Journal of Cereal Research
Volume 18 (2): 324-329
Homepage: http://epubs.icar.org.in/ejournal/index.php/JWR
Research Article

Foliar Potassium Nitrate for Yield Enhancement and Terminal Heat Stress Mitigation in Wheat under Farmer Field Conditions in Punjab

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Article history:
Received: 15 Jun., 2026
Revised: 21 Aug., 2026
Accepted: 23 Aug., 2026

Citation:
Rampal VK, A Singh, M Singh and H Singh. 2026. Foliar Potassium Nitrate for Yield Enhancement and Terminal Heat Stress Mitigation in Wheat under Farmer Field Conditions in Punjab. *Journal of Cereal Research* ***18 (2):*** *324-329.* http://doi.org/10.25174/2582-2675/2026/180207

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Abstract

A field survey followed by farmer-participatory field experiments was conducted in Fatehgarh Sahib and Kapurthala districts of Punjab, India, to evaluate the adoption pattern and agronomic benefits of foliar potassium nitrate (KNO_3) application in wheat cultivar PBW 826 under terminal heat stress conditions. The survey of 90 farmers (45 from each district) revealed that KNO_3 adoption was 42.2% in Fatehgarh Sahib and 33.3% in Kapurthala. Among adopters, the 2.0% KNO_3 concentration was the most commonly used in both districts (22.2%), followed by 1.0% and 1.5% concentrations. Two foliar sprays were preferred over a single spray, indicating farmers' inclination towards repeated applications. Farmers primarily perceived KNO_3 as a heat-stress mitigation input, while a considerable proportion also reported yield improvement as a major benefit. Based on the survey findings, farmer-participatory field experiments were conducted in 10 farmer fields in each district, comprising three treatments: control, 1% KNO_3, and 2% KNO_3 applied at the booting and anthesis stages. Foliar application of 2% KNO_3 significantly improved growth and yield attributes in both districts. In Fatehgarh Sahib, the treatment recorded the highest plant height (98.6 cm), effective tillers (406 m^{-2}), 1000-grain weight (42.47 g), grain yield (5.87 tonnes ha^{-1}), and straw yield (8.72 tonnes ha^{-1}), while corresponding values in Kapurthala were 100.3 cm, 407 m^{-2}, 42.90 g, 6.01 tonnes ha^{-1}, and 9.19 tonnes ha^{-1}, respectively. Economic analysis also showed maximum profitability under the 2% KNO_3 treatment, with gross returns of Rs. 1,42,288 and Rs. 1,45,683 $acre^{-1}$ and net returns of Rs. 94,985 and Rs. 98,505 $acre^{-1}$ in Fatehgarh Sahib and Kapurthala, respectively. The study demonstrated that foliar application of potassium nitrate @ 2% at critical growth stages is an effective and economically viable strategy for enhancing wheat productivity and mitigating the adverse effects of terminal heat stress under farmer field conditions.

Keywords: Economics, grain, heat stress, potassium nitrate, wheat and yield

1. Introduction

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops worldwide and plays a crucial role in ensuring food and nutritional security. In India, wheat is the second most important staple crop after rice and contributes significantly to the country's food grain production (Vijayakumar *et al.* 2022). The Indo-Gangetic Plains constitute the major wheat-growing region of the country, particularly in the states of Punjab, Haryana, and Uttar Pradesh, which together contribute a substantial share of the country's national wheat production (Tripathi and

Mishra, 2017). The rice–wheat cropping system practiced in this region has been instrumental in achieving food self-sufficiency; however, the long-term sustainability of this system is facing several agronomic and environmental challenges. Among the various constraints affecting wheat productivity, climatic variability has emerged as a significant factor. Rising temperatures and irregular weather patterns during the reproductive phase of wheat often expose the crop to terminal heat stress. High temperature during flowering and grain filling stages reduces grain development and shortens the grain filling duration, thereby negatively affecting grain yield (Ferris *et al.*, 1998; Hussain *et al.*, 2020). Such conditions have become increasingly common in north-western India, making it essential to adopt suitable agronomic strategies that can mitigate the adverse effects of heat stress and maintain stable crop productivity. Another major issue associated with intensive cultivation of the rice–wheat cropping system is the imbalance in nutrient management. Farmers often apply higher quantities of urea (N) and DAP (P) fertilizers while MOP(K) application is frequently inadequate or neglected. Continuous cropping without proper replenishment of potassium has resulted in depletion of soil potassium reserves in many intensively cultivated regions (Bijay-Singh *et al.*, 2003). Potassium is an essential macronutrient that plays a key role in several physiological processes including enzyme activation, photosynthesis, regulation of stomatal activity and translocation of assimilates within the plant. Adequate potassium nutrition enhances plant vigour, improves stress tolerance and ultimately increases crop productivity and quality (Hegde and Babu, 2004). In recent years, foliar application of nutrients has gained importance as an efficient method of supplying nutrients during critical growth stages. Foliar fertilization ensures rapid nutrient uptake and utilization by plants, especially where soil nutrient availability or root uptake is limited. Potassium nitrate is commonly used for foliar application as it supplies both potassium and nitrogen in readily available forms. Research studies have reported that foliar application of potassium nitrate during important growth stages of wheat can improve yield attributes, grain yield and economic returns (Vijayakumar *et al.*, 2019; Singh and Singh, 2020). Furthermore, foliar application of potassium plays an important role in enhancing plant physiological efficiency, improving stress tolerance, and supporting grain filling. However, limited information is available on the effectiveness of foliar potassium nutrition in wheat under actual farmer field conditions, particularly through systematic evaluation using Front Line Demonstrations (FLDs). Most existing studies have focused on experimental or controlled conditions, creating a need to validate the technology under diverse and practical farming situations. FLDs provide an effective mechanism for assessing improved technologies under real-world conditions and generating location-specific evidence for wider farmer adoption. Therefore, the present study was undertaken to evaluate the effectiveness of foliar application of potassium nitrate (KNO_3) on the growth, yield attributes, and productivity of wheat under farmer field conditions through Front Line Demonstrations, thereby generating practical evidence on the potential of foliar potassium nutrition as an agronomic intervention.

2. Material and Methods

2.1 Survey study

The survey was conducted in Fatehgarh Sahib and Kapurthala districts of Punjab to assess farmers' perceptions and adoption of potassium nitrate foliar application in wheat. A total of 45 farmers were selected from five blocks, with nine farmers from each block, to ensure equal spatial representation of the study area. The district was selected because of the dominance of the rice-wheat cropping system and the growing relevance of foliar nutrition for managing terminal heat stress in wheat. Primary data were collected through personal interviews using a structured questionnaire. Information was recorded by a personal interview schedule on potassium nitrate use, dose applied, number of sprays, grade of fertilizer, spray volume, stage of application, heat stress reduction, yield increment, and use of any other foliar fertilizer. Responses were coded as yes/no, numerical values, or percentage concentrations, depending on the nature of the observation. Each variable was entered separately for all 45 respondents from each district to maintain clarity and consistency in the dataset. The compiled data were then summarized using descriptive statistics such as frequency, percentage, and mean for interpretation in the extension-based research paper.

2.2 Field study

The present study was conducted at Fatehgarh Sahib and Kapurthala District during the *Rabi* season of 2024–25 on

twenty farmers' fields (10 from Fatehgarh Sahib and 10 from Kapurthala) to evaluate the effect of foliar potassium fertilization on the growth and productivity of wheat. The experiment was laid out under Front Line Demonstration (FLD) conditions using a randomized treatment arrangement with three treatments and ten farmer fieldsin each district. Each treatment was implemented on an area of 0.2 ha. The treatments consisted of: T_1- Control (no foliar spray), T_2 -potassium nitrate (KNO_3) 1% foliar spray at boot stage and anthesis stage (2 kg KNO_3 dissolved in 200 L water)., and T_3- potassium nitrate (KNO_3) 2% foliar spray at boot stage and anthesis stage (4 kg KNO_3 dissolved in 200 L water). The foliar sprays were applied using a knapsack sprayer to ensure the uniform coverage of the crop canopy. The experiment was conducted on fields having varying soil fertility status. The soil available nutrient content across the experimental sites ranged from 165–210 kg N ha^{-1}, 16–26 kg P_2O_5 ha^{-1} and 125–157 kg K_2O ha^{-1}, representing the typical fertility conditions of the region. Wheat variety PBW 826 was sown in all the experimental fields. The crop was established using the Super Seeder under crop residue management practices. The sowing of wheat was carried out between 15th November and 30th November 2024 depending on field conditions. The number of irrigations applied during the crop growth period depends on soil moisture conditions and farmer management practices. All other agronomic practices including seed rate, fertilizer application and plant protection measures were followed as per the recommended package of practices of Punjab Agricultural University, Ludhiana. Observations on various growth and yield parameters such as plant height, number of effective tillers per square meter, 1000-grain weight, grain yield and straw yield were recorded from each treatment plot at maturity. Plant height was measured from the ground level to the tip of the spike excluding awns from randomly selected plants and expressed in centimeters. The number of effective tillers was counted from a representative area and expressed as number per square meter. 1000-grain weight was recorded by weighing 1000 grains from each treatment and expressed in grams. Grain and straw yields were recorded from the net harvested area and converted into quintals per hectare. The recorded data were subjected to statistical analysis using Duncan's Multiple Range Test (DMRT) to determine the significance of differences among treatments.

3. Result and Discussion

3.1 Survey analysis

Potassium nitrate (KNO_3) was used by 19 farmers (42.2%) in Fatehgarh Sahib and 15 farmers (33.3%) in Kapurthala, while 26 farmers (57.8%) and 30 farmers (66.7%), respectively, did not use it, indicating that adoption was below half of the sampled respondents in both districts (Table 1). The table also shows that the most frequently used dose of potassium nitrate was 2% in both districts, followed by 1.0% (13.3%) and 1.5% (6.7%), respectively, in Fatehgarh Sahib. But in Kapurthala District, 1.0% potassium nitrate concentration used by 2.2% and 1.5% potassium nitrate dose by 8.9% of respondents, showing

Table 1. Adoption pattern of potassium nitrate (KNO_3) foliar spray and perceived benefits among surveyed wheat farmers (n = 45)

Parameter	Category	Fatehgarh Sahib		Kapurthala	
		Number of farmers (n)	Percentage (%)	Number of farmers (n)	Percentage (%)
Adoption of potassium nitrate (KNO_3)	Yes	19	42.2	15	33.3
	No	26	57.8	30	66.7
Dose of KNO_3 used	1.0%	6	13.3	1	2.2
	1.5%	3	6.7	4	8.9
	2.0%	10	22.2	10	22.2
Number of foliar sprays	Two sprays	13	28.9	11	24.4
	One spray	6	13.3	4	8.9
Perceived role in heat stress management	Yes	19	42.2	15	33.3
	No	26	57.8	30	66.7
Perceived yield increment	Yes	15	33.3	17	37.8
	No	30	66.7	28	62.2

a clear preference for the PAU-recommended spray concentration within the adopted group. Two sprays were preferred by 13 farmers (28.9%) in Fatehgarh Sahib and 11 farmers (24.4%) in Kapurthala, compared with one spray by 6 farmers (13.3%) and 4 farmers (8.9%), respectively, suggesting that repeated foliar applications were preferred against single application. Heat stress management was reported by 19 farmers (42.2%) in Fatehgarh Sahib and 15 farmers (33.3%) in Kapurthala, while yield increment was reported by 15 farmers (33.3%) and 17 farmers (37.8%), respectively, in both districts, indicating that farmers perceived KNO_3 primarily as a stress-mitigation input with a moderate yield response. Table 1 shows that KNO_3 adoption was limited in both districts, while the non-adoption group remained higher. Among users, the 2.0% KNO_3 concentration and two sprays were most common, indicating a preference for a stronger and repeated foliar treatment. Heat-stress management was reported more often than yield increment in Fatehgarh Sahib, whereas in Kapurthala, both benefits were reported at comparable levels. Overall, the findings suggest that farmers perceived KNO_3 mainly as a stress-mitigation input rather than a consistent yield enhancer.

3.2 Growth attributes

Foliar application of potassium nitrate exerted a significant influence on the growth parameters of wheat in both Fatehgarh Sahib and Kapurthala (Table 2). Among the different treatments, foliar spray of potassium nitrate at 2% recorded the maximum plant height (98.6 cm and 100.3 cm in both district respectively), which was significantly higher than the other treatments. The minimum plant height was observed under the control treatment (96.6 cm and 96.2 cm in both districts, respectively). The enhancement in plant height with potassium nitrate application may be attributed to improved nutrient availability and stimulation of physiological processes that promote vegetative growth. Potassium plays a crucial role in cell elongation, regulation of photosynthesis, and translocation of assimilates, thereby enhancing overall plant growth (Hegde and Babu, 2004).

Table 2. Effect of potassium nitrate on the growth attributes of wheat

Treatments	Fatehgarh Sahib			Kapurthala		
	Plant height (cm)	Effective tillers (No./m^2)	1000-grain weight (g)	Plant height (cm)	Effective tillers (No./m^2)	1000-grain weight (g)
Control	96.6 c	391 c	41.81 c	96.2 c	385 c	41.73 c
Potassium Nitrate 1%	97.5 b	398 b	42.29 b	98.1 b	398 b	42.45 b
Potassium nitrate 2%	98.6 a	406 a	42.47 a	100.3 a	407 a	42.90 a

*Means followed by different letters within a column differ significantly at the 5% level of significance according to Duncan's Multiple Range Test (DMRT).

A similar trend was observed for the number of effective tillers per square meter. The highest number of effective tillers was recorded with foliar application of potassium nitrate at 2% (406 and 407 m^{-2} in Fatehgarh Sahib and Kapurthala, respectively), followed by 1% potassium nitrate (398 m^{-2} in both districts). The control treatment produced the lowest number of effective tillers (391 and 385 m^{-2}, respectively). The increase in tiller density with potassium nutrition may be associated with improved carbohydrate metabolism and enhanced nutrient uptake, which collectively support better tiller formation and development. Comparable findings were reported by Vijayakumar *et al.* (2019), who observed increased tiller production in wheat under potassium fertilization.

1000-grain weight also responded significantly to foliar potassium nitrate application. The maximum 1000-grain weight was recorded under the 2% potassium nitrate treatment (42.47 g in Fatehgarh Sahib and 42.90 g in Kapurthala), followed by 1% potassium nitrate (42.29 g and 42.45 g in both districts, respectively), whereas the minimum values were observed in the control treatment (41.81 g and 41.73 g, respectively). The improvement in 1000-grain weight may be attributed to enhanced grain filling and efficient translocation of photosynthates to developing grains under adequate potassium supply. These results corroborate the findings of Singh and Singh (2020), who reported that foliar potassium nitrate application improved yield attributes in wheat.

3.3 Yield

Grain yield exhibited a similar trend across treatments. The maximum grain yield was recorded with the application of potassium nitrate at 2%, yielding 5.87

tonnesha^{-1} in Fatehgarh Sahib and 6.01 tonnes ha^{-1} in Kapurthala, which was significantly higher than the remaining treatments. The lowest grain yield was observed in the control treatment, with 5.60 and 5.80 tonnes ha^{-1} in Fatehgarh Sahib and Kapurthala, respectively. The 1% potassium nitrate treatment produced intermediate yields in both districts, showing a moderate improvement over the untreated control.

The improvement in grain yield with foliar potassium nitrate application may be associated with enhanced photosynthetic efficiency, improved nutrient uptake, and better grain development during the reproductive phase (Hari Ram, 2020). Potassium plays a vital role in enzyme activation and assimilate transport, thereby contributing to higher productivity (Hegde and Babu, 2004). The positive response of wheat yield to foliar potassium nutrition has also been documented by Vijayakumar *et al.* (2019) and Singh and Singh (2020), who reported significant improvements in wheat productivity with potassium fertilization.

3.4 Economics

Economic analysis (Table 4) indicated that foliar application of potassium nitrate improved the profitability of wheat cultivation in both Fatehgarh Sahib and Kapurthala. The cost of cultivation was marginally higher under potassium nitrate treatments due to the additional cost associated with fertilizer and spraying operations. The highest cost of cultivation was recorded with the 2% potassium nitrate spray, amounting to Rs. 47,303 ha^{-1} in Fatehgarh Sahib and Rs. 47278 ha^{-1} in Kapurthala, whereas the lowest cost was observed under the control treatment (Rs. 45,303 and Rs. 45,328 ha^{-1}, respectively).

Table 3. Effect of potassium nitrate on the yield of wheat

Treatments	Fatehgarh Sahib		Kapurthala	
	Straw yield (tonnes/ha)	Grain yield (tonnes/ha)	Straw yield (tonnes/ha)	Grain yield (tonnes/ha)
Control	8.42c	5.60c	8.60c	5.80c
Potassium Nitrate 1%	8.52b	5.65b	8.94b	5.84b
Potassium nitrate 2%	8.72a	5.87a	9.19a	6.01a

*Means followed by different letters within a column differ significantly at the 5% level of significance according to Duncan's Multiple Range Test (DMRT).

Table 4. Effect of potassium nitrate on the economics of wheat

Treatments	Fatehgarh Sahib			Kapurthala		
	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)
Control	45303	135740	90438	45328	140590	95263
Potassium Nitrate 1%	46303	138650	92348	46365	141560	95195
Potassium nitrate 2%	47303	142288	94985	47178	145683	98505

Despite the slightly higher cultivation cost, potassium nitrate treatments generated greater economic returns owing to higher grain yield. The maximum gross returns were recorded with the 2% potassium nitrate treatment, amounting to Rs. 1,42,288 ha^{-1} in Fatehgarh Sahib and Rs. 1,45,683 ha^{-1} in Kapurthala. Similarly, the highest net returns were obtained under the 2% potassium nitrate treatment, reaching Rs. 94985 ha^{-1} and Rs. 98,505 ha^{-1} in Fatehgarh Sahib and Kapurthala, respectively. These values were followed by the 1% potassium nitrate treatment. In contrast, the control treatment recorded the lowest gross returns (Rs. 1,35,740 and Rs. 1,40,590 ha^{-1}) and net returns (Rs. 90,438 and Rs. 95,263 acre^{-1}) in Fatehgarh Sahib and Kapurthala, respectively.

The higher profitability under potassium nitrate treatments indicates that foliar potassium nutrition is an economically viable strategy for improving wheat productivity. The increase in gross and net returns may be attributed to enhanced growth, better grain development, and higher yields resulting from improved potassium nutrition. Similar economic advantages of potassium fertilization in wheat have been reported by Vijayakumar *et al.* (2019) and Prasad *et al.* (2004), who observed increased yield and profitability under balanced nutrient management.

Conclusion

Foliar application of potassium nitrate improved wheat growth, yield, and economic returns in both Fatehgarh Sahib and Kapurthala, with 2% KNO_3 applied at the booting and anthesis stages giving the best performance. The survey also showed that farmers mostly preferred the 2.0% dose and two sprays, and many reported reduced heat stress and yield improvement, indicating good field relevance of the practice. Overall, potassium nitrate foliar spray @ 2% at critical growth stages can be recommended as a technically sound and economically viable option for wheat under heat-stress conditions.

Funding Acknowledgment - The authors gratefully acknowledge Punjab Agricultural University (PAU), Ludhiana and the concerned Krishi Vigyan Kendra (KVK) for providing the necessary institutional support and facilities for conducting the Front Line Demonstrations and field observations. No specific external funding was received for this study.

Conflict of Interest: The authors declare that they have no conflict of interest related to the research, authorship, or publication of this article.

Author Contributions: V.K. Rampal: Conceptualization, supervision, and overall guidance of the study.

Amanpreet Singh: Field experimentation, data collection, analysis, interpretation of results, and manuscript preparation; Mandeep Singh: Field observations, data collection, and technical inputs; Harinder Singh: Field observations, data collection, and technical inputs. All authors contributed to the revision of the manuscript and approved the final version for publication.

Ethical Approval: The study involved agronomic field demonstrations conducted on farmers' fields and did not involve human or animal subjects requiring ethical approval.

Declaration on the Use of Generative AI or AI-Assisted Technologies: During the preparation of this manuscript, the authors did not use generative AI or AI-Assisted technologies.. The scientific content, experimental data, analysis, interpretation, and conclusions were generated and verified by the authors.

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