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Evaluation of Foliar Chemical Sprays for Improving Seed Quality of Field Pea (*Pisum sativum* var. *arvense* L.) under Terminal Heat Stress

Narang Kapoor [a], C.L. Maurya [a*], Sarvendra Kumar [b], Pranava Praanjal [c], Mridulata Pant [d], Aparna Jyoti [a], Amrit Kumar Nayak [b], Amit Kumar [b], Jay Singh [a] and Yogendra Pratap Singh [a]

[a] Department of Seed Science and Technology, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (Uttar Pradesh), 208002, India.
[b] Department of Genetics and Plant Breeding, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (Uttar Pradesh), 208002, India.
[c] Department of Vegetable and Spice Crops, Uttar Banga Krishi Vishwavidyalaya, Pundibari Cooch Behar, West Bengal, 736165, India.
[d] Department of Horticulture, Assam Agricultural University, Jorhat, Assam, 785013, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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**Corresponding author: E-mail: clmaurya@csauk.ac.in;*

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ABSTRACT

Field pea is a significant pulse crop globally, with one-third of the global population relying on it as a staple food. Nonetheless, due to shifting climate conditions and the occurrence of elevated temperatures, heat stress has emerged as a significant factor restraining its productivity. Therefore, the current research was carried out with the aim of formulating an effective approach to address heat stress. The field trial took place during rabi 2023-24 and rabi 2024-25 in the Department of Seed Science and Technology at Chandra Sekhar Azad University of Agriculture and Technology, Kanpur. 12 different Chemicals were used for the present study. Heat stress was found to have a significant influence on the seed quality parameters. Germination percentage and Vigour Index I (VG I), 100 seed weight, seedling length, seedling dry weight reduced significantly under late sown condition. Similar trend was observed for Vigour Index II. (VG II) Foliar sprays with different chemicals viz. Salicylic acid (400ppm), Thiourea (400ppm), Salicylic acid (800ppm), Thiourea (200ppm), Ascorbic acid (10ppm), KCL (1%) were carried out at vegetative (booting stage) and Anthesis stage. Seeds harvested from heat stressed environment showed a significant increase seed quality parameters when sprayed with various foliar sprays. The findings also indicated that spraying salicylic acid at 400ppm and Thiourea at 400ppm effectively enhances multiple seed quality attributes such as 100 seed weight, germination rate, and seedling height (cm). The germination of seeds and VG I and II also displayed upward trends. The use of thiourea notably increased soluble sugars and proline levels in leaves, likely preserving a longer duration of green area with elevated leaf chlorophyll, which ultimately improves seed quality traits and may enhance heat tolerance. Therefore, all foliar applications successfully alleviated heat stress effects; however, salicylic acid at 400ppm and Thiourea at 400ppm were identified as the most effective.

Keywords: Pea; foliar chemical sprays; salicylic acid; terminal heat stress.

1. INTRODUCTION

“Field pea (*Pisum sativum* var. arvense L.) is a self-pollinating cool season grain legume crop that grows at higher elevations in temperatures ranging from 7 to 30°C” (Seepal *et al.*, 2025). It belongs to the Fabaceae family, which has 450 genera and 1200 species, making it the biggest family of flowering plants (Luitel *et al.*, 2021). “It is the third-most produced legume globally and one of the oldest crops still in cultivation” (Azam *et al.*, 2024). It is acknowledged as one of the most fruitful, nutrient-dense legume crops with significant potential to combat protein malnutrition around the globe (Pandey *et al.*, 2021). The two types of peas that are historically cultivated worldwide are field peas and garden peas. Field peas can be utilized as dry matter fodder, silage, haylage, immature grain, green manure, straw, and green fodder while garden peas are mostly consumed for its edible green seeds for culinary purposes (Srivastava *et al.*, 2025). Field peas, however, are valued for its multipurpose usage and its versatility in adapting to diverse climatic conditions (Parihar *et al.*, 2023). “It grows best in well-drained loamy soils with a pH of 6.0 to 7.5, but it is quite vulnerable to waterlogging. Field peas have exceptional nutritional value that include high protein content (23%), vital vitamins like B1 (Thiamine) and B5 (Pantothenic acid), 2.2% minerals, 4.5% fibres, 56.5% carbohydrates, and 1.1% fat” (Anand *et al.*, 2024b).It improves soil health by fixing nitrogen from the environment (Sanwal *et al.*, 2024).In irrigated agro-regions, it currently competes as a crop for the diversification of cereal-based cropping systems (Kumar *et al.* 2018; Baishya *et al.* 2019).”Many industries, such as Bombay Chanachur, Ruchi, and PRAN Dal Vaja, employ field pea seeds as a raw source to create commodities with added value. The current global ambient temperature has increased by 1.2 °C between 1850 and 1900 and is expected to reach 2.7 °C by 2100, according to the Intergovernmental Panel on Climate Change” (Reisinger & Geden 2023). Plant physiology, morphology, and biochemistry are all altered by heat stress, which eventually reduces plant production (Chen *et al.*, 2021). When temperatures rise above the optimal range for a plant's healthy development, it is said to be experiencing heat stress (HS) (Shelake *et al.*, 2024). There is a significant need for high-quality field pea seeds in India. Compared to warm-season grain legumes, field peas and other cool-season grain legumes are more sensitive to high temperatures (Hall, 2001; Huang *et al.*, 2023). Additionally, compared to other winter legumes like chickpeas and lentils, field peas have a lower tolerance for heat (Siddique, 1999), hence production frequently decreases when the maximum day temperature goes over 25°C during the flowering stage (Guilioni *et al.*, 2003; Sadras & Lawson., 2013). Several researchers have reported on the effects of high temperatures in different agro-regions on field pea crop growth, physiology, and yields (Liu *et al.*, 2019; Jiang *et al.*, 2020; Devi *et al.*, 2023).

"High-quality seed production is essential for preserving the food and nutritional security of the country. Seed quality, which is often influenced by seed morphology, seed dormancy, germination, germination rate, and vigor, is significantly impacted by the environmental conditions that exist during the crop-growing season and later during processing and storage" (Rashid *et al.*, 2018; Lamichaney *et al.*, 2019). Recently, the usage of chemical growth regulators in crops have gained importance as having stress-alleviating effects on various crops, mostly alleviating heat-induced damages. These chemical compounds have been reported to have positive influence on physiological and biochemical tolerance pathways of the crop. Salicylic acid, plays a major role as signalling molecule in anti-oxidant defence and photosynthetic efficiency molecular pathway under heat stress conditions (Hassan *et al.*, 2022). Thiourea, a sulphur-containing chemical, facilitates accumulation of osmolytes and stability to chlorophyll, thereby keeping metabolic activity under control during stress (Ahmad *et al.*, 2022). Similarly, ascorbic acid acts as an antioxidant, protecting cell structures against oxidative damage, while potassium chloride (KCL) aids in osmotic balance and enzyme function during heat stress. Boron also aids cell wall building, pollen viability, and seed maturation, ensuring reproductive success even at high temperatures. Ethrel, a chemical that promotes ethylene release, may be applied to manage growth in the plant and promote maturation so that the crop will escape hot, harsh time spells. Together, the compounds reinforce the plant's defensive measures, maintain physiological stability, and sustain productivity under harsh thermal stress. The present study was therefore selected to evaluate the influence of various chemical applications such as salicylic acid, thiourea, cycocel, ascorbic acid, KCL, boron, and ethrel on alleviating terminal heat stress effects on the growth and developmental activity of field pea. By regulating the main metabolic processes of plants, salicylic acid (SA) in particular has been shown to be important in enhancing their ability to withstand abiotic stress (Khan *et al.*, 2015). According to Martel and Qaderi (2016), exogenous salicylic acid administration significantly enhanced all facets of the plant's growth and development under stress, resulting in a notable rise in net CO_2 assimilation and an increase in chlorophyll content. Under stressful conditions, SA controls vital plant physiological functions as photosynthesis and proline (Pro) metabolism, protecting the plant (Miura & Tada, 2014). It has been shown that heat stress tolerance mechanisms in maize can be induced by exogenously applying SA to stressed plants through irrigation, foliar application through spraying, seed soaking, or addition to nutritional medium (Kaur *et al.* 2016; Lakhran *et al.*, 2021). Under heat stress conditions, Thiourea (TU), a stress-relieving chemical with a redox regulation property provided by the -SH group (Sahu 2017), increases plant growth and development (Garg *et al.* 2006; Waqas *et al.* 2019).

This study was conducted to explore the role of foliage application of thiourea and salicylic acid to ameliorate the adverse effect of heat stress on seed quality parameters of field pea variety (KPMR-522) under heat stress condition.

2. MATERIALS AND METHODS

2.1 Experimental Site and Plant Material

The field experiment was conducted at the Student Research Farm, Chandra Shekhar Azad University of Agriculture and Technology (CSAUAT), Kanpur (Uttar Pradesh, India) during two consecutive rabi seasons of 2023-24 and 2024-25. The experimental site is situated in the central plains of Uttar Pradesh and is characterized by subtropical climatic conditions with cool winters and moderate rainfall. The soil of the experimental field is well-drained, sandy loam in texture, medium in fertility, and slightly alkaline in reaction. The field pea variety KPMR-522, known for its adaptability and high yield potential, was used as the test crop.

2.2 Experimental Design and Treatments

The experiment was laid out in a Randomised Block design with twelve treatments and three replications. Each plot measured 7.5 m², and recommended agronomic practices were followed to raise a healthy crop. The list of 12 treatments applied has been shown in Table 1.

2.3 Crop Management

The crop was sown at appropriate soil moisture levels following standard agronomic recommendations for field pea. All plots received a uniform basal dose of fertilizers as per the university package of practices. Irrigation, weed, and pest management were carried out uniformly across treatments. Foliar applications of the respective chemicals were made at the vegetative and anthesis stage using a hand sprayer.

2.4 Observations Recorded

Observations on various seed quality parameters were recorded from five randomly selected plants within each treatment plot to evaluate the influence of different chemical sprays under terminal heat stress conditions. The data were collected using standard procedures as described below:

2.4.1 Test weight 100 seed (g)

For estimation of test weight, 100 seed randomly sampled seeds from each treatment in each of the four replications were weighed and expression in gram.

2.4.2 Standard germination %

The germination test was conducted according to ISTA rules (ISTA, 1999). Four replications of 100 seeds for each treatment were evenly distributed on germination paper. Standard germination was carried out in the laboratory of the Department of Seed Science and Technology on moist germination paper and rolled in butter paper to avoid moisture evaporation during the test period. Samples were placed in plastic trays in slightly tilted position and transferred to a seed germinator at 20±2°C and 90±3% relative humidity. After eight days, the final count was done. The seedlings with normal roots and shoots were counted as normal seedlings.

Standard Germination (%) = (Germinated seeds / Total seeds tested) ×100

2.4.3 Seedling length (cm)

Seedling length (cm) was calculated for the 10 randomly selected normal seedling from each treatment and each replication at final count day. It was measured using centimetre scale, from base of the seedling to tip.

2.4.4 Seedling dry weight (g)

Randomly taken ten normal seedlings which were used for recording seedling length were placed in a container and dried for 24 hours in a hot air oven maintained at 80 °C. The dried seedlings were removed and cooled in desiccator for 30 minutes and then the dry weight of seedling was measured with the help an electronic balance and average weight was computed and expressed in gram per ten seedlings.

2.4.5 Vigour index- I

This index is calculated by multiplying the percentage of germinated seeds by the average length of seedlings. Seedling vigour index-1 was calculated as per the following formula (Abdul-Baki and Anderson, 1973). Seed Vigour Index- I = Standard Germination (%) x Seedling Length (cm).

2.4.6 Vigour index – II

Similar to Vigour Index I, but this index uses the average seedling dry weight. The seedling vigour index-II was calculated as per the following formula (Abdul-Baki & Anderson, 1973). **Seed Vigour Index-II** = Standard Germination (%) x Seedling Dry Weight (g).

2.5 Statistical Analysis

Data recorded on Hundred-seed weight, standard germination percentage, seedling length, seedling dry weight, vigour index - I and vigour index - II were analysed statistically as per the procedures appropriate for RBD with twelve treatments replicated thrice. Pooled data over the two years of study was used for analysis. Analysis of variance (ANOVA) was thus performed to test the significance of treatment effects for each parameter. The treatment and error mean square were worked out and F-test was applied at 5 % level of significance.

The precision of the experiment was determined by calculating the standard error of mean [SE(m)], critical difference (CD) at 5%, and coefficient of variation (CV%) for each trait. Descriptive statistics like treatment means, SE(m), CD and CV% were calculated through MS Excel 2016 whereas ANOVA and comparisons of treatment means were done through the OPSTAT statistical software prepared by CCSHAU, Hisar.

Table 1. Details of Treatment combinations

S. No.	Symbol	Description
T_1	Control	(Untreated)
T_2	Thiourea	Vegetative + anthesis stage @ 200pm
T_3	Thiourea	Vegetative + anthesis stage @ 400pm
T_4	Salicylic acid	Vegetative + anthesis stage @ 400 ppm
T_5	Salicylic acid	Vegetative + anthesis stage @ 800 ppm
T_6	Cycocel	Vegetative + anthesis stage @ 400 ppm
T_7	Cycocel	Vegetative + anthesis stage @ 800 ppm
T_8	Ascorbic acid	Vegetative + anthesis stage @ 10 ppm
T_9	KCl	Vegetative + anthesis stage @ 10,000 ppm
T_{10}	Ethrel	25 days after sowing @ 250 ppm
T_{11}	Boron	45 days after sowing @ 2,500 ppm
T_{12}	Ethrel + Boron	45 days after sowing [@250 ppm + 2,500 ppm]

3. RESULTS AND DISCUSSION

The effect of foliar applied exogenous chemicals on seed quality parameters of field pea was studied to investigate their role in stress alleviation. The pooled analysis results for all observed traits have been depicted in Table 2 and graphically presented in Fig. 1. The analysis revealed that there were significant differences among different treatments for seed quality parameters. As per analysis, it was seen that treatment T4 Salicylic acid @ 400ppm at both vegetative and anthesis stage recorded the highest 100 seed weight (27.55 g.), which was significantly higher than all other treatments followed by T3 thiourea @ 400ppm at both vegetative and anthesis stage (26.92 g.) and T2 Thiourea @ 200ppm at both vegetative and anthesis stage (26.52 g.). The lowest 100 seed weight was recorded in T1- Control (18.71 g.). The increase in hundred seed weight might be attributed to the effect of Salicylic acid (SA), which increases the activity of antioxidant enzymes that preserve cellular membranes during seed filling and lessen oxidative stress, including peroxidase (POD), catalase (CAT), and superoxide dismutase (SOD) (Alam *et al.*, 2022). By controlling the buildup of proline and soluble sugar, it also stabilizes cell membranes and enhances osmotic adjustment. All of these factors work together to improve grain filling and increase seed weight. Similar findings were reported by Murtaza *et al.* (2007) in Field pea, Choudhary *et al.* (2023) in Garden pea, Lakhran *et al.* (2020) in wheat and Iqbal *et al.* (2020) in maize.

Table 2. Effect of various treatments on seed quality parameters

Treatment	100 seed weight	Standard Germination %	Seedling Length	Seedling Dry weight	Vigour Index-I	Vigour Index-II
T_1	18.71	76.87	14.48	1.36	1113.34	105.10
T_2	26.52	89.75	18.52	1.62	1628.19	142.24
T_3	26.92	87.50	18.84	1.64	1686.92	147.31
T_4	27.55	90.00	19.17	1.67	1726.18	150.80
T_5	25.94	86.75	18.15	1.59	1575.29	138.27
T_6	19.86	79.75	15.49	1.42	1235.52	113.98
T_7	19.17	78.37	14.98	1.39	1174.57	109.35
T_8	23.98	86.12	17.84	1.56	1537.06	134.79
T_9	25.30	85.25	17.29	1.53	1474.31	130.97
T_{10}	21.87	81.62	16.42	1.47	1340.55	120.61
T_{11}	21.12	80.37	15.79	1.45	1269.16	116.56
T_{12}	22.74	83.00	16.74	1.50	1389.52	125.11
SE(m)	0.23	0.71	0.19	0.006	17.12	1.30
C.D.	0.65	2.02	0.56	0.019	48.34	3.67
C.V.	2.82	2.42	3.31	1.26	3.38	2.87

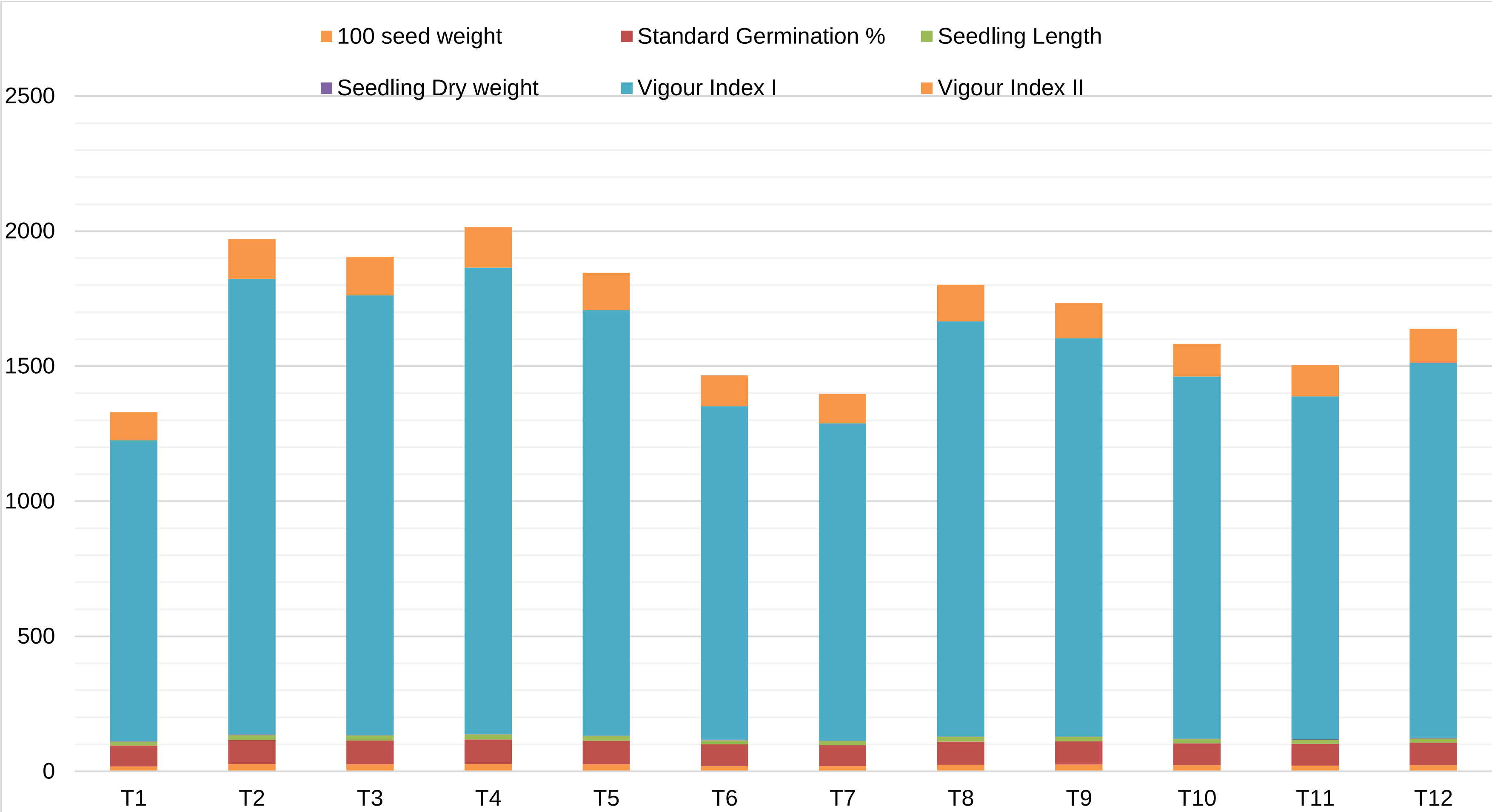

Fig. 1. Graphical representation of 100 seed weight, standard germination, Seedling length, Seedling dry weight, vigour Index-I, vigour Index- II as influenced by foliar application of various chemicals under heat stress condition

The highest standard germination was recorded in T4- Salicylic acid @ 400ppm at both vegetative and anthesis stage (90.00), which was significantly higher than all other treatments followed by T2 thiourea @ 200ppm (89.50) and T3 Thiourea @ 400ppm (87.75). The lowest standard germination was recorded in T1- Control (76.87). This may be because thiourea and salicylic acid preserve the physiological quality of seeds and guards against heat-induced oxidative damage, thereby improving the germination percentage under stress. Similar findings were also observed by Anjum *et al.* (2020) and Naseer *et al.* (2023) in field pea, Prasad *et al.*, (2020) in wheat, Sharma *et al.*, (2022) in mustard, Ferrazza *et al.* (2024) in maize, Zhang *et al.*, (2020) in ornamental pepper.

The highest seedling length was recorded in T4- Salicylic acid @ 400ppm at both vegetative and anthesis stage (19.17 cm), which was significantly higher than all other treatments followed by T3 thiourea @ 400ppm at both vegetative and anthesis stage (18.84 cm) and T2 Thiourea @ 200ppm (18.52 cm). The lowest standard germination was recorded in T1- Control (14.48 cm). This might be due to antioxidant defence, membrane integrity, and osmotic balance—all of which promote improved cell elongation and seedling growth. Similar findings were reported by Gharib and Hegazi (2010) in bean, Khalid *et al.*, (2023) in okra, Sharma *et al.*, (2022) in mustard, Ferrazza *et al.*, (2024) in maize.

The highest seedling dry weight was recorded in T4- Salicylic acid @ 400ppm at both vegetative and anthesis stage (1.67 g.), which was significantly higher than all other treatments followed by T3 thiourea @ 400ppm at both vegetative and anthesis stage (1.64 g.) and T2 Thiourea @ 200ppm at both vegetative and anthesis stage (1.62 g.). The lowest standard germination was recorded in T1- Control (1.36 g.). This could be because SA encourages the buildup of substances like soluble proteins, proline, and glycine betaine, which shield enzymes and preserve osmotic equilibrium, enabling seedlings to retain dry mass and development even in the face of stress. Similar findings were reported by Gharib and Hegazi (2010) in bean, Khalid *et al.*, (2023) in *Abelmoschus esculentus*, Singh *et al.*, (2024) in moong bean.

The highest vigour index I was recorded in T4- Salicylic acid @ 400ppm at both vegetative and anthesis stage (1726.18), which was significantly higher than all other treatments followed by T3 thiourea @ 400ppm at both vegetative and anthesis stage (1686.92) and T2 Thiourea @ 200ppm at both vegetative and anthesis stage (1628.19). The lowest vigour index I was recorded in T1- Control (1113.34). This could be because Higher vigour index I be the outcome of their function in improving germination potential, root-shoot elongation, and biomass accumulation. Improved membrane stability and antioxidant defense are primarily responsible for the improvement. As a result, both serve as stress protectors, improving seedling establishment. Similar findings were reported by Vijayakumar *et al.* (2021) and Gaurav (2024) in chickpea.

The highest vigour index II was recorded in T4- Salicylic acid @ 400ppm at both vegetative and anthesis stage (150.80), which was significantly higher than all other treatments followed by T3 thiourea @ 400ppm at both vegetative and anthesis stage (147.31) and T2 Thiourea @ 200ppm at both vegetative and anthesis stage (142.24). The lowest vigour index II was recorded in T1- Control (105.10). This might be due to enhanced antioxidant defence and preservation of cellular integrity in the face of heat stress due to application of salicylic acid, that shields seedlings oxidative damage and raises their dry weight and raises their Vigour Index-II. Concurrent findings have also been observed by Prasad *et al.* (2020) in wheat, Gaurav (2024) in chickpea and Singh *et al.* (2024) in moong bean.

4. CONCLUSION

The field pea (*Pisum sativum* var. *arvense* L.) was being severely affected by terminal heat stress-induced reduction in seed quality parameters. Foliar sprays of exogenous chemicals proved efficacious against this stress. Among all treatments, salicylic acid @ 400 ppm foliar sprayed at both the vegetative and anthesis stages (T_4) gave the best response by recording the highest 100 seed weight (27.55 g.), Standard germination percentage (90.00), Seedling length (19.17 cm), Seedling dry weight (1.67 g.), Vigour Index I (1726.18), and vigour Index II (150.80), under pooled analysis. Thiourea @ 400 ppm (T_2) and 800 ppm (T_3) treatments also showed considerable improvement over the control.

Improvements realized under SA and TU treatment can be attributed to their ability to regulate ROS activity, enhance membrane stability, and other physiological processes under heat stress. In general, the foliar application of SA @ 400 ppm or TU @ 400 ppm at the critical growth stage may be recommended as a practical and economical measure for circumventing terminal heat stress and maintaining field pea seed quality in warmer agro-climatic regions.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Abdul-Baki, A. A., & Anderson, J. D. (1973). Vigor determination in soybean seed by multiple criteria 1. Crop Science, 13(6), 630–633.

Ahmad, M., Waraich, E. A., Zulfiqar, U., Hussain, S., Yasin, M. U., & Farooq, M. (2022). Thiourea application improves the growth and seed and oil yields in canola by modulating gas exchange, antioxidant defense, and osmoprotection under heat stress. Journal of Soil Science and Plant Nutrition, 22(3), 3655–3666.

Alam, P., Balawi, T. A., & Faizan, M. (2022). Salicylic acid's impact on growth, photosynthesis, and antioxidant enzyme activity of Triticum aestivum when exposed to salt. Molecules, 28(1), 100.

Anand, K. J., Singh, Y., Nagre, S., & Katara, V. K. (2024b). Peas as a promising solution for combating malnutrition. Advances in Biological Sciences and Biotechnology, 6, 61–80.

Anjum, Q. S., Amjad, M., Ziaf, K., & Habib, A. (2020). Seed treatment with salicylic acid improves growth, biochemical attributes and quality seed production of pea. Pakistan Journal of Agricultural Sciences, 7(5), 1370–1379.

Azam, M. G., Sarker, U., Hossain, M. A., Alam, A. K. M. M., Islam, M. R., Hossain, N., & Alamri, S. (2024). Phenotypic diversity in qualitative and quantitative traits for selection of high yield potential field pea genotypes. Scientific Reports, 14, 18561.

Baishya, L. K., Rathore, S. S., Sarkar, D., Jamir, T., & Rajkhowa, D. J. (2019). Crop and varietal diversification for enhancing productivity and profitability of rice fallow system in eastern Himalayan region. Indian Journal of Agricultural Sciences, 89(5), 800–805.

Choudhary, R., Singh, B. K., Choudhary, A., Jat, S. K., Choudhary, A., & Bajia, R. (2023). Influence of plant growth regulators on growth, yield and yield components in garden pea. *Legume Research, 46*(10), 1366–1369.

Chen, J., Miao, W., Fei, K., Shen, H., Zhou, Y., Shen, Y., Li, C., He, J., Zhu, K., Wang, Z., & Yang, J. (2021). Jasmonates alleviate the harm of high-temperature stress during anthesis to stigma vitality of photo thermosensitive genetic male sterile rice lines. *Frontiers in Plant Science, 12*, 634959.

Devi, J., Sagar, V., Mishra, G. P., Jha, P. K., Gupta, N., Dubey, R. K., Singh, P. M., Behera, T. K., & Prasad, P. V. (2023). Heat stress tolerance in peas (*Pisum sativum* L.): Current status and way forward. *Frontiers in Plant Science, 13*, 1108276.

Ferrazza, F. L. F., Loro, M. V., Rocha, T. M., Dörtelmann, D. D. L., Paraginski, R. T., & Nunes, U. R. (2024). Salicylic acid on the physiological and sanitary quality of high- and low-vigor maize seeds. *Journal of Seed Science, 46*, e202446033.

Garg, B. K., Burman, U., & Kathju, S. (2006). Influence of thiourea on photosynthesis, nitrogen metabolism and yield of clusterbean (*Cyamopsis tetragonoloba* (L.) Taub.) under rainfed conditions of Indian arid zone. *Plant Growth Regulation, 48*(3), 237–245.

Gaurav, Y. (2024). *Studies on influence of terminal heat stress on seed yield and seed quality in chickpea (Cicer arietinum L.)* (Doctoral dissertation).

Gharib, F. A., & Hegazi, A. Z. (2010). Salicylic acid ameliorates germination, seedling growth, phytohormone and enzymes activity in bean (*Phaseolus vulgaris* L.)

under cold stress. *Journal of American Science, 6*(10), 675–683.

Guilioni, L., Wéry, J., & Lecoeur, J. (2003). High temperature and water deficit may reduce seed number in field pea purely by decreasing plant growth rate. *Functional Plant Biology, 30*, 1151–1164.

Hall, A. E. (2001). *Crop responses to environment.* Boca Raton, FL: CRC Press.

Hassan, M. U., Aamer, M., Chattha, M. U., Afzal, A., Batool, M., Ahmed, H. A. I., ... & Shahzad, B. (2022). Salicylic acid-mediated physiological and molecular mechanisms in plants under heat stress. *Managing Plant Stress Using Salicylic Acid: Physiological and Molecular Aspects,* 163–182.

Huang, S., Gali, K. K., Arganosa, G. C., Tar'an, B., Bueckert, R. A., & Warkentin, T. D. (2023). Breeding indicators for high-yielding field pea under normal and heat stress environments. *Canadian Journal of Plant Science, 103*(3), 259–269.

Iqbal, M. M., Ahmad, I., Basra, S. M. A., Ijaz, A. B., Tarar, Z. H., Ansar, M., ... & Mehmood, R. (2020). Induction of heat tolerance in maize through exogenous application of salicylic acid, ascorbic acid and hydrogen peroxide in a field study. *Pakistan Journal of Agricultural Research, 33*(3), 585–593. DOI: 10.17582/journal.pjar/2017/33

ISTA (1999) International Rules for Seed Testing. Seed Science and Technology, 27, 25-30.

Jiang, Y., Lindsay, D. L., Davis, A. R., Wang, Z., MacLean, D. E., Warkentin, T. D., & Bueckert, R. A. (2020). Impact of heat stress on pod-based yield components in field pea (*Pisum sativum* L.). *Journal of Agronomy and Crop Science, 206*(1), 76–89.

Kaur, A., Gupta, O. P., & Sharma, P. (2016). Comparative expression analysis of HSP genes in wheat and barley under heat stress. *Journal of Wheat Research, 8*, 63–64.

Khalid, U. B., Shah, B. H., Ahmed, I., Ali, M., Ayyub, S., & Ahmad, M. (2023). Temporal heat stress mitigation and physiological response in *Abelmoschus esculentus* L. by foliarly supplied salicylic acid. *Journal of Pure and Applied Agriculture, 8*(2).

Khan, M. I. R., Fatma, M., Per, T. S., Anjum, N. A., & Khan, N. A. (2015). Salicylic acid-induced abiotic stress tolerance and underlying mechanisms in plants. *Frontiers in Plant Science, 6*, 462.

Kumar, N., Hazra, K. K., Nath, C. P., Praharaj, C. S., & Singh, U. (2018). Grain legumes for resource conservation and agricultural sustainability in South Asia. In *Legumes for soil health and sustainable management* (pp. 77–107).

Lakhran, H., Sharma, O. P., Bajiya, R., Choudhary, J. R., Kanwar, S., & Choudhary, M. (2021). Effect of foliar application of bioregulators for improving high temperature tolerance of wheat (*Triticum aestivum* L.). *Journal of Environmental Biology, 42*(4), 1078–1084.

Lakhran, H., Sharma, O. P., Bajiya, R., Verma, H. P., & Choudhary, M. (2020). Dry matter partitioning and productivity of wheat (*Triticum aestivum* L.) as influenced by sowing thermal regimes and bio-regulators. *Current Journal of Applied Science and Technology*, *39*(31), 84–91.

Lamichaney, A., Swain, D. K., Biswal, P., Kumar, V., Singh, N. P., & Hazra, K. K. (2019). Elevated atmospheric carbon dioxide affects seed vigour of rice (*Oryza sativa* L.). *Environmental and Experimental Botany*, *157*, 171–176.

Liu, N., Karunakaran, C., Lahlali, R., Warkentin, T., & Bueckert, R. A. (2019). Genotypic and heat stress effects on leaf cuticles of field pea using ATR-FTIR spectroscopy. *Planta*, *249*, 601–613.

Luitel, B. P., Pun, T. B., & Bhandari, B. B. (2021). Evaluation of growth and yield characters of garden pea genotypes at Dailekh, Mid-Western Nepal. *Nepalese Horticulture*, *15*, 24–33.

Martel, A. B., & Qaderi, M. M. (2016). Does salicylic acid mitigate the adverse effects of temperature and ultraviolet-B radiation on pea (*Pisum sativum*) plants. *Environmental and Experimental Botany*, *122*, 39–48.

Miura, K., & Tada, Y. (2014). Regulation of water, salinity, and cold stress responses by salicylic acid. *Frontiers in Plant Science*, *5*, 4.

Murtaza, G. H. U. L. A. M., Asghar, R., Ahmad, S., & Majid, S. A. (2007). The yield and yield components of pea (*Pisum sativum*

L.) as influenced by salicylic acid. *Pakistan Journal of Botany*, 39(2), 551.

Naseer, H., Shaukat, K., Nizar, M., & Ahmed, J. (2023). Assessment of foliar spray of iron and salicylic acid under artificial magnetism on various metabolites of *Pisum sativum*. *Asian Journal of Research in Crop Science*, *8*(1), 1–15.

Pandey, A. K., Rubiales, D., Wang, Y., Fang, P., Sun, T., Liu, N., & Xu, P. (2021). Omics resources and omics-enabled approaches for achieving high productivity and improved quality in pea (*Pisum sativum* L.). *Theoretical and Applied Genetics*, *134*(3), 755–776.

Parihar, A. K., Hazra, K. K., Lamichaney, A., Singh, A. K., & Dixit, G. P. (2023). Delineating the role of plant stature towards heat stress tolerance in field pea (*Pisum sativum* L.). *Heliyon*, *9*(3), e14539.

Prasad, R. B., Joshi, M. A., Basu, S., & Gaikwad, K. B. (2020). Development of suitable mitigation strategy to counter the adverse effect of heat stress in wheat varieties (*Triticum aestivum* L.). *International Journal of Current Microbiology and Applied Sciences*, *9*, 646–653.

Rashid, M., Hampton, J. G., Rolston, M. P., Khan, K. M., & Saville, D. J. (2018). Heat stress during seed development affects forage brassica (*Brassica napus* L.) seed quality. *Journal of Agronomy and Crop Science*, 204(2), 147–154.

Reisinger, A., & Geden, O. (2023). Temporary overshoot: Origins, prospects, and a long path ahead. *One Earth*, *6(*12), 1631–1637.

Sadras, V. O., & Lawson, C. (2013). Nitrogen and water-use efficiency of Australian wheat varieties released between 1958 and 2007. *European Journal of Agronomy*, *46*, 34–41.

Sahu, M. P. (2017). Thiourea: A potential bioregulator for alleviating abiotic stresses. In *Abiotic Stress Management for Resilient Agriculture*. Springer, Singapore, 261–274.

Sanwal, S. K., Kesh, H., Devi, J., & Singh, B. (2024). Analysis of trait association and genetic diversity in garden pea (*Pisum sativum* L.) genotypes under Middle Gangetic Plain region of India. *Legume Research*, *47*(3), 385–390.

Seepal, Y. S., Sharma, V., Singh, C. M., Shukla, G., Gangwar, V., Kamaluddin, & Singh, K. S. (2025). Application of stress indices to identify terminal heat tolerance genotype in field pea (*Pisum sativum var. arvense*). *Legume Research*, *48*(1), 20–25.

Sharma, S., Singh, R., Gupta, H., & Vimal, S. (2022). Mitigating terminal heat stress in physiological parameters of Indian mustard (*Brassica juncea* L.). *Pharma Innovation*, *11*(3), 398–402.

Shelake, R. M., Wagh, S. G., Patil, A. M., Červený, J., Waghunde, R. R., & Kim, J. Y. (2024). Heat stress and plant–biotic interactions: Advances and perspectives. *Plants*, *13*(15), 2022.

Siddique, K. (1999). Abiotic stresses of cool season pulses in Australia. *Agriculture Western Australia, Centre for Legumes in Mediterranean Agriculture, and University of Western Australia*, Perth.

Singh, P. P., Ramakrishnan, R. S., Tiwari, G., Sharma, A., & Prajapati, S. S. (2024). Effect of thiourea and salicylic acid in enhancing growth and phenology of mungbean (*Vigna radiata* (L.) R. Wilczek) for quality seed production. *Plant Archives*, *24*, 371–375.

Srivastava, A., Nath, S., Singh, P., Sharma, P., Srivastava, S., Tyagi, A., & Yadav, K. S. (2025). Assessment of yield-contributing traits and genetic variability in field pea (*Pisum sativum* L.) under heat stress using half-diallel derived genotypes. *Legume Research*, *48*(10), 1627–1634.

Vijayakumar, H. P., Dhandapani, R., Somasundaram, G., Natarajan, S., Swarnalakshmi, K., Joshy, C., & Boraiah, K. (2021). Salicylic acid improves seed germination through modulating antioxidant enzymes under salt stress in chickpea (*Cicer arietinum*). *The Indian Journal of Agricultural Sciences*, *91*(11), 1665–1669.

Waqas, M. A., Kaya, C., Riaz, A., Farooq, M., Nawaz, I., Wilkes, A., & Li, Y. (2019). Potential mechanisms of abiotic stress tolerance in crop plants induced by thiourea. *Frontiers in Plant Science*, 10*,* 1336.

Zhang, Z., Lan, M., Han, X., Wu, J., & Wang-Pruski, G. (2020). Response of ornamental pepper to high-temperature stress and role of exogenous salicylic acid in mitigating high temperature. *Journal of Plant Growth Regulation*, *39*(1), 133–146.

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