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Effect of Active Silica on Growth and Profitability of Maize under Organic Farming

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Abstract: Irrational use of agro chemicals decreases the ecological diversity and increases the biotic and abiotic stresses, ultimately affects the crop yield. The use of active silica counters such ill effects and also enhances the crop yield especially under organic farming. Therefore, a field experiment was conducted during the *Kharif* season of 2018 and 2019 at Organic Unit of Instructional Farm, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur (Rajasthan). The experiment consisting of six soil application in main plots (0, 50, 75, 100, 125 and 150 kg ha^{-1}) and six foliar application of active silica in sub plots (no spray, water spray, 0.25, 0.50, 0.75 and 1.0%) was carried out in split plot design. The significantly higher chlorophyll content, plant height, dry matter accumulation, leaf area index, crop growth rate, relative growth and net assimilation rate was observed with 150 kg ha^{-1} active silica application. Similarly, higher biological yield, net return, B C ratio and available P in soil was recorded at 150 kg ha^{-1} active silica application. Among foliar application, the spray of 1.0% active silica significantly enhanced the chlorophyll content, plant height, dry matter accumulation, leaf area index, crop growth rate between 60 to 75 DAS, net assimilation rate, biological yield, economics and available P in soil in maize under organic production system. Overall, the use of 150 kg ha^{-1} active silica through soil or 1.0% foliar spray may be recommended to increase the maize growth and economics under organic farming condition.

Keywords: Active silica, Growth, Maize, Organic farming, Profitability

Maize is the third most important cereal crop in the world after rice and wheat (Arunjith and Arthanari 2021). Irrational use of chemical fertilizers and other agro-chemicals creates several harmful effects and poor quality of crops (Kumar et al 2021) which enhances the demand of organic farming based agricultural products (Lal et al 2021). In organic production, natural sources of Si can be used to increase the growth and yields of crops. Si is one of the second most abundant elements found in the earth's crust (27.72%), but it mostly inert and only slightly soluble. Although Si has not been classified as an essential element for higher plants but it is a naturally occurring beneficial nutrient which modulates plant growth and development events. Si has a key role in improving crops abilities to withstand biotic and abiotic stresses, such as disease and pest resistance, alleviation of heavy metal (Al, Mn, and Fe) toxicities, salinity resistance, resistance to drought stress and alleviation of freezing stress (Xiang et al 2012). In cereals develops narcosis, disturbance in leaf, photosynthetic efficiency, growth retardation by reduce amount of Si in plant. Si has does not play significant for vegetative growth but it support in healthy development under stresses. Si increases drought tolerance by maintaining plant water balance, erectness of leaves, photosynthetic activity, structure of xylem vessels and high transpiration rate in plant by application of Si resulted increasing in dry matter accumulation and grain yield. Si benefits in maize have been related to its effect on the improving of population quality, effective leaf area, and photosynthetic efficiency as well as the delay of leaf senescence. Photosynthesis is a determinant factor for crop growth and development as maximum photosynthesis contributes toward more yield and production, and it is the most basic and critical physiological process directly related to maize yield, especially at late developmental stages (Ahmed et al 2012). Crop yield potential can be increased by 50% by raising photosynthetic capacity (Covshoff and Hibberd 2012). Consequently, in cereals it can help in enhancing the growth and productivity and it can be used as 100% organic inputs. Optimum amount of Si is necessary for cell development and differentiation and significantly increased plant height stem diameter, number of leaves of maize. The production of aboveground biomass of wheat was enhanced by Si fertilization. The rise in biomass production was mainly caused by a substantial increase of straw biomass. The highest positive influence of Si application was observed with the use of Si both at the tillering and anthesis stages which provided higher resistance to drought by maintaining cellular membrane integrity and increasing chlorophyll content in wheat (Maghsoudi et al 2015; Prajapat et al 2021). The use of active silica counters such ill effects (biotic and abiotic effect) and also enhances the crop yield under organic farming.

MATERIAL AND METHODS

Field experiment was conducted at Maharana Pratap University of Agriculture and Technology, Udaipur (Rajasthan) during the *Kharif* season of 2018 and 2019. The experiment consisting of 36 treatment combinations of six active silica of soil application in main plots *viz.,* 0 (S_1), 50 (S_2), 75 (S_3), 100 (S_4), 125 (S_6) kg/ha and six foliar application of active silica in sub plot *viz*., No spray (F_1), water spray (F_2), 0.25 (F_3), 0.50 (F_4), 0.75 (F_5) and 1.0% (F_6). The experiment was in in split plot design with three replication. Soil application of active silica was done before sowing and foliar spray of active silica was done at 30 DAS and initiation of tasseling. Chlorophyll content was estimated from sampled plants by the method suggested by Arnon (1949).

$$\text{Chlorophyll content (mg/g fresh weight leaves)} = \frac{A(652) \times \text{Total volume (ml)}}{\alpha \times 1000 \times \text{Weight of sample}}$$

Where, α is the path length = 1 cm

Crop growth rate (CGR) represents dry weight gained by a unit area of crop in a unit time, expressed as g/m^2/day (Watson 1958).

$$\text{Crop Growth Rate (g/m}^2\text{/day)} = \frac{(W_2 - W_1)}{(t_2 - t_1)\,A}$$

Where, W_1 and W_2 indicate the total dry weight (g) of the plants at the time t_1 and t_2, respectively. A indicates land area over which the dry weight was recorded in m^2.

The mean relative growth rate and net assimilation ratio of the crop were calculated by using the following relationship (Redford 1967).

$$\text{Relative growth rate (g/g/day)} = \frac{(\log_e W_2 - \log_e W_1)}{(t_2 - t_1)}$$

$$\text{Net assimilation rate (g/cm}^2\text{/day)} = \frac{(W_2 - W_1)(\log_e L_2 - \log_e L_1)}{(t_2 - t_1)(L_2 - L_1)}$$

Where, L_1 and W_1 indicate the leaf area in cm^2 and dry weight of plant in g at time t_1. L_2 and W_2 indicate the leaf area in cm^2 and dry weight of plant in g at time t_1.

Available N, P and K in soil were estimated by colorimetric method using alkaline permanganate method (Subbiah and Asija 1956), Olsen's method (Olsen et al 1954) and Flame photometer (Richards 1968), respectively.

RESULTS AND DISCUSSION

Effect on growth parameters: Soil application of active silica revealed that chlorophyll content was significantly higher at 150 kg ha^{-1} which was at par with 125 kg/ha at 45 DAS and 100 and 125 kg ha^{-1} at 60 DAS. Plant height was also significantly higher at 150 kg ha^{-1} however, it was par with 100 and 125 kg ha^{-1} at 60 and 75 DAS and 125 kg ha^{-1} at harvest. Significantly higher dry matter accumulation was at 150 kg ha^{-1} which remained at par with 125 kg ha^{-1} at 60, 75 DAS and at harvest. Leaf area index (LAI) was significantly higher at 150 kg ha^{-1} but did not differ significantly from 125 kg ha^{-1} (Table 1). Crop growth rate (CGR) between 60 to 75 DAS and 75 DAS to harvest were significantly higher at 150 kg ha^{-1} which was at par with 125 kg ha^{-1}. The significantly higher relative growth rate (RGR) between 60 to 75 DAS and 75 DAS to harvest with 150 kg ha^{-1} was observed, however, it remained at par with 75, 100 and 125 kg/ha between 60 to 75 DAS and it was par with 125 kg ha^{-1} between 75 DAS and harvest. Net assimilation rate (NAR) between 60 to 75 DAS and 75 DAS to harvest were higher at 150 kg ha^{-1} and remained at par with 125 kg ha^{-1} between 60 to 75 DAS and 75 DAS to harvest (Table 2). Similar results were also reported by Patil et al (2018) and Jan et al (2018).

Among foliar application, 1.0% sprays of active silica recorded significantly higher chlorophyll content over control. However, chlorophyll content remained at par with 0.75% spray at 45 DAS and 65 DAS (Table 1). Plant height was significantly higher at 1.0% spray; however and was at par with 100 and 125 kg ha^{-1} at 60 DAS and 125 kg ha^{-1} at 75 DAS and at harvest. Significantly higher dry matter accumulation was recorded at 1.0% spay; however, was at par with 0.50 and 0.75% at 60, 75 DAS and at harvest. LAI was significantly higher at 1.0% which found at par with foliar application with 0.50 and 0.75% at par with 60, 75 DAS and at harvest. CGR between 75 DAS to harvest was recorded higher at 1.0% spray. RGR between 75 DAS to harvest was higher at 0.50% foliar spray. The significantly higher NAR was at 1.0% spray and was at par with 0.25, 0.50 and 0.75% spray between 60 to 75 DAS (Table 2). This might be owing to deposition of Si at cellular parts such as cell wall, cell lumens and intercellular space, and its deposition below and above cuticle layer that's why enhanced cell division and cell elongation than tissue parts more elongated and erect, cause erectness of leaves and stem which enhanced towards plant height and also increase in chlorophyll content. Further, these improvements resulted better leaf area index leads to better light interception and photosynthesis activity which enhanced higher dry matter accumulation. (Bassiouni et al 2020).

Effect on biological yield: Soil application of active silica revealed that biological yield was significantly increased with increasing dose of active silica up to 150 kg ha^{-1}. The biological yield were at par with 125 kg/ha (Table 3). In foliar spray, significantly higher biological yield were with 1.0% foliar application (Table 3) and remained at par with 0.75% for

Table 1. Effect of active silica on chlorophyll content, plant height, dry matter accumulation and leaf area index of maize under organic farming (Pooled of two years)

Treatments	Chlorophyll content (mg g^{-1} fresh weight of leaves)		Plant height (cm)			Dry matter accumulation (g $plant^{-1}$)			Leaf area index		
	45 DAS	65 DAS	60 DAS	75 DAS	Harvest	60 DAS	75 DAS	Harvest	60 DAS	75 DAS	Harvest
Soil application											
S1	2.212	2.017	132.65	149.31	158.45	66.40	95.15	109.47	3.14	3.27	3.48
S2	2.232	2.037	136.67	153.01	162.25	67.30	96.97	112.44	3.21	3.41	3.62
S3	2.272	2.108	138.16	155.56	164.02	69.40	101.17	118.73	3.28	3.48	3.70
S4	2.303	2.128	144.99	161.16	170.62	71.59	105.17	124.76	3.47	3.68	3.90
S5	2.363	2.168	145.92	163.31	172.85	74.80	113.18	135.71	3.48	3.69	3.91
S6	2.373	2.178	147.12	164.45	178.01	76.10	113.99	137.52	3.51	3.72	3.94
CD (p=0.05)	0.055	0.060	4.97	6.22	7.08	3.81	4.23	5.48	0.09	0.08	0.09
Foliar application											
F1	2.205	2.205	134.03	150.59	160.28	65.38	99.71	117.46	3.13	3.32	3.53
F2	2.283	2.283	138.15	154.89	164.71	68.92	102.37	120.72	3.22	3.41	3.62
F3	2.280	2.280	140.86	157.73	167.07	70.96	104.57	123.17	3.28	3.47	3.69
F4	2.294	2.294	143.01	159.61	169.54	72.56	105.59	124.86	3.49	3.67	3.89
F5	2.343	2.343	144.29	161.42	171.59	73.74	106.55	125.41	3.48	3.68	3.91
F6	2.351	2.351	145.17	162.57	173.01	74.02	106.83	127.00	3.49	3.69	3.91
CD (p=0.05)	0.035	0.035	2.80	2.91	3.34	2.09	2.04	2.56	0.07	0.06	0.07

Table 2. Effect of active silica on CGR, RGR and NAR of maize under organic farming (Pooled of two years)

Treatments	CGR (g m^{-2} day^{-1})		RGR (g g-^{1} day^{-1})		NAR (g cm^{-2} day^{-1})	
	Between 60 to 75 DAA	At between 75 DAS to harvest	Between 60 to 75 DAS	At between 75 DAS to harvest	Between 60 to 75 DAS	At between 75 DAS to harvest
Soil application						
S1	12.78	6.36	0.0247	0.0092	33.52	17.65
S2	13.19	6.88	0.0247	0.0099	35.97	19.63
S3	14.12	7.80	0.0251	0.0107	39.13	22.65
S4	14.92	8.71	0.0259	0.0114	43.07	26.33
S5	17.06	10.01	0.0279	0.0121	49.37	30.29
S6	16.84	10.46	0.0270	0.0125	49.02	31.83
CD (p=0.05)	0.97	0.56	0.0019	0.0004	2.73	1.78
Foliar application						
F1	15.26	7.89	0.0282	0.0107	40.65	22.21
F2	14.87	8.15	0.0264	0.0109	40.71	23.43
F3	14.94	8.27	0.0258	0.0108	41.47	24.09
F4	14.68	8.56	0.0250	0.0111	42.59	25.92
F5	14.58	8.38	0.0250	0.0108	42.30	25.45
F6	14.58	8.97	0.0249	0.0114	42.36	27.28
CD (p=0.05)	NS	0.27	0.0012	0.0002	1.42	0.70

Table 3. Effect of active silica on biological yield, economics and available N, P and K on soil of maize under organic farming (Pooled of two years)

Treatments	Biological yield (kg ha^{-1})	Net return (ha^{-1})	B C ratio	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Soil application						
S1	5640	36687	1.27	238.92	33.46	306.97
S2	6245	42501	1.45	239.20	33.50	307.34
S3	6442	44549	1.51	239.98	34.86	307.56
S4	6861	49831	1.67	241.30	35.79	309.09
S5	7095	52786	1.76	242.25	38.73	309.24
S6	7165	53205	1.76	242.75	41.18	311.22
CD (p=0.05)	247	2657	0.09	NS	1.275	NS
Foliar application						
F1	5658	36861	1.26	238.53	35.45	307.58
F2	6348	44023	1.48	239.40	35.67	308.67
F3	6498	45734	1.54	241.00	35.96	308.48
F4	6865	49638	1.67	241.65	36.77	308.78
F5	6990	51242	1.72	241.79	36.65	309.03
F6	7089	52059	1.75	242.03	37.00	308.88
CD (p=0.05)	164	1809	0.06	NS	NS	NS

biological yield. This might be due to Si accumulation in plant parts which reduce its lodging and enhanced resistance against biotic and abiotic stress, ultimately resulted into higher biological yield (Patil et al 2017, Sarma et al 2017).

Effect on economics: Soil application of active silica revealed that net return were significantly increased with increasing dose of active silica up to 150 kg ha^{-1}. The net return was at par with 125 kg ha^{-1}. Significantly higher B C ratio was at 150 kg ha^{-1} which found at par with 100 and 125 kg ha^{-1}. The Jawahar and Vaiyapuri (2013) and Rao et al (2018) also observed same trend. In case of foliar spray, significantly higher net return was with 1.0% foliar application (Table 3) and was remained at par with 0.75%. Maximum B C ratio was recorded higher at 1.0% spray and was at par with 0.75% spray. Similar results were also reported by Pooja et al (2019).

Effect on available N, P and K on soil: Available P was significantly higher with soil application of 150 kg ha^{-1} active silica (Table 3). There non-significant difference was observed with different doses of active silica in soil as well as foliar application on N, K and P foliar application. With increasing of doses of soil applied active silica available P content in soil also increase over control. This might be owing to silicate anion (monosilicic acid) adsorbs on the labile phosphates of calcium in alkaline soil and desorbs (releases) the phosphate anion into soil solution increasing the total amount of soluble phosphorus available to the plant. The negative charge of the silicate anion repels the phosphate anions, keeping dissolved phosphorus in a soluble form in the soil solution (Daniela et al 2006).

CONCLUSIONS

Soil application of 150 kg ha^{-1} active silica significantly enhances the growth, net return, B C ratio and post harvest available P of soil. Among foliar application, spray of 1.0% active silica improves the growth and net returns. Overall, 150 kg ha^{-1} active silica through soil application or 1.0% foliar spray may be recommended to increase the maize growth and profitability under organic farming condition.

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