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Influence of potassium silicate as a source of silicon on soil properties of chickpea (*Cicer arietinum* L.) in central dry zone of Karnataka

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Abstract

A field experiment entitled “Influence of Potassium Silicate as a Source of Silicon on Soil Properties of Chickpea (*Cicer arietinum* L.) in Central Dry Zone of Karnataka” was conducted during Rabi 2025 at Zonal Agricultural and Horticultural Research Station (ZAHRS), Babbur Farm, Hiriyur, Karnataka. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications and eight treatments. The treatments comprised an absolute control, RDF + FYM, soil application of potassium silicate @ 25, 50 and 75 kg ha⁻¹ and foliar application of potassium silicate @ 1, 2 and 3 per cent along with RDF and FYM. The results revealed that soil pH, electrical conductivity, organic carbon, exchangeable Ca and Mg, available S and DTPA-extractable Fe, Mn, Zn and Cu were not significantly influenced by K₂SiO₃ application. However, available N, P and K improved with K₂SiO₃ application, with higher available N and K recorded under 2 per cent foliar application. Available Si was significantly improved at 60 and 90 DAS and at harvest, with soil application of K₂SiO₃ @ 50 kg ha⁻¹ recording the highest available Si. Thus, potassium silicate application, particularly 50 kg ha⁻¹ through soil application, showed potential for improving soil available silicon and nutrient status of chickpea without adversely affecting the major soil chemical properties during the cropping season.

Keywords: chickpea, potassium silicate, silicon, soil properties, available NPK, available silicon, soil fertility.

Introduction

India holds a prominent position as one of the world's largest producers and consumers of pulses. Pulses are an important component of sustainable food production and nutritional security owing to their high protein content and their ability to supplement cereals with essential amino acids such as lysine, which is often limited in cereals. The importance of pulses in food and nutritional security was further recognized by the United Nations through the declaration of 2016 as the “International Year of Pulses”, with the objective of promoting their nutritional benefits and cultivation as an important component of sustainable food systems.

Chickpea (*Cicer arietinum* L.) is the second most important pulse crop in the world and India is the largest producer of chickpea. During 2024–25, India produced 11.11 million tonnes of chickpea from an area of 9.12 million hectares, with an average productivity of 1218 kg ha⁻¹. Major chickpea-growing regions are located in arid and semi-arid environments where the crop is predominantly grown under rainfed conditions and is frequently exposed to terminal drought stress. In Karnataka, chickpea occupies about 1.072 million hectares with a production of 0.879 million tonnes and average productivity of 820 kg ha⁻¹ (Anon, 2024) ^[1], with nearly 90 per cent of the cultivated area concentrated in the northern districts. (Singh *et al.*, 2015) ^[17]

Chickpea is nutritionally important and contains about 22 per cent protein, 67 per cent total carbohydrates, 47 per cent starch, 5 per cent fat and 8 per cent crude fibre. It is also a good source of minerals such as phosphorus, potassium, calcium and iron. Besides its nutritional importance, chickpea contributes to soil fertility through biological nitrogen fixation by its root nodule. Hence, maintenance of favourable soil fertility and nutrient availability is essential for sustaining chickpea production, particularly under rainfed conditions.

Balanced and adequate nutrition is essential for optimum crop growth, development and productivity. Although at least 17 elements are recognized as essential for normal plant growth, several other elements such as silicon have been identified as beneficial to plants under specific conditions. Increasing nutrient depletion associated with intensive cultivation has increased the occurrence of nutrient deficiencies, making balanced nutrition particularly important in legume crops. Maintaining adequate availability of essential and beneficial elements is therefore important for sustaining soil fertility and crop productivity.

Silicon (Si), although not classified as an essential element, is one of the most abundant elements in soil and has gained considerable attention because of its potential agronomic benefits. It is associated with enhanced stress resistance, improved water-use efficiency and nutrient availability and may also influence soil physical and chemical properties. Silicon occurs mainly in combination with other elements as silicates and oxides, while plants absorb it predominantly in the form of uncharged silicic acid $[\text{Si}(\text{OH})_4]$. However, a major proportion of soil silicon occurs in relatively insoluble forms and is therefore not readily available for plant uptake (Richmond and Sussman, 2003) [16].

Potassium silicate (K_2SiO_3) is an important source of soluble silicon in agriculture and provides the additional advantage of supplying potassium along with silicon. Because of its high solubility, K_2SiO_3 can

be applied through both soil and foliar methods. Soil application can contribute directly to the soil-available silicon pool, whereas foliar application provides silicon to the plant canopy and may subsequently contribute to nutrient cycling within the soil-plant system. The combined supply of potassium and silicon through K_2SiO_3 may therefore influence nutrient availability and soil fertility while supporting crop growth.

Despite the potential benefits of silicon, its role in nutrient-management practices has received comparatively less attention than conventional macronutrients. In particular, information on the influence of potassium silicate application on soil pH, electrical conductivity, organic carbon, available N, P, K and Si, secondary nutrients and micronutrient availability under chickpea is limited. Understanding these changes is important for assessing whether potassium silicate can improve soil nutrient availability and silicon status without adversely affecting the inherent physicochemical properties of soil.

Keeping the above considerations in view, an experiment entitled “Influence of Potassium Silicate as a Source of Silicon on Soil Properties of Chickpea (*Cicer arietinum* L.)”, at Zonal Agricultural Zonal Agricultural and Horticultural Research Station, Hiriya, to study the influence of potassium silicate application on growth and yield of chickpea (*Cicer arietinum* L.) and soil properties in central dry zone of Karnataka.

Methodology

The field experiment was conducted during Rabi 2025 at the Zonal Agricultural and Horticultural Research Station (ZAHRS), Babbur Farm, Hiriya, under Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences (KSNUAHS), Shivamogga, Karnataka. The experimental site falls under Agro-Climatic Zone IV (Central Dry Zone) of Karnataka and is situated at $13^{\circ}96'01''$ N latitude and $76^{\circ}64'94''$ E longitude, with an altitude of 613 m above mean sea level. During the cropping period from November 2025 to February 2026, the total rainfall received was 33.4 mm. The maximum temperature ranged from 29.4 to 34.0 °C, while the minimum temperature was as low as 13.0 °C during January. Relative humidity ranged from 74.2 to 51.05 per cent during the crop period.

Before initiation of the experiment, a representative composite soil sample was collected from the experimental field, air-dried under shade, processed and passed through a 2 mm sieve for characterization. The experimental soil was clay loam in texture and alkaline in reaction, with a pH of 8.19, electrical conductivity of 0.93 dS m^{-1} at 25 °C and organic carbon content of 7.80 g kg^{-1} . The soil contained $270.32 \text{ kg ha}^{-1}$ available N, 34.16 kg ha^{-1} P_2O_5 , $213.36 \text{ kg ha}^{-1}$ K_2O and 55.40 mg kg^{-1} available Si. Exchangeable Ca and Mg were 12.42 and $9.56 \text{ cmol}(\text{p}^+) \text{ kg}^{-1}$, respectively, while available S was 36.64 mg kg^{-1} . The DTPA-extractable Zn, Cu, Mn and Fe contents were 0.60, 1.06, 3.11 and 4.00 mg kg^{-1} , respectively.

Potassium silicate (K_2SiO_3) used in the experiment was procured in white powder form and served as a source of both potassium and silicon. The material was odourless and stable under ambient conditions, with a bulk density of 0.147 g cm^{-3} , K_2O content of 32.45 ± 0.5 per cent, SiO_2 content of 66.52 ± 0.5 per cent, $\text{K}_2\text{O}:\text{SiO}_2$ ratio of $1:2.05 \pm 0.1$ and total solids content of 98.97 ± 0.5 per cent.

The experiment was laid out in a Randomized Complete Block Design with eight treatments and three replications. Chickpea (*Cicer arietinum* L.) cv. JG-11 was used as the test crop. The gross plot size was $3.0 \text{ m} \times 3.0 \text{ m}$, with a spacing of $30 \text{ cm} \times 10 \text{ cm}$ and a seed rate of 25 kg ha^{-1} . The recommended dose of fertilizer was $12.5:25:25 \text{ kg N:P}_2\text{O}_5:\text{K}_2\text{O ha}^{-1}$, with FYM applied at 7.5 t ha^{-1} . The treatments comprised an absolute control (T_1), RDF + FYM (T_2), soil application of K_2SiO_3 at 25, 50 and 75 kg ha^{-1} (T_3 , T_4 and T_5 , respectively), and foliar application of K_2SiO_3 at 1, 2 and 3 per cent along with RDF and FYM (T_6 , T_7 and T_8 , respectively). Soil application of K_2SiO_3 was carried out at sowing, whereas foliar applications were made at 35 and 50 DAS, corresponding to the flowering and pod-initiation stages.

Table 1: Initial soil properties of the experimental field

Physico - chemical properties	
pH (1:2.5)	8.19
Electrical conductivity (dS m^{-1} @ 25 °C)	0.93
Organic carbon (g kg^{-1})	7.80
Textural class	Clay loam
Available macronutrient status (kg ha^{-1})	
Available N	270.32
Available P_2O_5	34.16
Available K_2O	213.36
Available S (ppm)	36.64
Exchangeable Ca [$\text{cmol}(\text{p}^+) \text{ kg}^{-1}$]	12.42
Exchangeable Mg [$\text{cmol}(\text{p}^+) \text{ kg}^{-1}$]	9.56
Available Si (mg kg^{-1})	55.40
Micronutrient status (mg kg^{-1})	
DTPA - Extractable Zn	0.60
DTPA - Extractable Cu	1.06
DTPA - Extractable Mn	3.11
DTPA - Extractable Fe	4.00

Soil samples were collected from the experimental plots at 0–15 cm depth before sowing and after harvest to assess the changes in soil physico-chemical and nutrient properties due to potassium silicate application. The collected samples were shade-dried, gently powdered, passed through a 2 mm sieve and stored for further analysis. Soil pH was determined in a 1:2.5 soil-to-water suspension, while electrical conductivity was measured in the same extract using a conductivity meter. Organic carbon was estimated by the Walkley and Black method (1934) [21]. Available nitrogen was determined by the alkaline potassium permanganate method (Subbaiah and Asija, 1956) [18], available phosphorus by Olsen's method (1945) as described by Jackson (1973) [6], and

available potassium by extraction with neutral normal ammonium acetate followed by flame photometric determination (Jackson, 1973)^[6]. Exchangeable calcium and magnesium were determined using neutral normal ammonium acetate extraction followed by EDTA titration (Jackson, 1973)^[6], while available sulphur was estimated by the calcium chloride extraction and turbidimetric method (Black *et al.*, 1965)^[2]. DTPA-extractable iron, manganese, zinc and copper were determined using DTPA extraction followed by estimation using an atomic absorption spectrophotometer (Lindsay and Norvell, 1978)^[10]. Available silicon was extracted using 0.5 M acetic acid at a 1:2.5 soil-to-extractant ratio (Korndorfer *et al.*, 2001)^[8] and estimated colorimetrically using ammonium molybdate and ANSA as the reducing agent, with absorbance measured at 630 nm using a UV-visible spectrophotometer (Narayanaswamy and Prakash, 2009)^[14].

The data obtained from the experiment were subjected to analysis of variance appropriate for the Randomized Complete Block Design following the procedure described by Gomez and Gomez

(1984)^[4]. The significance of treatment effects was tested using the F-test at 5 per cent probability level. The standard error of mean ($\text{Sem} \pm$) was calculated for each parameter, and the critical difference (CD) at 5 per cent probability was worked out wherever the treatment effect was significant. Non-significant treatment effects were denoted as NS.

Results and Discussion

Soil pH, electrical conductivity and organic carbon

Soil pH, EC and organic carbon after harvest were not significantly influenced by soil and foliar application of K_2SiO_3 (Table 2). Soil pH ranged from 8.07 to 8.15, EC from 0.76 to 0.81 dS m^{-1} , and organic carbon from 5.20 to 6.07 g kg^{-1} . The absence of significant changes indicates that K_2SiO_3 application did not markedly modify the basic chemical properties of soil during one cropping season. Similar observations were reported by Rao *et al.* (2018)^[15] and Ji *et al.* (2019)^[7]. Silicon fertilization can influence soil chemical properties, but the magnitude of response depends strongly on soil type, fertilizer source and duration of application.

Table 2: Influence of potassium silicate soil and foliar application on pH, EC and OC of soil after chickpea harvest

Treatments	pH	EC (dS m^{-1})	Organic Carbon (g/kg)
T ₁ : Absolute Control	8.07	0.76	5.20
T ₂ : RDF + FYM	8.09	0.77	5.50
T ₃ : 25 kg ha^{-1} K_2SiO_3 soil application	8.11	0.78	5.70
T ₄ : 50 kg ha^{-1} K_2SiO_3 soil application	8.14	0.79	6.00
T ₅ : 75 kg ha^{-1} K_2SiO_3 soil application	8.13	0.79	5.90
T ₆ : T ₂ + 1% K_2SiO_3 foliar application	8.12	0.80	5.80
T ₇ : T ₂ + 2% K_2SiO_3 foliar application	8.15	0.80	6.07
T ₈ : T ₂ + 3% K_2SiO_3 foliar application	8.13	0.81	5.70
S. Em. $\pm$	0.11	0.02	0.01
CD @5%	NS	NS	NS

Available nitrogen

Available N after harvest was significantly influenced by K_2SiO_3 application (Table 3). The highest available N was recorded in T₇ (280.73 kg ha^{-1}), followed by T₄ (279.64 kg ha^{-1}), whereas T₁ recorded the lowest value (262.35 kg ha^{-1}). The improvement in available N may be associated with improved root development, rhizosphere activity and biological N fixation under silicon nutrition. Kurdali *et al.* (2013)^[9] reported enhanced growth and N fixation in chickpea supplied with silicon and potassium, while Steiner *et al.* (2018)^[18] observed improved nodule formation and symbiotic N fixation with silicate fertilization. Silicon-induced improvement in nutrient availability and accumulation has also been reported across crops.

Available phosphorus

Available P increased with K_2SiO_3 application (Table 3). The highest numerical value was recorded in T₅ (27.31 kg ha^{-1}), followed by T₄ (26.48 kg ha^{-1}) and T₇ (26.35 kg ha^{-1}), while T₁ recorded the lowest value (24.10 kg ha^{-1}). The increase in

available P may be associated with the interaction of silicate with soil mineral surfaces, potentially reducing phosphate fixation and improving its availability. Meena *et al.* (2014)^[13] reported the potential of silicon fertilization to improve nutrient availability in soils, while Greger *et al.* (2018)^[5] highlighted the influence of Si on mineral nutrient availability. Similar Si-mediated effects on soil nutrient availability have been reported in broader reviews.

Available potassium

Available K_2O was significantly influenced by K_2SiO_3 application (Table 3). T₇ recorded the highest available K_2O (192.73 kg ha^{-1}) and was on par with T₄ (192.20 kg ha^{-1}), whereas T₁ recorded the lowest value (170.40 kg ha^{-1}). The increase may primarily be attributed to the direct contribution of K from K_2SiO_3 . Silicon fertilization may additionally influence K retention and plant K nutrition through changes in soil-plant interactions. Similar responses were reported by Malav *et al.* (2015)^[12] and Cuong *et al.* (2017)^[3].

Table 3: Influence of potassium silicate soil and foliar application on available NPK in soil after chickpea harvest

Treatments	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T ₁ : Absolute Control	262.35	24.10	170.40
T ₂ : RDF + FYM	268.42	30.25	184.70
T ₃ : 25 kg ha^{-1} K_2SiO_3 soil application	274.18	28.36	187.80
T ₄ : 50 kg ha^{-1} K_2SiO_3 soil application	279.64	26.48	192.20
T ₅ : 75 kg ha^{-1} K_2SiO_3 soil application	277.82	27.31	190.50
T ₆ : T ₂ + 1% K_2SiO_3 foliar application	276.95	26.95	191.20
T ₇ : T ₂ + 2% K_2SiO_3 foliar application	280.73	26.35	192.73
T ₈ : T ₂ + 3% K_2SiO_3 foliar application	272.56	28.24	192.00
S. Em. $\pm$	2.85	1.02	2.50
CD @5%	8.65	3.09	7.59

Exchangeable calcium, magnesium and available sulphur

Exchangeable Ca, Mg and available S were not significantly influenced by K_2SiO_3 application (Table 4). Although numerical differences occurred among treatments, the response was insufficient to produce significant changes during the experimental season. The relatively stable behaviour of these nutrients may be associated with their native soil reserves and buffering processes. Silicon fertilization has been reported to influence nutrient cycling, but responses vary with soil properties and fertilizer source (Greger *et al.*, 2018; Zhao *et al.*, 2022) [5, 22].

DTPA-extractable micronutrients

DTPA-extractable Fe, Zn, Mn and Cu were not significantly influenced by K_2SiO_3 application (Table 5). T_4 generally recorded higher numerical values, whereas the lowest values were observed in T_1 . The absence of significant changes suggests that a single season of K_2SiO_3 application was insufficient to substantially modify the extractable micronutrient pools. Silicon can affect mineral nutrient availability and accumulation, but its

effects differ among nutrients, crops and soil environments (Greger *et al.*, 2018) [5].

Available silicon

Available Si was significantly influenced by K_2SiO_3 application at 60 and 90 DAS and at harvest, whereas treatment differences at 30 DAS were non-significant (Table 6). T_4 recorded the highest available Si at 60 DAS (57.65 mg kg⁻¹), 90 DAS (56.78 mg kg⁻¹) and harvest (55.87 mg kg⁻¹), while T_1 consistently recorded the lowest values. The higher available Si under soil-applied K_2SiO_3 may be attributed to the direct addition and dissolution of silicate, increasing the soluble and plant-available Si pool in soil. Soil Si availability is controlled by dissolution of Si-bearing minerals, adsorption-desorption processes and recycling through plant residues; therefore, application of soluble Si sources can increase the available Si pool. Korndorfer *et al.* (2001) [8], Narayanaswamy and Prakash (2009) [14], Ma and Takahashi (2002) [11] and Tubana *et al.* (2016) [20] reported the importance of soil available Si and Si fertilization in crop production.

Table 4: Influence of potassium silicate soil and foliar application on exchangeable Ca, Mg and available sulphur in soil after chickpea harvest

Treatments	Exchangeable Ca (cmol(p ⁺) kg ⁻¹)	Exchangeable Mg (cmol(p ⁺) kg ⁻¹)	Available S (ppm)
T_1 : Absolute Control	10.26	8.38	30.92
T_2 : RDF + FYM	10.92	8.76	31.74
T_3 : 25 kg ha ⁻¹ K_2SiO_3 soil application	11.23	9.25	32.18
T_4 : 50 kg ha ⁻¹ K_2SiO_3 soil application	11.54	9.40	34.26
T_5 : 75 kg ha ⁻¹ K_2SiO_3 soil application	11.42	9.38	34.38
T_6 : T_2 + 1% K_2SiO_3 foliar application	11.49	9.21	32.08
T_7 : T_2 + 2% K_2SiO_3 foliar application	11.63	9.43	34.22
T_8 : T_2 + 3% K_2SiO_3 foliar application	11.50	9.35	33.14
S. Em. ±	0.47	0.36	1.14
CD @5%	NS	NS	NS

Table 5: Influence of potassium silicate soil and foliar application on DTPA extractable micronutrients in soil after chickpea harvest

Treatments	Fe (mg kg ⁻¹)	Mn (mg kg ⁻¹)	Zn (mg kg ⁻¹)	Cu (mg kg ⁻¹)
T_1 : Absolute Control	3.22	2.69	0.58	0.52
T_2 : RDF + FYM	3.35	2.72	0.61	0.55
T_3 : 25 kg ha ⁻¹ K_2SiO_3 soil application	3.49	2.84	0.65	0.58
T_4 : 50 kg ha ⁻¹ K_2SiO_3 soil application	3.75	2.88	0.72	0.63
T_5 : 75 kg ha ⁻¹ K_2SiO_3 soil application	3.59	2.91	0.69	0.61
T_6 : T_2 + 1% K_2SiO_3 foliar application	3.68	2.82	0.62	0.56
T_7 : T_2 + 2% K_2SiO_3 foliar application	3.73	2.98	0.68	0.60
T_8 : T_2 + 3% K_2SiO_3 foliar application	3.68	2.96	0.66	0.58
S. Em. ±	0.12	0.07	0.03	0.03
CD @5%	NS	NS	NS	NS

Table 6: Influence of potassium silicate soil and foliar application on available Si in soil after chickpea harvest

Treatments	Available silicon (mg kg ⁻¹)			
	30 DAS	60 DAS	90 DAS	At harvest
T_1 : Absolute Control	49.94	49.01	48.82	47.74
T_2 : RDF + FYM	52.33	51.22	50.82	49.89
T_3 : 25 kg ha ⁻¹ K_2SiO_3 soil application	56.87	55.58	54.68	53.89
T_4 : 50 kg ha ⁻¹ K_2SiO_3 soil application	58.80	57.65	56.78	55.87
T_5 : 75 kg ha ⁻¹ K_2SiO_3 soil application	57.57	56.62	56.17	54.97
T_6 : T_2 + 1% K_2SiO_3 foliar application	52.53	51.19	53.48	50.80
T_7 : T_2 + 2% K_2SiO_3 foliar application	52.33	51.82	51.00	50.92
T_8 : T_2 + 3% K_2SiO_3 foliar application	50.83	50.15	49.02	48.21
S. Em. ±	2.01	2.44	1.39	1.32
CD @5%	NS	5.23	4.21	3.99

Conclusion

On the basis of the results obtained from one-year experimentation, it could be concluded that: (i) application of potassium silicate significantly improved the availability of N, P, K and Si in soil after harvest of chickpea, with RDF + FYM + 2%

foliar K_2SiO_3 (T_7) recording higher available N and K, while RDF + FYM + 50 kg ha⁻¹ K_2SiO_3 through soil application (T_4) recorded the highest available Si during the later crop growth stages and at harvest; (ii) soil pH, electrical conductivity, organic carbon, exchangeable Ca and Mg, available S and DTPA-extractable Fe,

Zn, Mn and Cu were not significantly affected by K_2SiO_3 application, indicating no adverse alteration of these soil properties during the experimental season; and (iii) among the tested treatments, soil application of K_2SiO_3 at 50 kg ha^{-1} was particularly effective in improving soil available Si, whereas 2% foliar application showed better overall nutrient availability and crop response. However, these findings are based on one year of experimentation at a single location and therefore require further multi-year and multi-location studies for wider recommendation.

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