

Impact of Foliar Application of Potassium Silicate on Growth and Productivity of Wheat by Alleviating High Temperature Stress

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Article history:

Received: 30 Oct., 2025

Revised: 26 Nov., 2025

Accepted: 02 Dec., 2025

Citation:

Kaur M, JS Deol, N Gupta and GS Mavi. 2025. Impact of foliar application of potassium silicate on growth and productivity of wheat by alleviating high temperature stress. *Journal of Cereal Research* 17 (3): 328-334. <http://doi.org/10.25174/2582-2675/2025/172923>

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Abstract

High temperature stress significantly affects the crop at every zodiac stage either directly or indirectly by altering hydration status. To evaluate the role of potassium silicate to mitigate high temperature stress in wheat, the study was conducted during *Rabi* 2021-22 & 2022-23 at Punjab Agricultural University, Ludhiana, Punjab, India. An experiment laid out in split plot design comprised of four environments i.e; 25th October (D₁), 5th November (D₂), 15th November (D₃) and 25th November (D₄) in main plots and eight potassium silicate (K₂SiO₃) treatments i.e; control (T₁), 2% potassium silicate (K₂SiO₃) at boot leaf (T₂), 2% K₂SiO₃ at anthesis (T₃), 3% K₂SiO₃ at boot leaf stage (T₄), 3% K₂SiO₃ at anthesis (T₅), 2% K₂SiO₃ at boot leaf stage + anthesis (T₆), 3% K₂SiO₃ at boot leaf stage + anthesis (T₇) and 2% KNO₃ at boot leaf stage + anthesis (T₈) in sub-plots. The study found that D₁ planting results in 8-11 and 6-7 per cent increase in leaf area index (LAI) and dry matter accumulation (DMA), respectively, whereas 20-26 per cent LAI increase was recorded with foliar spray of 3% potassium silicate at boot leaf + anthesis stages contributed for yield enhancement. It is concluded that early sowing of wheat on 25th October, combined with foliar application of 3% potassium silicate at booting + anthesis stages, effectively mitigates the adverse effects of high-temperature stress and contributes to improved growth, yield attributes, and overall productivity of wheat.

Key words: High temperature stress, potassium silicate, sowing environments, wheat yield.

1. Introduction

Wheat (*Triticum aestivum* L.), is the staple food for billions of people and a crucial source of proteins and calories (Poole *et al.*, 2021). Wheat production has many challenges including climate change (Paymard *et al.*, 2018), limitation of irrigation water (Kirby *et al.*, 2017), uneven and random rainfall (Arshad *et al.*, 2018), and imbalance fertilizer dose and timings of application (Ghosh *et al.*, 2020). Changing climate is the prime dynamic source that affects the sustainability and variability in wheat crop yield, which ultimately poses the greatest threat to the food security of

developing economies like India. Abiotic stress, especially drought and heat stresses have been considered as one of the major threats for the crop plants. Out of these, terminal and continual heat stresses affect the wheat crop growth, development and restrict the exploitation of the genetic potential of the wheat genotypes. Globally, per degree rise in temperature decreases the wheat grain yield at the rate of 0.07 per cent but a per degree rise in temperature at the reproductive stage, especially at grain filling state, reduces six per cent wheat yield. In case of South Asia, including



India and Pakistan, wheat yield adversely declines at the rate of 3-17 per cent with per degree rise in temperature (Pask *et al.*, 2014 and Asseng *et al.*, 2015). Such a decline in yield can reach to 6 per cent if adaptive measures such as seed priming and exogenous application of stress protectants augmenting with improved germplasm are not realized (Zhao *et al.*, 2017).

The exogenous application of stress protectants, phytohormones, signaling molecules and trace elements have resulted in the potential to protect the plants by neutralizing the harmful and adverse effects of heat stress (Upreti and Sharma 2016). The foliar application of potassium had been found to benefit the metabolic regulation under physiological stress. The potassium containing fertilizers are reported to delay leaf senescence (Benbella and Paulsen 1998), increase soluble sugar and proline content in leaf tissues (Hong-Bo *et al.*, 2006), increase the activity of superoxide dismutase (SOD) and peroxidase antioxidant enzymes which resulting in increased 1000-grain weight and grain yield of wheat (Lv *et al.*, 2017) under high temperature stress. After oxygen (49%), silicon is the second most copious element (31%) in the lithosphere and is mainly exists in the form of silicates. Nevertheless, Si has not been documented as an essential plant element, the benefits of exogenous application of Si application in improving growth & yield attributes and thus the yield of many plant species are well-documented (Cooke and Leishman 2016; Verma *et al.*, 2020, Hassan *et al.*, 2021 and Kafi *et al.*, 2021), hence Si regarded as a 'quasi-essential' element (Al Murad *et al.*, 2020). Shreds of evidence substantiate Si as a potent arbitrator in increasing crop yield by improving germination, photosynthesis, and relative water content (Souri *et al.*, 2020). Si also plays a vital function in alleviating environmental stresses like heat, drought, salinity, hypoxia (flooding), mineral and heavy metal (Al and Cd) toxicity by inducing plant organogenesis (Kim *et al.*, 2015 and Abdelaal *et al.*, 2020). Foliar application potassium silicate improved the tolerances of cotton to salinity stress, brassica napus L., maize, banana, faba bean, ajwain, sorghum, wheat to water and drought stress (Nazim *et al.*, 2024). Saudy *et al.*, (2023) revealed that potassium silicate application improved grain weight spike⁻¹ by about 1.06 times whether with IW80 or IW60 and seed index increased by 1.03, 1.06 and 1.04 times due to potassium silicate under IW100, IW80 and IW60 treatments, respectively. Under water-deficit stress, irrigation at fifteen

days interval combined with three times foliar application of potassium silicate resulted in highest values of maize grain yield and yield components Foliar application of potassium silicate + Lithovit improves rice physiological processes resulting in highest values of leaf area index, chlorophyll A and B, yield attributes and thus, the grain yield (Goma *et al.*, 2021). Therefore, the present study has been planned to find out the potentiality of different environments and potassium silicate in improving heat tolerance in bread wheat.

2. Materials and Methods

A field study was conducted at research farm of Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana, India, during the *Rabi* season of 2021-22 and 2022-23. The experiment comprised four sowing dates in main plot and eight foliar sprays of potassium silicate in the sub-plots, replicated thrice.

The treatment details are as under:

Main plots: Date of sowing, D₁-25th October, D₂-5th November, D₃-15th November and D₄- 25th November.

Sub-plot treatments: T₁ – control (no spray), T₂ - 2% potassium silicate (K₂SiO₃) at boot leaf, T₃ - 2% K₂SiO₃ at anthesis, T₄ - 3% K₂SiO₃ at boot leaf stage, T₅ - 3% K₂SiO₃ at anthesis, T₆ - 2% K₂SiO₃ at boot leaf stage + anthesis, T₇ - 3% K₂SiO₃ at boot leaf stage + anthesis and T₈ - 2% KNO₃ at boot leaf stage + anthesis. The field experiment laid out in split plot design.

The soil of the experimental field was sandy-loam in texture, optimal pH (7.5) and EC (0.20 dSm⁻¹ at 25°C), low in available nitrogen (172.4 kg ha⁻¹), medium in available phosphorus (17.2 kg ha⁻¹) and potassium (183.5 kg ha⁻¹). The wheat variety PBW 725 was sown by using seed rate @ 100 kg ha⁻¹ by maintaining a row spacing of 22.5 cm. The crop was raised by adopting the recommended crop husbandry operations for wheat cultivation under Punjab conditions. The study was planned to ameliorate the high temperature stress in wheat. Statistical analysis was done as per the procedure given by Cochran and Cox (1967) using OPSTAT software.

3. Results and Discussion

3.1 Growth parameters

Sowing environments and foliar sprays of potassium silicate significantly affected the growth parameters of wheat crop such as plant height, leaf area index, dry matter



accumulation and improves the high temperature stress tolerance by maintaining high chlorophyll index in the leaves of wheat crop.

Among the sowing environments, wheat crop sown on 25th October (D₁) recorded highest plant height, leaf area index, dry matter accumulation and chlorophyll index which was statistically at par with wheat crop sown on 05th November (D₂) whereas the lowest growth parameters were recorded in D₄. It might be due to the favourable maximum and minimum air temperatures, extended growth period and cool environmental conditions during growth and developmental stages which favours enhanced crop growth, especially the plant height, dry matter accumulation and LAI in early sown wheat crop. The studies on response of date of sowing to attain the higher wheat grain yield revealed that growth parameters of wheat crop decreased with delay in sowing due to the high temperature during reproductive stage shortens the

zodiac stages and force the wheat crop maturity (Singh *et al.*, 2014, Akter and Islam 2017, Dar 2017, Khan *et al.*, 2020, Nizamani *et al.*, 2020, Ram and Kaur 2021 and Kaur *et al.*, 2021).

Among the foliar treatments, during both the consecutive years of the study, 3 per cent potassium silicate at booting + anthesis stage recorded highest growth parameters which were statistically at par 2 per cent potassium silicate and potassium nitrate applied at booting and anthesis stages. The potassium silicate treatments resulted in higher LAI and DMA was due to more plant height and tiller number. Due to better osmotic balance in plant for a longer period leads to improve morpho-physiological parameters and grain yield by ameliorating the water stress effect within the plant. The findings of the study are similar with Dehghanipoodeh *et al.*, (2018), Younis *et al.*, (2020) Aurangzaib *et al.*, (2021), Hassan *et al.*, (2021) Khalid *et al.*, (2022) and Afzal *et al.*, (2022).

Table 1: Effect of sowing environments and potassium silicate on growth parameters of wheat over the consecutive years of study

Treatments	Plant height (cm)		Leaf area index		DMA (gm ²)		Chlorophyll index	
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
Environment								
D ₁	93.44	94.02	3.61	3.81	745.06	750.64	51.73	50.13
D ₂	92.79	92.30	3.63	3.49	739.46	735.15	51.48	50.11
D ₃	90.86	89.40	3.32	3.39	720.98	718.25	48.67	46.79
D ₄	84.36	85.50	2.24	2.84	699.72	694.15	44.36	42.49
CD (p=0.05)	3.19	5.84	0.14	0.26	15.54	15.11	1.22	1.07
Foliar Spray								
T ₁	89.50	88.60	2.76	2.82	669.54	639.73	46.58	44.70
T ₂	90.21	89.20	3.07	3.19	680.24	651.72	48.21	46.59
T ₃	91.38	89.82	3.09	3.25	682.52	695.99	48.61	46.74
T ₄	90.17	90.06	3.21	3.32	705.52	723.68	49.31	47.55
T ₅	91.00	90.44	3.28	3.40	735.42	759.27	49.50	47.76
T ₆	90.65	91.06	3.36	3.64	760.35	780.00	50.17	48.59
T ₇	90.46	91.93	3.47	3.84	785.54	790.60	50.26	48.82
T ₈	89.54	91.35	3.37	3.60	745.25	755.40	49.84	48.27
CD (p=0.05)	NS	1.96	0.09	0.09	6.85	5.62	1.45	1.12

3.2 Effect on Grain Yield attributes:

Data revealed that sowing environment had significant effect on grain yield parameters during both the years. Highest grain yield attributes were recorded when wheat crop sown on 25th October (D₁) which was significantly better than all the sowing environments. The decrease in magnitude of spike density from D₁ to D₄ was 19.24 & 10.56 % during 2021-22 and 2022-23, respectively.

Similarly, grains per spike and 1000-grain weight were highest with D₁ sowing environment.

Foliar application of potassium silicate had considerable influence on the grain yield attributes of wheat crop. The maximum grain yield attributes were recorded when potassium silicate was applied at booting + anthesis stage @ 3 per cent which was statistically at par with 2 per cent potassium nitrate & potassium silicate at booting +



anthesis stage. The foliar application of potassium silicate and nitrate increases stay greenness effect in plant by improving chlorophyll index that leads to improved production of assimilates and maintain the water balance that mitigate the high temperature stress by enhancing translocation of photosynthates from source to sink. These results are in conformity with the research finding of Tomar *et al.*, (2014) and Deshmukh *et al.*, (2015). Diminution in growth parameters with delayed sowing resulted in reduction of grain yield and yield attributes might be due to forced overlapping of phenological stages, higher pollen sterility and prevailing high temperature during reproductive stage. Similar findings were reported

by Marasini *et al.*, (2016), Meena *et al.*, (2015), Gill *et al.*, (2015), Ram and Kaur (2021) and Kaur *et al.*, (2021).

3.3 Effect on grain yield

The wheat crop sown on D₁ environment recorded higher grain yield as the yield has a direct relationship with the effective tillers (m⁻²), grains per spike, 1000-grain weight. Similarly, the foliar application of 3% potassium silicate at booting + anthesis stages alleviates the high temperature effects on plant growth and thus resulting in higher grain yield of wheat crop. The effect of potassium silicate and nitrate at booting and anthesis stage was pronounced on grain and biological yield. Similar results were observed by Aurangzaib *et al.*, (2021) and Mustafa *et al.*, (2021).

Table 2: Effect of sowing environments and potassium silicate on yield attributes of wheat over the consecutive years of study

Treatments	Spike density (m ²)		Grains per spike		1000 Grain weight (g)		Grain yield (qha ⁻¹)	
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
Environment								
D ₁	411.60	410.04	33.36	30.93	45.97	44.88	54.99	52.85
D ₂	387.80	390.38	32.98	29.39	42.07	41.42	51.97	48.92
D ₃	376.80	384.25	30.89	28.38	35.54	35.09	47.49	47.06
D ₄	357.00	360.88	28.76	27.56	31.09	31.23	44.41	45.72
CD (p=0.05)	10.70	17.01	2.03	1.86	3.50	1.72	2.42	2.42
Foliar Spray								
T ₁	362.20	369.33	28.68	27.58	31.23	30.60	40.98	41.70
T ₂	376.40	379.42	29.58	28.32	34.76	34.26	44.92	44.28
T ₃	379.70	383.08	30.58	28.79	36.94	36.58	46.99	46.28
T ₄	384.80	386.75	31.30	28.93	38.56	38.02	48.98	47.62
T ₅	389.70	391.58	32.22	29.21	39.71	39.38	51.19	49.79
T ₆	392.80	396.17	32.96	29.94	42.52	41.83	54.32	52.70
T ₇	397.60	401.17	33.88	30.63	43.48	43.35	56.40	54.51
T ₈	383.30	383.58	32.77	29.12	42.16	41.25	53.93	52.22
CD (p=0.05)	6.51	7.56	1.54	1.25	1.39	0.97	1.20	1.58

Conclusion

To combat with the changing climates, it is concluded that early sowing (25th October) of wheat resulted in better growth parameters viz; plant height, DMA, and LAI and yield attributes viz; spike density (m²), grains per spike, thousand grain weight and grain yield of wheat as compared to delayed sowing. Foliar application of potassium silicate @ 3 % at booting + anthesis stage resulted in higher plant growth & yield attributes and production of wheat. Early sowing with foliar spray of potassium silicate @ 3% at booting + anthesis stages gave better growth and yield parameters of wheat. It

may be concluded that early sowing of wheat (25th October) and foliar spray of potassium silicate @ 3 % at booting + anthesis stage helps in mitigating effect of high temperature stress during reproductive stage for better productivity of wheat. Hence, the combination of 3 per cent potassium silicate at booting + anthesis stages along with timely sowing can be recommended as an effective agronomic practice to enhance wheat productivity and profitability under changing climatic conditions.

Author's contribution

Maninder Kaur: Data collection, compilation and analysis, interpretation of results, manuscript drafting; J S Deol:



Planning, interpretation and manuscript editing; Neha Gupta: Data collection and compilation; G S Mavi: Experiment conduction. All the authors read and finalized the manuscript.

Conflict of interest

The authors declare that they have no conflict of interest.

Ethical Approval

This article doesn't contain any study involving ethical approval.

Funding

Not applicable

Declaration on the use of Generative AI or AI-assisted technologies

The authors declare that no generative AI or AI-assisted technologies were used in the preparation of this manuscript. All text, data interpretation, and analysis were conducted entirely by the authors.

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