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RESEARCH PAPER

Effect of silicon nutrition on yield, yield attributes and physiological parameters of Sugarcane

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Abstract: A field experiment was conducted during 2021 to study the response of sugarcane to silicon nutrition at Agriculture Research Station, Hukkeri, Karnataka. The experiment was laid out in split plot design with two treatments of soil application of silicon as main plot and eight treatments of foliar application of silicon as sub plots along with control (Recommended package of practice with no silicon application). The main plot treatments were *viz*., soil application of (DE) Diatomaceous earth (60 % SiO_2) @ 300 (S_1) and 600 (S_2) kg ha^{-1}, respectively. Sub plot treatments were foliar application *viz.*, F_1: (HAS) Hydrated aluminium silicate (60 % SiO_2) @ 0.25 % at 60 days after planting (DAP), F_2: HAS @ 0.25 % at 90 DAP,F_3:HAS @ 0.5 % at 60 DAP, F_4: HAS @ 0.5 % at 90 DAP, F_5: (OSA) Ortho silicic acid (2 % Si as H_4SiO_4) @ 0.2 % at 60 DAP, F_6: OSA @ 0.2 % at 90 DAP, F_7: OSA @ 0.4 % at 60 DAP and F_8: OSA @ 0.4 % at 90 DAP. Soil application of DE @ 300 kg ha^{-1} recorded significantly higher single cane weight, number of millable cane and cane yield. Foliar application of OSA @ 0.2 % at 60 DAP recorded significantly higher single cane weight, number of millable cane and cane yield. Among the interactions, soil application of DE @ 300 kg ha^{-1} with foliar application of OSA @ 0.2 % at 60 DAP recorded significantly higher single cane weight, number of millable cane and cane yield. Cane yield increased by 37.38 per cent over the control. Similar trend was observed for silicon uptake also. Application of DE @ 300 kg ha^{-1} with foliar application of OSA @ 0.2 % at 60 DAP was found promising for increasing the productivity.

Key words: Diatomaceous earth, Hydrated aluminium silicate, Ortho silicic acid, Sugarcane

Introduction

Sugarcane is an important commercial crop in India and holds a prominent position as a cash crop. India has second largest area and production of sugarcane next to Brazil in the world. Silicon (Si) is the most abundant element after oxygen (in the earth's crust) with soils containing approximately 28 per cent Si by weight. Plants absorb Si in the form of silicic acid [$Si(OH)_4$] or in ionized form [$Si(OH)_3O_2$] (Epstein,1994). Sugarcane is a silicon accumulator plant, which strongly responds to Si supply. The distribution of Si within the shoot and shoot parts is determined by the transpiration rate of the plant (Jones and Handreck, 1967). Most of the Si remains in the apoplasm mainly in the outer walls of the epidermal cells on both surfaces of the leaves as well as in the inflorescence bracts of graminaceous species and is deposited after water evaporation at the end of the transpiration stream. The silicic acid is deposited mainly in the walls of epidermal cells which contributes substantially to the strength of stem and become effective barrier against both fungal infections and water loss by cuticular transpiration. Silicon application will support the sugarcane in enhancing the drought tolerance capacity and also plays vital role in building resistance against the pests and diseases.

Material and methods

A field experiment was carried out at Agriculture Research Station, Hukkeri,Tq:Hukkeri, District: Belagavi, Karnataka, India during 2021. The soil was medium deep black clay in texture had low in soil available nitrogen, medium in available P_2O_5 and high in available K_2O. The experiment was laid out in split plot designwith two treatments of soil application of silicon as main plot and eight treatments of foliar application of silicon as sub plots along with control (Recommended package of practice). Sugarcane was planted at 120 cm row spacing. Recommended dose of fertilizer was 250:75:190 N, P_2O_5, K_2O kg ha^{-1}. Sugarcane was cut at ground level and cane yield from net plot was weighed and then expressed as cane yield t ha^{-1}. Number of millable cane (NMC) per plot was calculated and later expressed as thousand ha^{-1} and weight of single cane was recorded and expressed in kg. Silicon uptake was calculated by collecting plant samples (leaves and cane) from five randomly selected plants from the net plots. The samples were washed in distilled water, then oven dried (70^0 C) powdered and used for chemical analysis by adopting standard procedures (Maand Takahashi, 2002). It was expressed inkg ha^{-1}. Measurement of rate of stomatal conductance was made on the top fully expanded leaf by using infrared gas analyzer (IRGA) method. These measurements were made between 10.00 am and 12.00 noon and expressed in mmol H_2Om^{d2} s^{d1}. Proline content in sugarcane was estimated as per the procedure given by Bates *et al.* (1973) and expressed in micro gram per gram (µg g^{-1}).

Results and discussion

Effect of silicon nutrition on yield and yield attributes

Soil application of DE @ 300 kg ha^{-1} recorded significantly higher single cane weight (1.52 kg), number of millable canes (94296 ha^{-1}) and cane yield (124.00 t ha^{-1}) when compared to 600 kg ha^{-1} (1.36 kg, 85167 ha^{-1} and 111.64 t ha^{-1}, single cane weight, number of millable canes and cane yield, respectively). Foliar application of OSA @ 0.2 % at 60 DAP recorded significantly higher single cane weight (1.59 kg), number of millable canes (95462 ha^{-1}) and cane yield (129.50 t ha^{-1}). The over all interaction effect revealed that S_1F_5 *i.e.,* soil application of DE @ 300 kg ha^{-1} along with foliar application of OSA @ 0.2 % at 60 DAP recorded significantly higher single cane weight (1.70 kg), number of millable canes (99980 ha^{-1}) and cane yield (138.10 t ha^{-1}). The interaction S_1F_5 recorded significantly higher single cane weight (1.70 kg), number of millable canes (99980 ha^{-1}) and cane yield (138.10 t ha^{-1}) compared to control (without silicon application) *viz*., single cane weight (1.18 kg), number of millable canes (84502 ha^{-1}) and cane yield (100.72 t ha^{-1}) (Table 1). Soil application of Si @ 600 kg ha^{-1} has increased the tillers and created the competition for the recourses (Berthelsen *et al.,* 2003). It was reflected on NMC by increased mortality of tillers and reduction in single cane weight. Application of OSA @ 0.2 % at 60 DAP found ideal since foliar application during early stage helped to maintain the optimum water balance and reduced the crop water stress.

Effect of silicon nutrition on silicon uptake

Soil application of DE @ 300 kg ha^{-1} recorded significantly higher silicon uptake (85.63 kg ha^{-1}) when compared to 600 kg ha^{-1} (67.44 kg ha^{-1}). Foliar application of OSA @ 0.2 % at 60 DAP recorded significantly higher silicon uptake (88.60 kg ha^{-1}) when compared to rest of the foliar applications of silicon.The overall interaction effect revealed that S_1F_5 *i.e.,* soil application of DE @ 300 kg ha^{-1} along with foliar application of OSA @ 0.2 % at 60 DAP recorded significantly higher silicon uptake (96.15 kg ha^{-1}). The interaction S_1F_5 recorded significantly higher silicon uptake (96.15 kg ha^{-1}) compared to control (50.57 kg ha^{-1}) (Table 1). Higher nutrient uptake can be traced back to higher dry matter accumulation in sugarcane along with optimum application of silicon fertilizers in early growth stage to translocate more nutrients to the sink of the crop during entire life cycle.

Table 1. Yield, yield attributes and physiological parameters of sugarcane as influenced by soil and foliar application of silicon

Treatment		Single cane weight (kg)	NMC ha^{-1}	Cane yield (t ha^{-1})	Si uptake (kg ha^{-1})	Stomatal conductance (mmol m^{-2} s^{-1}) at 120 DAP	Proline (µg g^{-1}) at 120 DAP
Main plot (Soil application of silicon)							
S_1	SA of silicon @ 300 kg ha^{-1}	1.52^{a}	94296^{a}	124.00^{a}	85.63^{a}	0.46^{a}	0.20^{b}
S_2	SA of silicon @ 600 kg ha^{-1}	1.36^{b}	85167^{b}	111.64^{b}	67.44^{b}	0.39^{b}	0.28^{a}
S. Em. ±		0.02	1320	1.77	1.15	0.01	0.01
Sub plot (Foliar application of silicon)							
F_1	FA of HAS @ 0.25 % at 60 DAP	1.48^{b}	91214^{b}	120.22^{b}	81.69^{b}	0.44^{b}	0.21^{cd}
F_2	FA of HAS @ 0.25 % at 90 DAP	1.39^{b-d}	87918^{c}	113.86^{b}	74.67^{bc}	0.41^{bc}	0.25^{b}
F_3	FA of HAS @ 0.5 % at 60 DAP	1.57^{ab}	94381^{a}	128.29^{a}	86.61^{a}	0.47^{a}	0.20^{d}
F_4	FA of HAS @ 0.5 % at 90 DAP	1.34^{cd}	86731^{b}	109.12^{b}	64.99^{c}	0.38^{c}	0.29^{a}
F_5	FA of OSA @ 0.2 % at 60 DAP	1.59^{a}	95462^{a}	129.50^{a}	88.60^{a}	0.48^{a}	0.18^{d}
F_6	FA of OSA @ 0.2 % at 90 DAP	1.44^{bc}	89533^{bc}	116.65^{bc}	78.14^{b}	0.43^{b}	0.22^{bc}
F_7	FA of OSA @ 0.4 % at 60 DAP	1.41^{bc}	87545^{bc}	116.58^{bc}	75.19^{bc}	0.42^{bc}	0.23^{bc}
F_8	FA of OSA @ 0.4 % at 90 DAP	1.32^{d}	85070^{d}	108.34^{c}	61.42^{cd}	0.37^{cd}	0.30^{a}
S. Em. ±		0.03	2214	2.88	1.86	0.01	0.01
Interaction (I X F with control)							
	S_1F_1	1.56^{b}	90715^{bc}	125.47^{bc}	90.37^{b}	0.46^{bc}	0.19^{h}
	S_1F_2	1.48^{b-d}	90412^{b-e}	121.57^{cd}	84.25^{b-d}	0.41^{c-e}	0.22^{f}
	S_1F_3	1.68^{a}	98920^{ab}	136.20^{ab}	94.98^{a}	0.50^{ab}	0.16^{gh}
	S_1F_4	1.38^{c-f}	90647^{b-f}	112.52^{c-e}	74.70^{e-g}	0.41^{e-g}	0.26^{c-e}
	S_1F_5	1.70^{a}	99980^{a}	138.10^{a}	96.15^{a}	0.51^{a}	0.14^{h}
	S_1F_6	1.52^{bc}	90645^{b-d}	123.10^{cd}	88.13^{bc}	0.46^{bc}	0.20^{ef}
	S_1F_7	1.49^{b-d}	90489^{b-e}	123.02^{cd}	84.67^{b-d}	0.45^{cd}	0.21^{ef}
	S_1F_8	1.37^{c-f}	88920^{b-f}	111.99^{c-e}	71.78^{f-h}	0.40^{e-h}	0.26^{c-e}
	S_2F_1	1.41^{b-f}	86317^{c-f}	114.97^{c-e}	75.01^{e-g}	0.41^{d-f}	0.25^{c-f}
	S_2F_2	1.30^{e-g}	82925^{ef}	106.15^{e}	65.08^{h}	0.36^{hi}	0.28^{c}
	S_2F_3	1.46^{b-e}	89521^{b-f}	120.38^{cd}	78.23^{d-f}	0.42^{c-e}	0.24^{d-f}
	S_2F_4	1.29^{fg}	80814^{f}	105.71^{e}	55.27^{i}	0.35^{i}	0.33^{b}
	S_2F_5	1.47^{b-d}	90143^{b-f}	120.90^{cd}	81.04^{c-e}	0.43^{b-d}	0.23^{ef}
	S_2F_6	1.36^{c-f}	84621^{d-f}	110.19^{de}	68.15^{gh}	0.38^{f-i}	0.27^{cd}
	S_2F_7	1.33^{d-g}	83654^{ef}	110.14^{de}	65.70^{h}	0.37^{g-i}	0.27^{cd}
	S_2F_8	1.26^{fg}	82220^{ef}	104.70^{e}	51.05^{i}	0.36^{i}	0.35^{b}
RPP (Control)		1.18^{g}	81502^{f}	100.72^{e}	50.57^{i}	0.34^{hi}	0.50^{a}
S. Em. ±		0.05	3185	4.14	1.64	0.01	0.01

DAP- Days after planting, SA- Soil application, FA- Foliar application and
RPP- Recommended package of practice (no silicon application)
Soil application- Diatomaceous Earth (DE) (60 % SiO_2)
Foliar application- Hydrated Aluminium Silicate (HAS) (SiO_2) 80 % silicon or
Ortho Silicic Acid (OSA) (2 % Si as H_4SiO_4)

Effect of silicon nutrition on physiological parameters

Soil application of DE @ 300 kg ha^{-1} recorded significantly higher stomatal conductance (0.46 mmol m^{d2} s^{d1}) when compared to 600 kg ha^{-1}(0.39 mmol m^{d2} s^{d1}). Foliar application of OSA @ 0.2 % at 60 DAP recorded significantly higher stomatal conductance (0.48 mmol m^{d2} s^{d1}) when compared to rest of the foliar applications of silicon. The overall interaction effect revealed that S_1F_5 *i.e.,* soil application of DE @ 300 kg ha^{-1} alongwith foliar application of OSA @ 0.2 % at 60 DAP recorded significantly higher stomatal conductance (0.51 mmol m^{d2} s^{d1}). The interaction S_1F_5 recorded significantly higher stomatal conductance (0.51 mmol m^{d2} s^{d1}) compared to control (0.34 mmol m^{d2} s^{d1}) (Table 1). Optimum application of silicon in early crop growth stage increased photosynthesis thereby, improved stomatal activity (opening and closing) which in turn increased stomatal conductance.

Soil application of DE @ 300 kg ha^{-1} recorded significantly lower proline content (0.20 μg g^{-1}) when compared to 600 kg ha^{-1} (0.28 μg g^{-1}). Foliar application of OSA @ 0.2 % at 60 DAP recorded significantly lower proline content (0.18 μg g^{-1}). The overall interaction effect revealed that S_1F_5 *i.e.,* soil application of DE @ 300 kg ha^{-1} along with foliar application of OSA @ 0.2 % at 60 DAP recorded significantly lower proline content (0.14 μg g^{-1}) compared to control (0.50 μg g^{-1}) (Table 1). This was due to application of silicon maintained optimum water balance and reduced the crop water stress thereby, decreased transpiration rate. So, less stress indicated less proline content in plant (Verma *et al*., 2019).

Conclusion

Irrespective of source and concentration of silicon for foliar spray, application at 60 DAP was superior for cane yield compared to 90 DAP. Soil application of DE @ 300 kg ha^{-1} along with foliar application of OSA @ 0.2 % at 60 DAP (S_1F_5) recorded significantly highercane yield (138.10 t ha^{-1}) in sugarcane which was 37.38 per cent higher compared to recommended package of practice (100.72 t ha^{-1}).

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