



Potassium Silicate Modulates Leaf Water Relations and Membrane Integrity in Cotton (*Gossypium hirsutum* L.)

J. Annie Sheeba^{1*}, Kanjana D.² and Prakash A.H.¹

¹Department of Plant Physiology,

ICAR- Central Institute for Cotton Research, Regional Station, Coimbatore (TN), India.

²Department of Soil Science,

ICAR- Central Institute for Cotton Research, Regional Station, Coimbatore (TN), India.

(Corresponding author: J. Annie Sheeba*)

(Received: 15 October 2025; Revised: 25 October 2025; Accepted: 27 October 2025; Published online: 01 November 2025)

(Published by Research Trend)

DOI: <https://doi.org/10.65041/BF.2025.17.11.2>

ABSTRACT: Potassium (K) and silica (SiO₂) are important nutrient elements offering tolerance to various abiotic and biotic stresses faced by plants. Potassium silicate (K₂SiO₃) is a potential source of K and Si. A study was conducted to evaluate the effect of the application of K₂SiO₃ on drought tolerance in the cotton hybrid Bunny Bt 2. Foliar sprays of different concentrations of K₂SiO₃ (40, 60, 80 µl/l) were taken up under irrigated and water-stressed conditions. Relative water content (RWC), proline content and cell membrane stability were increased significantly, whereas lipid peroxidation and per cent membrane injury decreased with the application of K₂SiO₃ when compared with control. Under water stress conditions, 40µl of potassium silicate treated plants recorded higher K contents over control plants. This study suggests the positive effect of K₂SiO₃ on water relations and membrane integrity which can help alleviate the negative effects of water stress in cotton plants.

Keywords: Potassium silicate, RWC, Proline, Lipid peroxidation.

INTRODUCTION

Climate change, with rising temperatures and fluctuating weather patterns, increases the frequency of droughts, floods, and salinity which affects the productivity of commercially important crops like cotton. When exposed to stress, plants close their stomata slowing down metabolism and enhancing senescence and cell death. Potassium (K) and silica (SiO₂) are important nutrient elements offering tolerance to various abiotic stresses faced by plants. K is essential for maintaining turgidity of plant cells, especially guard cells of stomata, thus regulating opening and closure of stomata (Qi *et al.*, 2019). Under ideal conditions, plants can grow even without silicon as it is considered to be a beneficial element and not an essential one. However, silicon was found to enhance plants' tolerance to various abiotic stresses by modulating water relations, cell-wall flexibility and membrane stability (Rehman *et al.*, 2019; Tuladhar *et al.*, 2021). Silicon is absorbed by plants in the form of silicic acid. This compound forms an amorphous gel-like physical barrier between cuticle and cell wall and cell wall and plasma membrane thus reducing evaporation loss of water. Potassium silicate (K₂SiO₃) is a potential source of K and Si. Spraying potassium silicate eliminated the adverse effects of drought stress on crops (Zahedi *et al.*, 2020). Potassium silicate was

found to positively influence the quantitative and qualitative performance of potato plants (Talebi *et al.*, 2015). Application of potassium silicate was found to improve drought tolerance in sweet corn (Karvar *et al.*, 2023). Exogenous application of potassium silicate was found to improve drought tolerance in cotton genotypes (Nazim *et al.*, 2024). This study was aimed at investigating whether potassium silicate will alleviate the negative effects caused by drought stress by modulating leaf water relations and membrane integrity in cotton plants.

MATERIALS AND METHODS

The experiment was conducted at the Central Institute for Cotton Research, Nagpur at Plant Physiology glass house during 2016-2017 in a factorial completely randomised design. Bunny Bt 2 plants were raised in cement tanks with dimensions of 258 × 88 cm with a spacing of 60 × 30 cm. The cement tanks were filled with farm soil (fine smectitic hyperthermic typic haplustert) with pH 7.9 and field capacity of 42.4%. Plants were irrigated up to 40 DAS and irrigation was withheld for 10 days during flowering. Experimental plants were subjected to foliar spray of 40, 60 and 80 µl/l of potassium silicate {Agrisil (L)} 60 DAS (10 days after imposing stress); control plants were sprayed water. Six plants were tagged per treatment, and

morphological and yield parameters recorded. Relative water content (RWC) and proline content were estimated by following the methodology of Barrs and Weatherley (1962) and Bates (1973), respectively. Lipid peroxidation assay was performed according to the methodology of Velikova *et al.* (2000). Cell membrane stability was determined by the methodology of Deshmukh *et al.* (1991). Percent membrane injury was quantified by following the methodology of Sullivan *et al.* (1972). Potassium content was estimated by the flame photometric method given by Johnston *et al.*, 1952. Statistical Analysis is done using standard Analysis of Variance.

RESULTS AND DISCUSSION

Under stressed conditions, plants that received foliar spray of 40 $\mu\text{l/l}$ of potassium silicate exhibited high relative water content (RWC) (98%) [60 $\mu\text{l/l}$ (89.4%) and 80 $\mu\text{l/l}$ (80.4%)] as against control (73%). Under irrigated conditions, RWC was higher in plants treated with 60 $\mu\text{l/l}$ of potassium silicate (83.3%) relative to

control (76.4%). Under drought conditions leaf RWC tends to decrease, which is influenced by stomatal responses and carbon economy (Rad *et al.*, 2023). However, potassium silicate-applied cotton plants were able to maintain higher RWC (Fig. 1). This is in accordance with the findings of Eyni-Nargeseh *et al.* (2022), Rad *et al.* (2023) and Nazim *et al.* (2024). The increase in leaf RWC after the application of potassium silicate might be due to the silicon deposition on the leaf cuticle layer which might have increased leaf thickness and hence reduced the leaf transpiration under water-stress conditions (Ma and Yamaji 2006). Leaf water potential is closely related to the RWC of leaves (O'Neill *et al.*, 2006) and indicates the plant water content status and drought tolerance (Sairam and Srivastava 2001). In the present study, plants treated with 80 $\mu\text{l/l}$ of potassium silicate recorded higher leaf water potential under irrigated (-12.0 bars) and stressed conditions (-21.3 bars) when compared with control plants under irrigated (-16.8 bars) and stressed conditions (-23.0 bars) (Fig. 2).

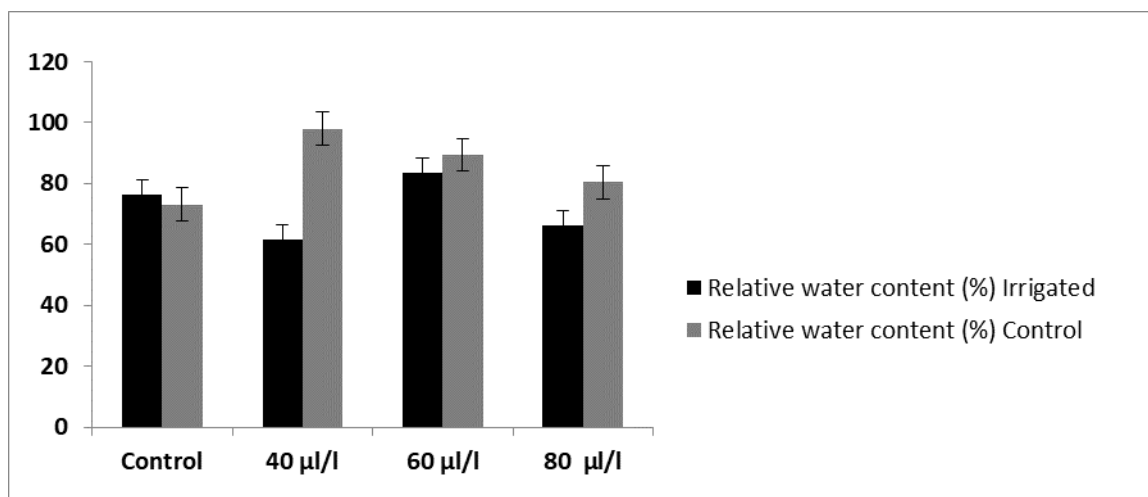


Fig. 1. Relative Water Content as influenced by foliar application of potassium silicate.

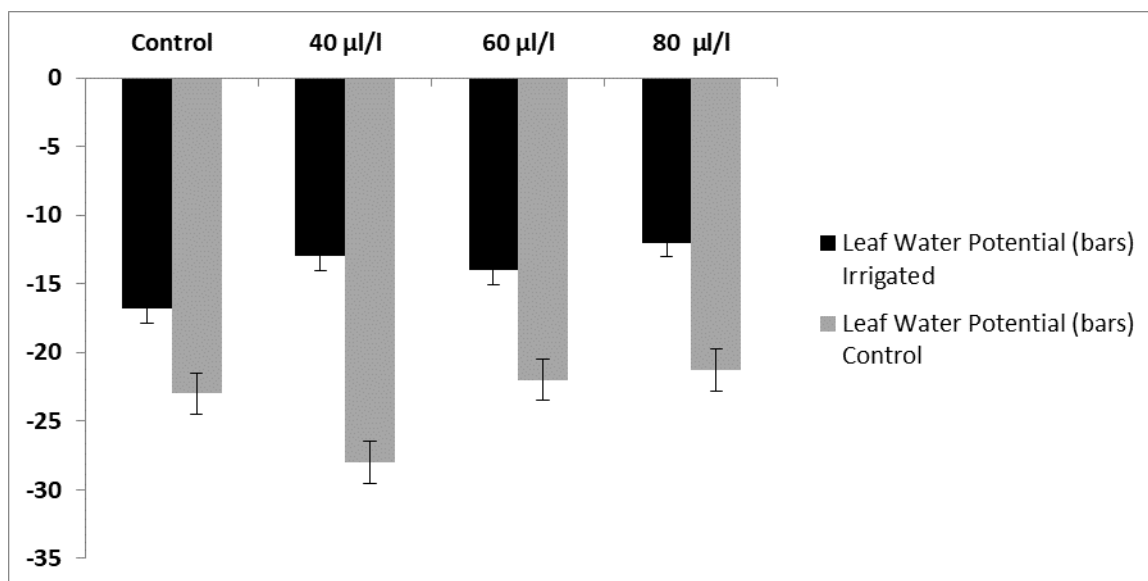


Fig. 2. Leaf Water Potential as influenced by foliar application of potassium silicate

The RWC and leaf water potential were found to be enhanced with the application of potassium silicate. Plants with relatively higher water content towards the terminal stress period are considered to be more drought-tolerant (Basu, 2004). Hence the role of increasing RWC in improving drought tolerance could be validated. Potassium silicate-treated plants recorded higher proline content than control plants both under irrigated and stressed conditions. Plants sprayed with 40 $\mu\text{l/l}$ potassium silicate recorded higher proline content of 654.8 $\mu\text{mol/g}$ FW under water-stressed conditions as against water-sprayed control (553.8 $\mu\text{mol/g}$ FW) (Fig. 3). This result is concordant with the findings of Hajiboland *et al.* (2017), who observed that the concentration of osmotic regulators like proline increased significantly when potassium silicate was applied under water-deficit conditions. The increase in proline content might be attributed to the silicon-induced activity of pyrroline-5-carboxylate synthetase (P5 CS) and glutamate dehydrogenase (GDH), the precursors of proline biosynthesis as reported by Garg

and Sing (2018). Liu *et al.*, 2015 and Coskun *et al.*, 2016 found that silicon could improve the osmotic adjustment in plants by promoting the accumulation of proline and sugars. Potassium silicate concentrations above 40 $\mu\text{l/l}$ decreased the proline accumulation probably because of the stress-mitigating effects of potassium. Potassium-applied plants were found to maintain higher leaf water potential, turgor potential and RWC and lower osmotic potential when compared with untreated plants of *Vigna radiata* (Nandwal *et al.*, 1998) grown under water-stress conditions. Since potassium content is higher in higher doses of potassium silicate and as it helps maintain the higher water potential by itself, plants might not have the need to invest in biosynthesis of proline to maintain the turgidity of leaves. Under irrigated conditions, control plants recorded higher K % than potassium silicate-treated plants. Under stress conditions, plants treated with 40 $\mu\text{l/l}$ of potassium silicate recorded higher K (1.17%) content when compared with control plants (0.9%). (Fig. 4).

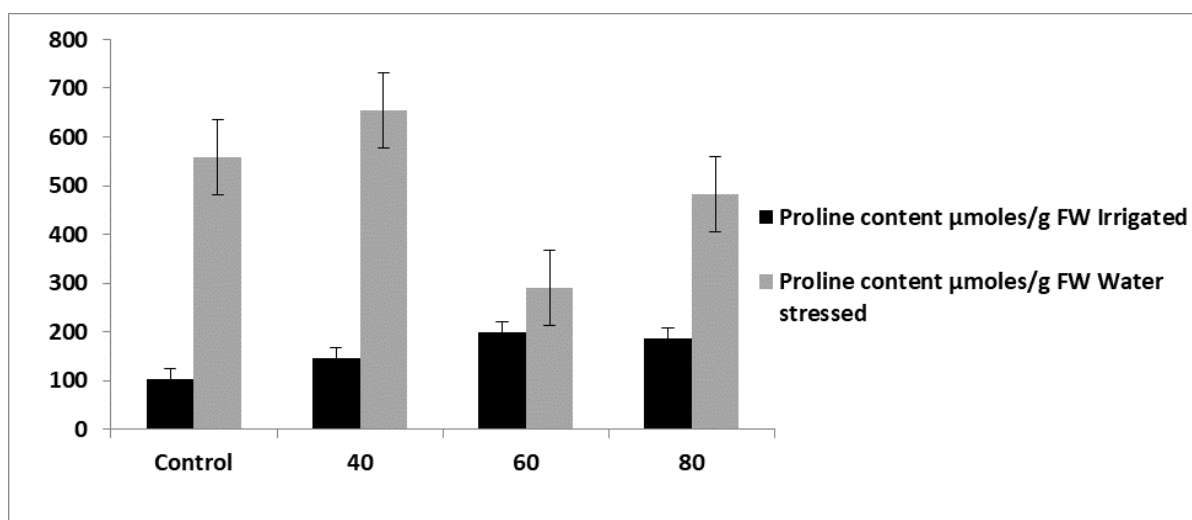


Fig. 3. Proline content as influenced by foliar application of potassium silicate.

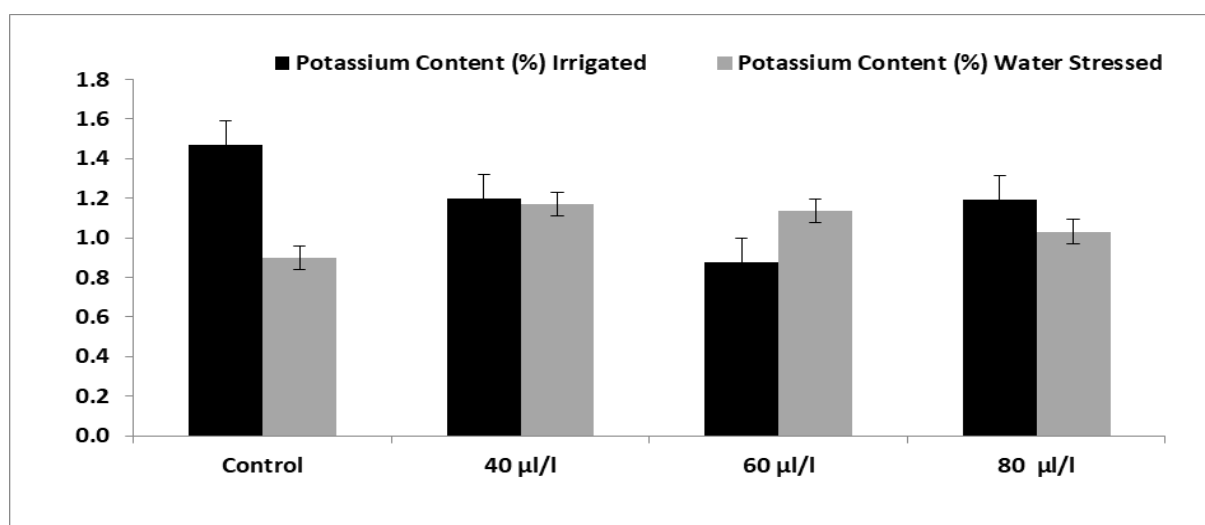


Fig. 4. Potassium content as influenced by foliar application of potassium silicate.

This is similar to the findings of Oraee and Tehranifar (2023) where application of K_2SiO_3 were found to enhance the accumulation of silicon (Si) and potassium (K) in daisy plants. Lipid peroxidation was lower in all the potassium silicate-treated plants when compared with the control plants after the second spray. While control plants recorded higher lipid peroxidation (5.9 $\mu\text{mol MDA/g FW}$), plants treated with 80 $\mu\text{l/l}$ potassium silicate recorded lower lipid peroxidation (0.7 $\mu\text{mol MDA/g FW}$) under stressed conditions (Fig. 5). Cell membrane integrity was higher in plants subjected to potassium silicate treatments when compared with control plants and hence membrane

injury was lower in plants treated with potassium silicate both under irrigated and stressed conditions (Fig. 6 and 7). The decreased lipid peroxidation and percent membrane injury and increased membrane integrity might be attributed to the increase in proline content (Garg and Sing 2018). Moreover, lower lipid peroxidation might be attributed to higher K content due to potassium silicate application (Fang *et al.*, 2022). Hence the significance of potassium and silicon in protecting cell membranes and maintaining RWC under water-stressed conditions has been demonstrated in the present study.

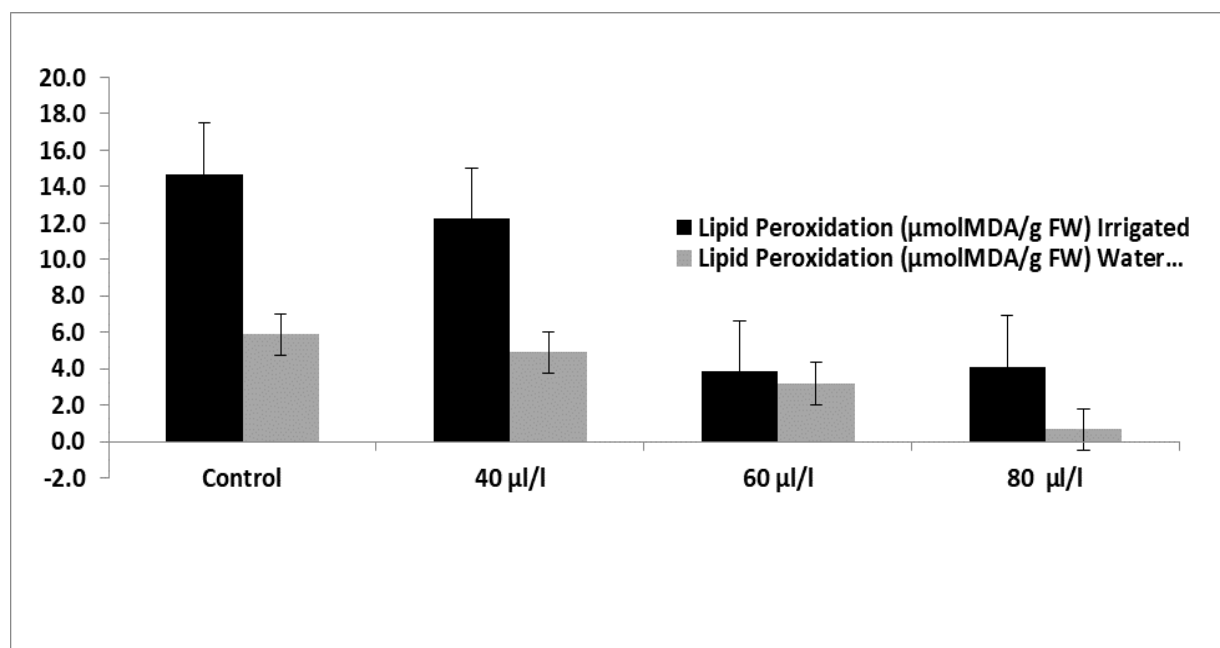


Fig. 5. Lipid Peroxidation as influenced by foliar application of potassium silicate.

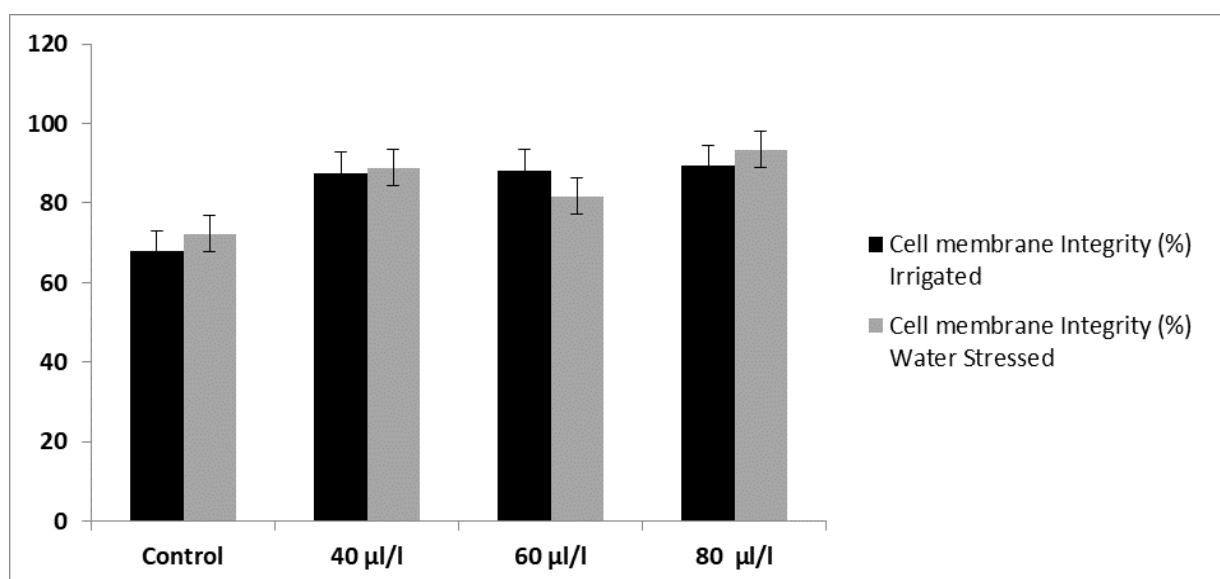


Fig. 6. Cell Membrane Integrity as influenced by foliar application of potassium silicate.

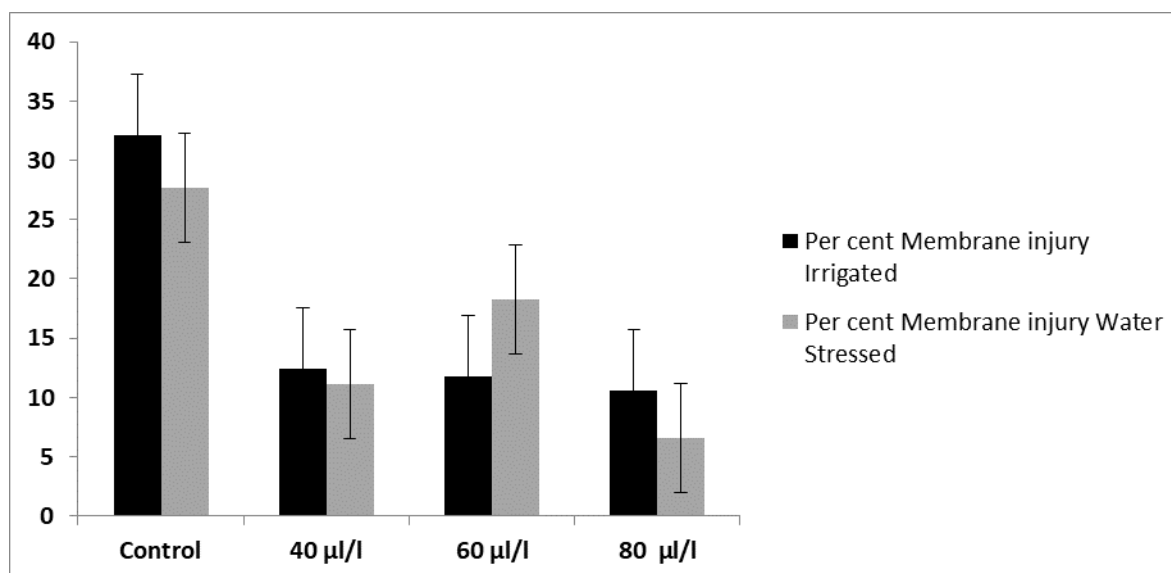


Fig. 7. Per cent Membrane injury as influenced by foliar application of potassium.

CONCLUSIONS

Potassium silicate treatment was found to positively influence leaf water relations in terms of RWC and leaf water potential and thence to increased stress tolerance. Cell membrane integrity was increased due to potassium silicate treatments leading to reduction in membrane injury and ion leakage under stress conditions. Potassium silicate treatment increased the proline content and decreased lipid peroxidation thus decreasing the oxidative stress on plants. Under stress conditions, potassium silicate positively influenced the K uptake of cotton plants. Foliar application of potassium silicate could alleviate the negative effects of water stress in cotton plants.

FUTURE SCOPE

With the adversities being caused by the climate change in recent years, frequently resulting in drought like conditions, molecules like potassium silicate would be a boon to cotton crop to improve productivity in cotton under water-limited conditions.

Author contributions.

J. Annie Sheeba and A.H. Prakash: Conceived and designed the research work.

D. Kanjana : Contributed data.

Acknowledgement. This Research was supported by the Indian Council of Agricultural Research, Department of Agricultural Research and Education, Government of India

Conflict of interest. There is no conflict of interest among the authors

REFERENCES

- Barrs, H. D. and Weatherley, P. E. (1962). A reexamination of the relative turgidity technique for estimating water deficits in leaves. — *Austr. J. Biol. Sci.*, 15, 413-428.
- Basu, S. and Nautiyal, P. C. (2004). Improving water use efficiency and drought tolerance in groundnut by trait-based breeding programmes in India, vol 2. Brisbane, Australia. pp 98

- Bates, L. S., Waldren R. P. and Teare I. D. (1973). Rapid determination of free proline for water stress studies. *Plant Soil*, 39, 205-207.
- Coskun D., Britto D. T., Huynh Wayne. Q. and Kronzucker, H. J. (2016). The role of silicon in higher plants under salinity and drought stress. *Front Plant Sci.*, 7, 1072.
- Eyni-Nargeseh, H., Shirani Rad, A. H. and Shiranirad, S. (2022). Does Potassium Silicate Improve Physiological and Agronomic Traits and Oil Compositions of Rapeseed Genotypes Under Well-Watered and Water-Limited Conditions? *Gesunde Pflanzen.*, 74, 801-816.
- Fang, S., Yang, H., Wei G., Shen, T., Wan Z., Wang, M., Wang, X. and Wu, Z. (2022). Potassium application enhances drought tolerance in sesame by mitigating oxidative damage and regulating osmotic adjustment. *Front. Plant Sci.*, 13, 1096606.
- Garg, N. and Singh, S. (2018). Arbuscular mycorrhiza *Rhizophagus irregularis* and silicon modulate growth, proline biosynthesis and yield in *Cajanus cajan* L. Millsp. (pigeonpea) genotypes under cadmium and zinc stress. *J. Plant Growth Regul.*, 37, 46-63.
- Hajiboland, R., Cheraghvareh, L., Poschenrieder, C. (2017). Improvement of drought tolerance in tobacco (*Nicotiana rustica* L.) plants by silicon. *J. Plant Nutr.* 40(12), 1661-1676.
- Johnston, B. R., Duncan, C. W., Lawton, K. and Benne, E. J. (1952). Determination of Potassium in Plant Materials with a Flame Photometer, *J. AOAC. Int.*, 35(4), 813-816.
- Karvar, M., Azari, A., Rahimi, A. and Maddah-Hosseini, S. (2023). Potassium silicate reduces water consumption, improves drought tolerance, and enhances the productivity of sweet corn (*Zea mays*) under deficit irrigation. *Acta Physiol Plant*, 45, 38.
- Liu, P., Yin, L., Wang, S., Zhang, M., Deng, X., Zhang, S. and Tanaka, K. (2015). Enhanced root hydraulic conductance by aquaporin regulation accounts for silicon alleviated salt-induced osmotic stress in *Sorghum bicolor* L. *Environ Exp. Botany*, 111(42), 51.
- Ma, J. F. and Yamaji, N. (2006). Silicon uptake and accumulation in higher plants. *Trend Plant Sci.*, 11, 392-397.

- Nazim, M., Li, X., Tariq, A. and Shahzad, K. (2024). Exogenous Potassium Silicate Improves Drought Tolerance in Cotton Genotypes by Modulating Growth, Gas Exchange and Antioxidant Metabolism. *J. Crop Health*, 76, 883–901.
- Nandwal, A. S. Hooda, A. and Datta, D. (1998). Effect of substrate moisture and potassium on water relations and C, N and K distribution in *Vigna radiata*. *Biol. Plant*, 41(1), 149-153.
- O'Neill, P. M., Shanahan, J. F. and Schepers, J. S. (2006). Use of chlorophyll fluorescence assessments to differentiate corn hybrid response to variable water conditions. *Crop Sci.*, 46, 681–687
- Oraee, A. and Tehranifar (2023). A relationship between silicon through potassium silicate and salinity tolerance in *Bellis perennis* L. *Silicon*, 15, 93–107.
- Qi, J., Sun, S., Yang, L., Li, M., Ma, F. and Zou Y. (2019) - Potassium uptake and transport in apple roots under drought stress. - *Hortic. Plant J.*, 5, 10-16.
- Rad, A. H. S., Malmir, M. and Eyni-Nargeseh, H. (2024). Potassium silicate positively affects oil content, physiologic, and agronomic traits of *Camelina sativa* L. under optimal water supply and drought stress conditions. *Silicon*, 16, 1071–1082.
- Rehman, S., Abbas, G., Shahid, M., Saqib, M., Farooq A. B. U. and Hussain. M. (2019). Effect of salinity on cadmium tolerance, ionic homeostasis and oxidative stress responses in conocarpus exposed to cadmium stress: implications for phytoremediation. *Ecotoxicol. Environ. Saf.*, 171, 146–153.
- Sairam, R. and Srivastava, G. (2001). Water stress tolerance of wheat (*Triticum aestivum* L.) variations in hydrogen peroxide accumulation and antioxidant activity in tolerant and susceptible genotypes. *J. Agron. Crop Sci.*, 186, 63–70.
- Sullivan, C. Y. (1972). Mechanism of heat and drought resistance in grains Sorghum and methods of measurement. In: N. G. P. Rao and L.R. House (Eds.) Sorghum in the seventies., Oxford and IBH Publishing Co, New Delhi, India. PP. 247 – 264.
- Talebi, S., Majd, A., Mirzai, M., Jafari, S. and Abedini, M. (2015). The study of potassium silicate effects on qualitative and quantitative Performance of Potato (*Solanum tuberosum* L.). *Biological Forum – An International Journal*, 7(2), 1021-1026.
- Tuladhar, P., Sasidharan, S. and Saudagar, P. (2021). Role of phenols and polyphenols in plant defense response to biotic and abiotic stresses. In: Biocontrol Agents and Secondary Metabolites, pp. 419–441.
- Velikova, V., Yordancv, I. and Edreva, A. (2000). Oxidative stress and some antioxidant systems in acid rain treated bean plants. Protective role of exogenous polyamines. *Plant Sci.*, 151, 59-66.
- Zahedi, S.M., Moharrami, F., Sarikhani, S. and Padervand M. (2020). Selenium and silica nanostructure-based recovery of strawberry plants subjected to drought stress. *Sci. Rep.*, 10, 1-18.

How to cite this article: J. Annie Sheeba, Kanjana D. and Prakash A.H. (2025). Potassium Silicate Modulates Leaf Water Relations and Membrane Integrity in Cotton (*Gossypium hirsutum* L.). *Biological Forum*, 17(11): 05-10.