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EXOGENOUS APPLICATION OF POTASSIUM SILICATE FOR GROWTH ENHANCEMENT AND SALT STRESS ALLEVIATION IN CORIANDER *(CORIANDRUM SATIVUM* L.)

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Abstract

Salinity is a major threat to agriculture and its adverse effect on farming land is expanding day by day. In the present study effects of potassium silicate on germination and biochemical parameters of *Coriandrum sativum* under salt stress were studied. The maximum seed germination (94%) of coriander seeds was observed with potassium silicate. Total chlorophyll content showed the following order: PS > C > NaCl (2mM) + PS > NaCl (4 mM) +PS > NaCl (6mM) +PS > NaCl. Potassium silicate enhanced biochemical components such as sugar, proline, protein and total antioxidant contents in coriander seedlings. The maximum total antioxidant content (46%) was observed in NaCl (6mM) + PS treatment. Hence, potassium silicate acts as a growth stimulating agent and can be used as fertilizer for coriander plants under salt stress.

Introduction

Soil salinity is one of the major abiotic stress responsible for decline in crop productivity at global level (Zhu *et al.* 2019). Approximately 40% of cultivable land is affected by salinity (Hafez *et al.* 2021) and saline area is increasing annually as per the rate of 10% due to change in climate conditions, poor cultural practices, utilization of chemical fertilizers and irrigation by using saline water (Abdel Latef *et al.* 2021). Salinity has already affected almost 954 million hectares of the world's total land area (Saddiq *et al.* 2021). Salt stress adversely affects morphological, physiological and biochemical parameters of plants (Farhangi-Abriz and Torabian 2018). Salinity enhances uptake of Na^+ and Cl^- from the soil and reduces transport of essential nutrients and generates osmotic and oxidative stress which may lead to cell death (Safdar *et al.* 2019). The imbalance in ionic and nutritional components disturb osmotic balance, resulting in physiological drought which prevents water uptake in plants (Riaz *et al.* 2019). Various approaches such as development of salt resistant crops, use of plant growth-promoting bacteria, endophytes have been used to overcome the negative impacts of salt stress for sustainable crop production. All the above mentioned methods are expensive, time consuming and not economically feasible at large scale.

According to Zargar *et al.* (2019), silicon is a multitalented element and can be used as a fertilizer for enhancing crop production. The uptake of potassium and calcium was also improved over sodium absorption with silicon utilization and enhanced the growth of rice, sunflower and sorghum (Hurtado *et al.* 2020). The use of silicon decreased Na^+ translocation from roots to shoots and leaves of chickpea plant (Garg and Bhandari 2016).

Coriander (*Coriandrum sativum* L.; belonging to Apiaceae), an annual herbaceous plant is most widely used due to its nutritional as well as medicinal properties.Coriander seeds have been used as a spice or traditional medicine for the treatment of indigestion, nausea, dysentery whereas its leaves stimulate appetite (Laribi *et al.* 2015). The presence of essential oil in coriander seeds

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shows antimicrobial, anti-inflammatory, antiseptic, anticancerous and free radical scavenging properties (Chahal *et al.* 2017). Application of silicon can be considered as one of the promising methods to improve plant resilience under salt stress (Almeida *et al.* 2017). No reports are available in literature about the impact of potassium silicate for salt stress mitigation in coriander. Therefore, present investigation was carried out to study the role of potassium silicate on growth and biochemical parameters of coriander under salt stress.

Materials and Methods

Coriandrum sativum L. variety Kasturi seeds were procured from seed agency of Ghaziabad, India. Different concentrations of NaCl (2 mM, 4mM and 6 mM) and 2 mM Potassium silicate (K_2SiO_3) were used for the treatment. The coriander seeds were surface sterilized with 0.01% $HgCl_2$ solution, then washed with distilled water. Thirty seeds were divided into three replicates of 10 seeds and each were immersed in 10 ml of different concentrations of NaCl solution and potassium silicate for five hrs. Petri dishes were kept in a growth chamber under temperature (25 ± 2°C), photoperiod 16/8 hrs and photon flux density was kept 240 μmol $m^{-2}s^{-1}$for 10 days. Petridishes were kept moist by adding different concentrations of salt, potassium silicate or distilled water as and when required according to the treatment. Different growth characteristics of coriander such as germination percentage, relative germination rate and germination index were determined by the following formula of Li (2008). The radicle and plumule length were measured with a measuring scale.Vigour index of the coriander seedlings was estimated by the method of Abdul - Baki and Anderson (1973). The fresh weight of coriander seedlings was measured ten days after seed sowing. After that, seedlings were oven dried at 65^0C for 72 hrs and dry weight was estimated. RWC was calculated by the modified method of Barrs and Weatherly (1962).

The estimation of chlorophyll a, b and total chlorophyll was done by the modified method of Misyura *et al.* (2013) and carotenoid content was analyzed by Kirk and Allen (1965).Total sugar content was analyzed by the method of Hedge and Hofreiter (1962). Proline content was assessed by the method of Bates *et al.* (1973). The protein content was measured by the method of Lowry *et al.* (1951) by using BSA standard curve. The total antioxidant content in coriander seedlings was evaluated by Prieto *et al.* (1999). Treatments were organized with three replicates in randomized block design. The data were determined by using ANOVA and SPSS software. Mean of treatment was assessed by DMRT at $p < 0.05$.

Results and Discussion

Potassium silicate treatment showed maximum seed germination (94%) in coriander seeds whereas (89%) was reported in control. Relative germination rate and germination index were more with potassium silicate as compared to other treatments. Maximum (84%) reduction in seed germination was observed with salt treatment (Table 1). Similarly, silicon significantly increased the rate of seed germination in tomato (Shi *et al.* 2014).

Relative water content and vigour index reflected the following trend: PS > C > NaCl (2 mM) + PS > NaCl (4mM) + PS > NaCl (6 mM) + PS > NaCl (Table 2). The present results reflected the same trend with the work of Wu *et al.* (2015) who found the same enhancement in the root and shoot growth in cucumber and tomato by applying silicon under salt stress. Liu *et al.* (2015) reported that addition of silicon improved water uptake in sorghum by up-regulation of aquaporin genes in roots. Silicon improved root growth by promoting Casparian band formation and biosynthesis of suberin and lignin which may check Na^+ ions entry into the transpiration stream (Guerriero *et al.* 2016).

Table 1. Effect of salt stress on seed germination, relative germination rate and germination index of *Coriandrum sativum*L. var. Kasturi with or without application of potassium silicate.

Treatment	Germination (%)	Relative germination rate(RGR)	Germination index(GI)
Control	89 ± 0.62[a]	-	8.9 ± 0.21[a]
NaCl (6 mM)	14 ± 0.05[d]	0.16 ± 0.02[c]	1.4 ± 0.10[d]
PS (2mM)	94 ± 0.84[a]	1.06 ± 0.59[a]	9.4 ± 0.32[a]
NaCl (2mM)+PS	42 ± 0.41[b]	0.47 ± 0.21[b]	4.2 ± 0.19[b]
NaCl (4mM)+PS	31 ± 0.29[b]	0.35 ± 0.14[b]	3.1 ± 0.12[b]
NaCl (6mM)+PS	23 ± 0.18[c]	0.26 ± 0.07[b]	2.3 ± 0.07[c]

Values are mean ± SE of three replicates from three independent experiments.

Table 2. Effect of salt stress on seedling length, biomass and vigour index of *Coriandrum sativum* L. var. Kasturi with or without application of potassium silicate.

Treatment	Radicle length (cm)	Plumule length (cm)	Fresh weight (mg/g)	Dry weight (mg/g)	Relative water content (%)	Vigour index
Control	5.62 ±0.21[a]	13.51 ± 0.41[a]	4.22 ± 0.23[a]	1.20 ± 0.08[a]	91.23± 0.82[a]	16643.1[a]
NaCl (6mM)	2.21 ±0.17[c]	5.10 ± 0.24[c]	1.14 ± 0.18[c]	0.29 ± 0.01[c]	65.14 ± 0.21[b]	877.2[d]
PS (2mM)	7.91± 0.25[a]	14.22 ± 0.33[a]	4.71 ± 0.52[a]	1.59 ± 0.12[a]	94.52 ± 0.37[a]	20359.6[a]
NaCl (2mM)+PS	6.12± 0.33[a]	11.24± 0.62[b]	4.02 ± 0.23[a]	0.98 ± 0.07[b]	78.34 ± 0.24[b]	7464.8[b]
NaCl (4mM)+PS	5.54 ±0.47[a]	9.81 ± 0.72[b]	3.76 ± 0.63[b]	0.91 ± 0.08[b]	67.23± 0.21[b]	5372.5[b]
NaCl (6mM)+PS	3.82± 0.19[b]	7.56 ± 0.19[c]	2.19 ± 0.44[b]	0.72 ± 0.02[b]	58.12 ± 0.15[c]	2617.4[c]

Values are mean ± SE of three replicates from three independent experiments.

Chlorophyll content reflected significant increase with potassium silicate treatmentas compared to control and NaCl treatment. Total chlorophyll content reflected the following trend: PS > C >NaCl (2mM) +PS >NaCl (4mM)+PS >NaCl (6mM)+PS >NaCl.The carotenoid content was highest in NaCl (6mM)+PS treatment. It might be due to the protective role of carotenoid in coriander seeds against salt stress (Table 3). Similarly, Silicon improves the rigidity and erectness of leaves to enhance photosynthesis in sugarcane (Verma *et al.* 2019). Reduction in photosynthesis in *Medicago truncatula* under salt stress could be due to the reduction in chlorophyll contents, damage of photosynthetic apparatus and inhibition of ribulose-1,5-bisphophate enzyme which resulted reduction in PSII efficiency (Najar *et al.* 2019).

The cell membranes are first target of environmental stresses, due to this membrane damage was evaluated through electrolyte leakage. The electrolyte leakage was maximum (37%) in salt treated coriander seeds (Fig. 1). Malondialdehyde (MDA) is product of lipid peroxidation which showed the following trend: NaCl > NaCl (6mM) + PS >NaCl (4 mM) + PS > NaCl (2mM) + PS > C > PS (Fig. 1). The gradual increase in MDA content was observed in coriander seedlings with increase in NaCl concentration. Results revealed that potassium silicate treatment reduced MDA content by 59% signifying its protective role under salt stress. This result was in agreement with the work of Soleimannejad *et al.* (2019) who reported that silicon improved plasma membrane activity by lowering electrolyte leakage via increasing H^+-ATPase activity which helps in Na^+ exclusion from plant tissues.

Table 3. Effect of salt stress on pigment content of *Coriandrum sativum* L. var. Kasturi with or without application of potassium silicate.

Treatment	Chlorophyll a ($mg.g^{-1}$ FW)	Chlorophyll b ($mg.g^{-1}$ FW)	Total Chlorophyll ($mg.g^{-1}$ FW)	Carotenoids ($mg.g^{-1}$ FW)
Control	1.82 ± 0.43^a	0.84 ± 0.07^a	2.66 ± 0.98^a	0.58 ± 0.03^b
NaCl (6 mM)	0.87 ± 0.37^c	0.31 ± 0.01^c	1.18 ± 0.71^c	0.25 ± 0.01^c
PS (2 mM)	1.96 ± 0.58^a	0.93 ± 0.04^a	2.89 ± 0.52^a	0.62 ± 0.08^a
NaCl (2 mM) + PS	1.18 ± 0.31^b	0.62 ± 0.02^b	1.80 ± 0.34^b	0.53 ± 0.06^b
NaCl (4 mM) + PS	0.99 ± 0.62^b	0.45 ± 0.02^b	1.44 ± 0.21^b	0.64 ± 0.04^a
NaCl (6 mM) + PS	0.93 ± 0.58^b	0.39 ± 0.04^c	1.32 ± 0.14^c	0.71 ± 0.11^a

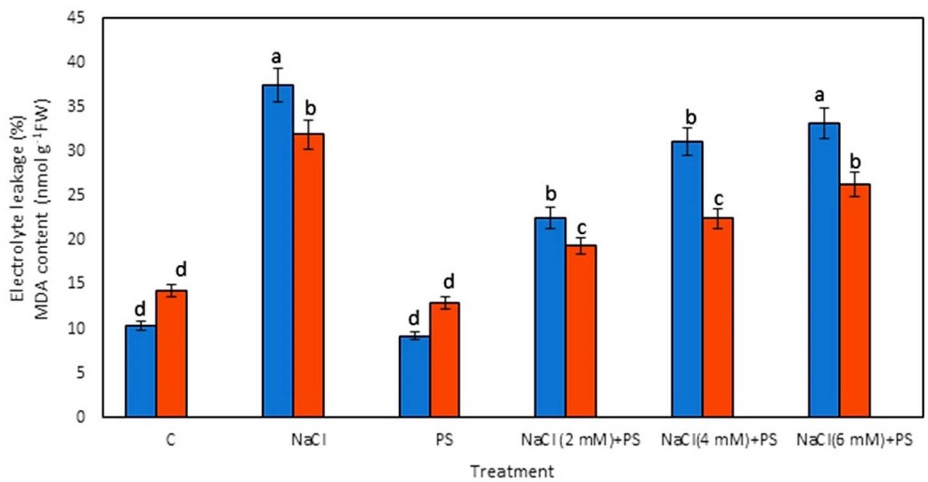

Fig. 1. Effect of salt stress on electrolyte leakage and lipid peroxidation of *Coriandrum sativum* L. var. Kasturi with or without application of potassium silicate.

Biochemical constituents such as sugar, proline and protein contents were also affected by salt stress. Maximum amount of sugar and protein contents were present in coriander leaves with potassium silicate treatment (Table 4). Similarly, compatible osmolytes stabilize enzymes and protein complexes under salt stress (Rajasheker *et al.* 2019). Proline content showed following trend: NaCl (6mM) + PS >NaCl (4mM) + PS > NaCl (2mM) + PS > NaCl > PS > C.

The impact of salt stress on total antioxidant content in the leaves of *Coriandrum sativum* L. var. Kasturiwas studied with or without application of potassium silicate. It showed following trend: NaCl (6mM) + PS > NaCl (4 mM) + PS > NaCl (2mM) + PS > PS > NaCl > C. Maximum total antioxidant content 46% was recorded in NaCl (6mM) + PS treatment (Fig. 2). This result is supported by Yin *et al.* (2019) who found that silicon application enhanced polyamine accumulation in cucumber plants which might play a significant function in modulation of antioxidant defense system by reducing oxidative stress, thus increasing the salt tolerance ability.

Table 4. Effect of salt stress on sugar, proline and protein contents of *Coriandrum sativum* L. var. Kasturi with or without application of potassium silicate.

Treatment	Sugar ($mg.g^{-1}$ DW)	Proline ($\mu M.g^{-1}$ DW)	Protein ($mg.g^{-1}$ FW)
Control	2.54 ± 0.72^{b}	16.2 ± 0.12^{c}	10.42 ± 0.12^{b}
NaCl (6 mM)	2.05 ± 0.21^{c}	27.11 ± 0.56^{b}	8.15 ± 0.07^{c}
PS (2 mM)	3.87 ± 0.54^{a}	26.32 ± 0.18^{b}	14.76 ± 0.37^{a}
NaCl (2 mM) + PS	2.83 ± 0.41^{b}	37.24 ± 0.42^{a}	10.15 ± 0.53^{b}
NaCl (4 mM) + PS	3.10 ± 0.39^{a}	$44..31 \pm 0.35^{a}$	9.52 ± 0.45^{b}
NaCl (6 mM) + PS	3.29 ± 0.22^{a}	47.49 ± 0.49^{a}	8.24 ± 0.09^{c}

Values are mean ± SE of three replicates from three independent experiments.

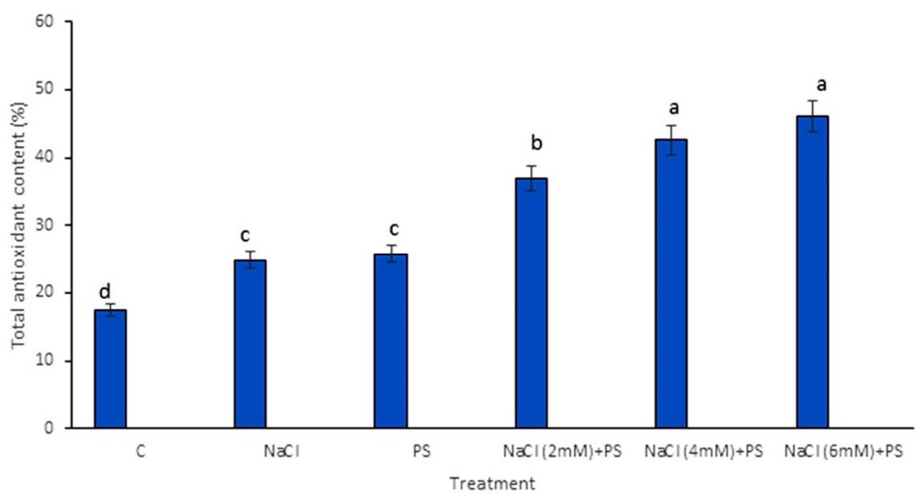

Fig. 2. Effect of salt stress on total antioxidant content of *Coriandrum sativum* L. var. Kasturi with or without application of potassium silicate.

Potassium silicate utilization in crop fields to combat salinity is eco-friendly, cost-effective and sustainable approach. It contains both potassium and highly soluble silicon which is required for plant growth and its application does not release any hazardous by-products in nature. Hence, the use of potassium silicate can be recommended for the growth of coriander plants under saline conditions.

Salt stress significantly reduced seed germination and growth parameters of coriander. It exhibited electrolyte leakage and lipid peroxidation and reduced pigment, sugar and protein contents but enhanced proline accumulation. Potassium silicate supplementation mitigated unfavorable effects of salt stress in coriander by triggering the up-regulation of proline and total antioxidant activity.

More focus is required on the effects of potassium silicate under field conditions with multiple stresses rather than laboratory studies. Further in-depth studies are needed to explore biochemical nature of potassium silicate and potassium silicate mediated salt tolerance mechanism at the transcriptome, proteome and metabolome level. Potassium silicate utilization in crop fields to combat salinity is eco-friendly, cost-effective and sustainable approach. It contains both potassium and highly soluble silicon which are required for plant growth and its application does not release any hazardous by-products in nature. Hence, the use of potassium silicate can be recommended for the growth of coriander plants under saline conditions.

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