Normal Sown; T_2: Late Sown; V_1: Pusa Mustard-26; V_2: RGN-145; P_1: Control; P_2: SA 0.5 mM; P_3: SA 1.0 mM; P_4: Thiourea

Table 2: Number of primary branches plant^{-1} of mustard genotypes as influenced by Salicylic acid and Thiourea under high temperature stress at harvest stage.

	2017-18					2018-19				
	P_1	P_2	P_3	P_4	Mean	P_1	P_2	P_3	P_4	Mean
T_1V_1	6.52	7.07	7.85	7.74	**7.30**	6.39	6.34	7.03	6.94	**6.68**
T_1V_2	5.13	5.80	6.57	6.75	**6.06**	4.60	5.20	5.89	6.05	**5.43**
T_2V_1	5.62	6.19	6.94	6.93	**6.42**	5.14	5.66	6.34	6.34	**5.87**
T_2V_2	3.86	4.55	5.26	5.59	**4.81**	3.53	4.16	4.81	5.11	**4.40**
Mean	**5.28**	**5.90**	**6.65**	**6.75**		**4.91**	**5.34**	**6.02**	**6.11**	

	2017-18 SEm±	2017-18 LSD (P=0.05)	2018-19 SEm±	2018-19 LSD (P=0.05)
T	0.06	0.21	0.07	0.25
V	0.06	0.21	0.07	0.25
P	0.05	0.14	0.06	0.17
T×V	0.10	0.34	0.12	0.41
T×P	0.12	0.41	0.15	0.50
V×P	0.10	0.33	0.13	0.41
T×V×P	0.18	0.57	0.22	0.71

T_1: Normal Sown; T_2: Late Sown; V_1: Pusa Mustard-26; V_2: RGN-145; P_1: Control; P_2: SA 0.5 mM; P_3: SA 1.0 mM; P_4: Thiourea

Table 3: Number of secondary branches plant^{-1} of mustard genotypes as influenced by Salicylic acid and Thiourea under high temperature stress at harvest stage.

	2017-18					2018-19				
	P_1	P_2	P_3	P_4	Mean	P_1	P_2	P_3	P_4	Mean
T_1V_1	9.52	10.96	11.12	11.30	**10.72**	9.32	9.25	10.19	10.13	**9.72**
T_1V_2	6.84	8.21	8.51	9.01	**8.14**	6.69	7.56	8.50	8.81	**7.89**
T_2V_1	8.62	10.08	10.33	10.63	**9.91**	7.49	8.26	9.19	9.25	**8.55**
T_2V_2	5.42	6.77	7.16	7.84	**6.80**	5.14	6.05	6.94	7.44	**6.39**
Mean	**7.60**	**9.00**	**9.28**	**9.70**		**7.16**	**7.78**	**8.71**	**8.91**	

	2017-18 SEm±	2017-18 LSD (P=0.05)	2018-19 SEm±	2018-19 LSD (P=0.05)
T	0.13	0.44	0.11	0.37
V	0.13	0.44	0.11	0.37
P	0.13	0.38	0.09	0.25
T×V	0.21	0.71	0.17	0.60
T×P	0.30	0.94	0.22	0.73
V×P	0.24	0.77	0.18	0.60
T×V×P	0.42	1.33	0.32	1.03

T_1: Normal Sown; T_2: Late Sown; V_1: Pusa Mustard-26; V_2: RGN-145; P_1: Control; P_2: SA 0.5 mM; P_3: SA 1.0 mM; P_4: Thiourea

Table 4: Relative water content (%) of mustard genotypes as influenced by Salicylic acid and Thiourea under high temperature stress.

	2017-18					2018-19				
	P_1	P_2	P_3	P_4	Mean	P_1	P_2	P_3	P_4	Mean
T_1V_1	88.42	88.56	90.09	89.78	**89.21**	80.84	83.43	86.57	88.01	**84.71**
T_1V_2	83.98	84.28	86.74	86.55	**85.39**	75.27	77.83	81.71	83.17	**79.50**
T_2V_1	80.65	82.26	84.67	85.50	**83.27**	75.98	79.84	83.83	86.35	**81.50**
T_2V_2	71.28	74.49	78.45	80.90	**76.28**	65.83	70.87	76.14	80.10	**73.24**
Mean	**81.08**	**82.40**	**84.99**	**85.68**		**74.48**	**77.99**	**82.06**	**84.41**	

	2017-18 SEm±	2017-18 LSD (P=0.05)	2018-19 SEm±	2018-19 LSD (P=0.05)
T	1.08	3.73	1.17	4.05
V	1.08	3.73	1.17	4.05
P	0.92	2.70	1.08	3.14
T×V	1.76	6.09	1.91	6.61
T×P	2.32	7.49	2.60	8.34
V×P	1.89	6.11	2.12	6.81
T×V×P	3.28	10.59	3.67	11.79

T_1: Normal Sown; T_2: Late Sown; V_1: Pusa Mustard-26; V_2: RGN-145; P_1: Control; P_2: SA 0.5 mM; P_3: SA 1.0 mM; P_4: Thiourea

Table 5: Chlorophyll stability index of mustard genotypes as influenced by Salicylic acid and Thiourea under high temperature stress.

	2017-18					2018-19				
	P_1	P_2	P_3	P_4	Mean	P_1	P_2	P_3	P_4	Mean
T_1V_1	44.00	45.41	47.18	48.43	**46.26**	41.16	43.01	44.76	46.02	**43.74**
T_1V_2	40.00	41.37	43.53	44.75	**42.42**	37.72	39.50	41.64	42.87	**40.43**
T_2V_1	37.92	39.91	42.00	43.73	**40.89**	38.11	40.61	42.81	44.64	**41.54**
T_2V_2	31.86	34.44	37.16	39.59	**35.76**	32.25	35.32	38.19	40.76	**36.63**
Mean	**38.45**	**40.28**	**42.47**	**44.12**		**37.31**	**39.61**	**41.85**	**43.57**	

	2017-18 SEm±	2017-18 LSD (P=0.05)	2018-19 SEm±	2018-19 LSD (P=0.05)
T	0.60	2.08	0.56	1.92
V	0.60	2.08	0.56	1.92
P	0.51	1.50	0.56	1.62
T×V	0.98	3.39	0.91	3.14
T×P	1.29	4.17	1.28	4.09
V×P	1.05	3.41	1.05	3.34
T×V×P	1.83	5.90	1.82	5.79

T_1: Normal Sown; T_2: Late Sown; V_1: Pusa Mustard-26; V_2: RGN-145; P_1: Control; P_2: SA 0.5 mM; P_3: SA 1.0 mM; P_4: Thiourea

CONCLUSIONS

The study evaluated the effect of sowing time, variety and foliar application on morphological and physiological parameters of mustard. Significantly higher plant height, number of branches and relative water content were recorded with normal sowing of Pusa Mustard-26 variety. Among foliar treatments, application of thiourea led to better plant height, branches and chlorophyll stability index compared to control. Late sowing and RGN-145 variety showed lower performance. Thus, normal sowing of Pusa Mustard-26 with foliar spray of thiourea can improve growth and yield contributing attributes of mustard crop.

FUTURE SCOPE

Further research could explore the molecular mechanisms underlying the effects of salicylic acid and thiourea on mustard genotypes under high-temperature stress. Additionally, investigations into optimizing application concentrations and timings are warranted.

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