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EFFECTS OF SOURCES AND LEVELS OF SILICON ON CHEMICAL PROPERTIES AND NUTRIENTS AVAILABILITY OF SOIL AT HARVEST OF GARLIC

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ABSTRACT

The field experiment entitled "Effect of sources and levels of silicon on Chemical Properties and Nutrient availability of Soil at Harvest of Garlic " was conducted during Rabi season. at All India Co-ordinated Research Project, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri with a view to study the effect of sources and levels of silicon on Chemical Properties and Nutrient availability of Soil at Harvest of Garlic. The present investigation was carried out in Factorial Randomized Block Design (FRBD). Fifteen treatments comprised of five levels of silicon (0, 50, 100, 150 and 200 kg Si ha^{1}) through three sources of silicon viz. Diatomaceous earth, calcium silicate and bagasse ash. The chemical properties viz. pH, EC and OC showed significantly influenced due to application of different sources. In case of sources the source A (DE) recorded significantly superior pH and OC (8.40 and 0.58% respectively) and the EC showed significantly highest (0.49 dSm-^{1}). The available nutrient at harvest viz. N, K, Si, Mn, Zn and Cu was significantly influenced due to application of different sources. In case of sources As (BA) recorded significantly superior N and K, (164.09 and 223.32 kg ha^{1} respectively) over all other sources and the available Mn was significantly superior Zn (0.65mg kg) over all the sources. In case of source A (DE) recorded significantly highest Si at harvest (73.62 kg ha^{1}) and the available Cu content recorded significantly highest (1.72 mg kg 1). From the above result it can be concluded that the application of silicon @ 200 kg ha^{1} through bagasse ash proved as good source of silicon for highest Electrical conductivity, Nitrogen and Potassium availability of soil at harvest of Garlic.

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INTRODUCTION

Silicon Silicon (Si) is a second most abundant element, either on the basis of weight and number of atoms, in the earth crust. Because of the strong affinity of Si with oxygen in nature Si always exists as a silica (SiO2 silicon dioxide) or silicates, Silicates occurring in nature as in combined form with various materials. Silicon dioxide comprises about 60 per cent of the earth's crust. In soil silicon dioxide accounts for more than 50 per cent of silicon concentration. In soil solution between 3.5 mg and 40 mg Si per litre in the form of silicic acid (Marschner, 1995). Therefore all plant root in soil contain silicon in their tissues. However, because of its universal existence, earlier researchers paid little attention to study the impact of silicon on the growth of plant. Although Si is abundant in the earth crust because of low solubility (Lindsay and Norvell 1978) many soils contain inadequate supply or are naturally low in plant available Si. Depletion of Si may occur in traditional soils with continuous monoculture, intensive cultivation of high yielding cultivars of crops and can be a limiting factor for sustainable crop production (Miyake, 1993).

Silicon does not form a constituent of any cellular components but primarily deposited on the walls of epidermis and vascular tissues conferring strength, rigidity and resistance to pests and diseases. Silicon nutrition also manages many abiotic stresses including physical stresses like lodging, drought, radiation, high temperature, freezing and chemical stresses like salt, metal toxicity and nutrient imbalance (Epstein, 1994). It plays a role in phosphorus nutrition and there is an interrelationship with phosphorus (Silva, 1971). Silicon has non significant role for the nutritional process of crops. Number of studies have been carried out to study the effect of silicon on plant growth. However until now silicon has not been put in list of essential elements for higher plants. According to the criteria processed by Arnon and Stout (1939) for essential element that for a given plant must be unable to complete life cycle in the absence of element. However no evidence has been shown that plant is unable to complete its life cycle in absence of silicon. One argument about this is that Si may function as a micro-nutrient and that is not possible to completely remove silicon from the growth medium by currently available techniques because of various contaminants. However, the fact that a large effect is that element must be directly involved in plant metabolism. Silicon plays a significant role in imparting both biotic and abiotic stress resistance and enhance the productivity. For this reason, Si has been recognized as agronomically essential element and silicate fertilizers have been applied to soils Ma and Takahashi (1990). In several studies Epstein and Bloom (2005) suggested that Si enhances disease resistance in plants, imparts turgidity to the cell walls and has been putative role in mitigating the metal toxicities. It is also suggested that Si plays a crucial role in preventing or minimizing the lodging in crop, a matter of great importance in term of agriculture productivity. Many Indian farmers are not aware about benefits of silicon and silicon sources. The ideal silicon source must have characteristics as a relatively high content of silicon, provide sufficient water-soluble silicon to meet the needs of the plant, be cost effective, ease in availability, have a physical nature that facilitates storage as well as application and not contain substances that will contaminate the soil (Gascho, 2001). Many potential sources meet the first requirement; however only a few meet all of these requirements.

REVIEW

Effect of sources and levels of silicon on soil chemical properties and availability of nutrients

PH: There was a significant increase in soil pH from its initial value of 5.38 to a maximum of 6.01 in at harvest in soil due to addition of silicon sources, while the interaction effect was also found to be statistically significant. The CaO of the soil might have interacted with water in the presence of CO2 and produced hydroxyl and other ionic forms in the soil solution and thereby carbonate are precipitated. These reaction's and the presence of Na, would responsible for the high pH value. Pichel and Hayer. (2013) also reported increase in pH with the addition of silicon source i.e. fly ash. It was also reported that uptake of Si by rice would tend to raise the pH. Kadlag et al. (2014) reported that the use of different silicon sources i.e. diatomaceous earth in sugarcane crop and the uptake of silicon would tends to rise in pH. Durgude et al. (2014) reported that the use of different silicon sources i.e. diatomaceous earth in garlic crop and the uptake of silicon would tends to rise in pH.

Electrical conductivity: Pichel and Hayer (2013) reported that the additional dose of silicon fertilizer gradually increased EC values of the soil. But no significant difference was observed in EC between 150-200 kg Si ha^{1}. Increasing EC values of soil due to addition of silicon through fly ash may be attributed soluble salt from silicon source, might have dissolved in soil moisture and there by increased the ionic concentration of the soil solution. Kadlag et al. (2014) reported that the addition dose of different silicon sources i.e. diatomaceous earth in sugarcane crop. With the finding uptake of silicon would tends to rise in EC and increasing the EC value of soil due to addition of silicon source diatomaceous earth. Durgude et al. (2014) reported that the use of different silicon sources i.e. diatomaceous earth in garlic crop uptake of silicon would tends to rise in EC.

Organic carbon: Pichel and Hayer (2013) observed that the organic carbon status of soil was found to be improved significantly with addition of FYM over control, as FYM contains considerable amount of organic matter. Organic carbon increased significantly with every subsequent increase in dose of source of silicon like fly ash over control. It has been seen that soil organic carbon tended to increase significantly whenfly ash was applied alone in comparison to fly ash integrated with RDF and FYM. Durgude et al. (2014) reported that the application of DE did not show distinguish variation in respect of soil chemical properties after harvest of garlic. The application of DE @ 400 kg ha full POP recorded significantly highest organic carbon.

Nitrogen: The rice yields are declining due to the excessive application of nitrogenous fertilizers. But the application of Si has the potential to raise the optimum N rate due to synergistic effect, thus enhancing the productivity of low land rice soils (Kono, 1969 and Ho et al., 1980). Application of N tends to decrease Si uptake in rice, and fertilizers containing NH4+-N may decrease it more than NO3-N (Kono and Takahashi 1958). Idris et al. (1975) reported that application of Si significantly increased the rigidity of rice stalk and this increase was remarkably higher at lower doses of nitrogen. The larger quantities of nitrogen greatly reduced the efficiency of Si in imparting rigidity to plants. Snyder et al. (1986) noticed that a decline in N concentration in histosols grown rice and attributed it to the possibility of dilution in the larger Si fertilized plants. In greater biomass where, N is limiting, the plants will show lower N concentration due to dilution. Nitrogen is the most common nutrient that limits rice production. Deficiency symptoms are frequently characterized by general chlorosis (yellowing) of leaves and a reduction in overall plant vigor and growth. At flowering. N deficient plants are stunted and have fewer tillers and smaller heads than healthy plants. Grain yield reduced primarily through a reduction in panicles. Nitrogen was essential for plant growth and development, and was often a limiting factor for high productivity. However, when applied in excess it may limit yield because of lodging, especially for cultivars of the traditional and intermediate groups, and promote shading and disease problems. These effects could be minimized by the use of Si (Ma et al., 2001). Durgude et al. (2014) reported that the use of different silicon sources i.e. diatomaceous earth in garlic crop. It was also reported that the uptake of silicon would tends to rise in available nitrogen.

Phosphorous: Kawaguchi (1966) noticed that the effects of silicon on phosphorus desorption or adsorption may be due to the interaction of silicon with sorption sites or due to inactivation of iron and aluminium by rendering them insoluble. The use of silicate also improved the efficiency of phosphorus fertilizers. Silicon exerted a solvent action on phosphorus fertilizers and rendered the P available to plant. The solubilised silicon has a larger interaction with other nutrients particularly phosphorus. The Si in solution renders phosphorus available to plants reversing its fixation as Si itself competes for phosphorus fixation sites in soil. It is to be noted here to some degree Si acts as a substitute for P in plant system. In soil system also application of silicates released more of Chandrasekaran, 1978). phosphorus (Chinnasami and Anon (1997) observed that there is increased available phosphorus to the plant with the application of 150 kg ha^{1}. Earlier in water logged area 26 per cent phosphorus was available but with addition of silicon it was increased to 35 per cent. He explained that actually in water logging areas there is already available phosphorus there is no doubt about it but silicon will further makes unavailable phosphorus to available form from releasing the fixed phosphorus from the soil as well as fixed phosphorus with Al and Fe. Savant et al. (1999) reported that application of silicates increased the water soluble P as the rate of application increased, despite the fact that pH of the soil also increased. The result suggests that the Si effect is not to reduce the formation of insoluble calcium phosphates, but rather to reduce the adsorption of P by the freshly precipitated Fe and Al hydroxides. Prakash et al. (2010) also found the positive effects of applied Si on the availability and utilization of P by the rice plants. Gerroh and Gascho (2005) observed that phosphorous sorption of soil was decreased by the application of soluble Si. The applied silicate likely increased the weight of maize by increasing soil pH there by making P more available, therefore increasing Puptake and utilization.

Potassium: Schelhass and Muller (1977) also found that application of CaSiO3 resulted in a strong increase of Si uptake. But significant effect on yield was only obtained at high levels of Si and K. Mohanthy et al. (1982) noticed that an exchangeable K displaced from cation exchange sites into the soil solution due to competition for exchange sites from Fe and Mn might have increased the solution K concentration. Sikka and Kansal (1995) reported that the pH and available nutrient status of soils after harvest of the rice and wheat crops were not affected by the application of fly ash. However, the mean DTPA extractable Fe content in soils increased significantly from 12 ppm in the control to 18.1 ppm in soils amended with 8 per cent fly ash. Sadgrove (2006) reported that reductions in leaching of N by 60 per cent for sandy soil and 10 per cent for potting mix, P by 30 per cent for sandy soil and by 95 per cent for clay, K by 60 per cent for sandy soil and 15 per cent for potting mix due to application of diatomaceous earth as source of silicon. The potassium and phosphate levels were improved for all soil types amended with diatomaceous earth. This was due to high moisture holding and cation exchange capacity of diatomaceous earth. Mali and Aery (2008) noticed that silicon application has been observed to increase plant yield by reducing the absorption of sodium and increasing uptake of potassium in wheat. Phonde et al. (2009) observed that availability of P and K in soil after 120 days silicon application appears to be increased under silicon applied plots. Significant increase in phosphate availability was observed under Calcium silicate, fly ash, pond ash and bagasse ash applied plots.

Silicon: Jones and Handreck (1967) reported that soil solution contain silicon 1 to 65 mg L^{-1}. Obihara and Russell (1972) reported that the silicon concentration in a soil is 14 controlled by the dissolution of the siliceous materials and by the sorption reactions between soluble silica and reactive soil materials, particularly the iron and aluminium oxides and hydroxides, other anions and soil pH also influence the reactions. Haysom and Chapman (1975) compared 0.01 M CaCl2, 0.5 M ammonium acetate and 0.005 M sulfuric acid for their ability to extract plant available Si from soils and found that Si extracted by $CaCl_2$ showed the greatest correlation to sugarcane yield (r = 0.82). Nayar et al. (1977) compared N sodium acetate buffer (pH 4.0) with three other chemical extractants (distilled water, 0.2 N HCI and 0.025 M citric acid) and it was found that extracting power of different extractants for Si as: 0.2 N HCI> 0.025 M citric acid > N acetate buffer > water. Silicon extracted by citric acid showed better correlation with the Si uptake by rice plants.

Iler (1979) found that the dissolved silicic acid in soil solutions primarily occurs as monomeric or oligomeric silicic acid. Imaizumi and Yoshida (1958) noticed the critical limit for soil Silicon extracted by N NaOAc as 49 mg kg and it is widely used in Japan and Taiwan. Inspite of higher Si content (71-181 ppm) in calcarious soils of china, as extracted by sodium acetate buffer, rice yields continued to respond to application of Si fertilizers Liang et al. (1994). Balasubramaniam et al. (2011) reported The addition of SSP and FYM resulted a consistent increase of N NaOAc (pH 4.0) extractable Si from 144.7 mg kg to 272.2 mg kg during 15th to 60th days after incubation, there after a slight decline in N NaOAc (pH 4.0) extractable Si was observed. Dhamapurkar (2011) concluded that application of 6 Mg ha^{1} calcium silicate slag significantly increased the available Si content of soil from 99 to 252 ppm (0.025 M citric acid) at harvest of rice. Durgude et al. (2014) observed in onion crop. The application of silicon source diatomaceous earth to rise the availability of silicon in soil through different levels.

Micronutrients: Okuda and Takahashi (1962) noticed that the increased concentration of Fe in rice has been found to be alleviated by Si application due to decreased Fe and Mn uptake suggesting antagonistic relationship between silicon with Fe and Mn. Alleviation of Mn and Fe toxicity might not be only because of reduced absorption but also because of increased internal tolerance of (Horiguchi, 1988). The decreased Mn and Fe in presence of Si due to increased oxidizing power of rice roots which might cause the deposition of Fe and Mn on the roots surface due to increased pH. Singh et al. (2005a) reported that with the application of 180 kg Si ha^{1} induced nutrient uptake of Zn (0.45 kg ha^{1}), Fe (3.05 kg ha^{1}), Mn (2.66 kg ha^{1}) respectively in rice plant. Matychenkov et al. (2011) reported that silicon has been elaborated for neutralization of metal toxicity in industrial waste-water.

Industrial waste-water contaminated by Fe, Al, Mn, Zn and Cu from battery manufacturing was used and the concentration of these heavy metals in rice plant was highly reduced with the application of silicon. Mali (2012) conducted the field experiment on maize crop in Inceptisol and reported the increase in micronutrient availability by the foliar application of ultra K. Durgude et al. (2014) conducted the field experiment on garlic crop in shallow soil and reported the increase in micronutrient by soil application of diatomaceous earth.

MATERIAL AND METHODS

An investigation was carried out by conducting a field experiment entitled, "Effect of sources and levels of silicon on Chemical Properties and Nutrient availability of Soil at Harvest of Garlic at Department of Horticulture, All India Co-ordinated Research Project on Vegetable Crop, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri *Rabi* season. The details of material used in experimental techniques and analytical methods adopted during the investigation are presented in this chapter. The details of material used in experimental techniques are presented here as follow.

Location of experimental site: The experiment was carried out at the All India Co-ordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar during *Rabi* season. Geographically, Central campus of M.P.K.V., Rahuri lies between 19^{0}47' N to 19^{0}57' N latitude and 74^{0}19' to 74^{0}42' E longitudes with elevation of 525 m above mean sea level. The tract lies on the eastern side of Western Ghats and falls under scarcity of rainfall zone.

Soil : The topography of experimental site was uniform field, leveled and flat beds were prepared for garlic planting, soil was medium deep black well drained having good water holding capacity. The soil of experimental plot is grouped under the order vertisol. The texture of soil was medium deep black with pH (8.02) alkaline in nature. The electrical conductivity of soil is 0.45 dS m^{-1}. The soils an low in available nitrogen (195.47 kg ha^{-1}), medium in available phosphorus (24.12 kg ha^{-1}) and high in available potassium (288 kg ha^{-1}). The available silicon is 68.88 mg kg^{-1}. No deficiency of micronutrient were observed except iron which was deficient in soil (3.94 ppm).

Table 1. Initial soil properties of experimental plot

Sr. No.	Particulars	Value
A.	Physical properties	
1.	Texture	
i.	Sand (%)	12.65
ii.	Silt (%)	29.11
iii.	Clay (%)	58.54
	Textural class	Clay
2.	Bulk density	1.21
B.	Chemical properties	
1.	pH (1:2.5)	8.02
2.	EC (dS m^{-1})	0.45
3.	Organic carbon (%)	0.63
4.	Available nitrogen (kg ha^{-1})	195.47
5.	Available phosphorous (kg ha^{-1})	24.12
6.	Available potassium (kg ha^{-1})	288
7.	Available silicon (mg kg^{-1})	68.88
8.	Fe (mg kg^{-1})	3.94
9.	Mn (mg kg^{-1})	8.90
10.	Zn (mg kg^{-1})	0.69
11.	Cu (mg kg^{-1})	1.72

Note: Available iron was deficient in soil hence application of $FeSO_4$ $7H_2O$ @ 25 kg ha^{-1} was done at basal dose with FYM.

Selection of crop: The Garlic (Phule Nilima) was selected as a test crop during *Rabi* season.

Treatment details

A.	**Experimental details for field trial**		
1.	Name of crop	:	Garlic
2.	Crop variety	:	Phule Nilima
3.	Soil type	:	Medium deep black soil
4.	Experimental location	:	AICRP on vegetable crop farm
5.	Design of experiment	:	Factorial Randomized Block Design (FRBD)
6.	Number of treatment	:	15
7.	Replication	:	3
8.	RDF	:	100:50:50kg ha^{-1} N, P_2O_5 and K_2O respectively +20 t ha^{-1} FYM
9.	Planting distance	:	15 x 10cm

10.	Plot size	:	Gross plot= 4m x 2m Net plot= 3.70m x 1.80m
B.	**Treatment detail**		
a.	**Factor A**		Source of Silicon
1.	A_1	:	Diatomaceous earth (36%)
2.	A_2	:	Calcium Silicate (36%)
3.	A_3	:	Bagasse ash(27.9%)
b.	**Factor B**		Level of Si kgha^{-1}
1.	B_1		0
2.	B_2		50
3.	B_3		100
4.	B_4		150
5.	B_5		200

Note: The soil application of nutrients to Garlic was be applied to all treatments plots as per GRDF (*i.e.* 100:50:50 kg ha^{-1} N:P_2O_5:K_2O + 20 t ha^{-1}FYM) as per schedule.

The present investigation was carried out in Factorial Randomized Block Design (FRBD). Treatments comprised of five levels of silicon (0, 50, 100, 150, 200 kg Si ha^{-1}) applied through three sources of silicon as diatomaceous earth, calcium silicate, bagasse ash, and were replicated thrice. The general recommended dose comprised of FYM and NPK fertilizers were applied as per following schedule.

Preparatory tillage: The experimental site was ploughed and harrowing was done with the help of tractor drawn implements. The clod crushing was done by rotavator. The field was leveled with the help of wooden plank and was made ready for layout.

Sampling techniques: Five hills were selected from randomly in each net plot. The selected hills were marked by fixing pegs. All the plant growth observations were recorded on these hills.

Application of silicon sources and fertilizers: Different silicon sources as diatomaceous earth, calcium silicate, bagasse ash, were applied as basal dose before planting. The recommended fertilizer dose of 100:50:50; N:P_2O_5:K_2O kg ha^{-1} and 20 t ha^{-1} FYM applied. A basal dose of 50:50:50; N:P_2O_5:K_2O kg ha^{-1} was applied at the time of planting through urea, single super phosphate and muriate of potash for all treatments. The second split dose of nitrogen i.e.50 kg N ha^{-1} was applied at 50 days after planting.

Irrigation: Optimum soil moisture was maintained in each treatment by periodically irrigating the plot during the crop period as per requirements considering rainfall and crop growth stages.

Methods: The analytical work was done in the research laboratory of the Department of Horticulture and Department of Soil Science and Agricultural Chemistry, Post Graduate Institute, Rahuri. The methods adopted for recording the observations of soil and plant are explained here under different subheads.

Characterization of silicon sources: Total silicon was determined by HCl (12.1*N*) + HF (48 %) method by Korndorfer *et al.* (2004). In this method of 0.1 g sample, 1 ml of HCl and 4 ml of hydrogen floride taken in a 250 ml silicon free plastic conical flask. After 12 hrs, 50 ml of boric acid (70 g l-^{1}) and 40 ml of distilled water were added. Silicon in the extract was determined colorimetrically by using spectrophotometer at 630 ηm wavelength.

Soil analysis*:* Before sowing and after harvest of Garlic crop the representative soil samples were collected from each experimental plots. The collected soil samples were air dried under shade, pounded in wooden pestle and mortar, sieved through 2 mm sieve and utilized

Table 2. Treatment combination

Treatment	Combination
T_1	A_1B_1
T_2	A_1B_2
T_3	A_1B_3
T_4	A_1B_4
T_5	A_1B_5
T_6	A_2B_1
T_7	A_2B_2
T_8	A_2B_3
T_9	A_2B_4
T_{10}	A_2B_5
T_{11}	A_3B_1
T_{12}	A_3B_2
T_{13}	A_3B_3
T_{14}	A_3B_4
T_{15}	A_3B_5

3. Standard analytical methods

Sr. No	Parameter	Method	Reference
I.	Total silicon from various sources	HCl (12.1N) +HF (48%)	Korndorfer *et al.* (2004)
II.	Physical properties of soil		
1.	Texture	International pipette method	Black (1965)
2.	Bulk density	Core method	Blake and Hartage (1986)
III.	Chemical properties of soil		
1.	pH (1:2.5)	Potentiometric	Jackson (1973)
2.	EC (1:2.5)	Conductometric	Jackson (1973)
3.	Organic carbon	Wet oxidation	Nelson and Sommer (1982)
4.	Available N	Alkaline Permanganate	Subbiah and Asija (1956)
5.	Available P	0.5 M NaHCO3 (pH 8.5)	Watanabe and Olsen (1965)
6.	Available K	Flame photometry Neutral N NH_4OAc	Jackson (1973)
7.	Available Silicon	$CaCl_2$	Korndorfer *et al.* (1999)
8.	Av. Fe, Mn, Cu, and Zn.	DTPA extractant (Atomic Asorption Spectrophotometer)	Lindsay and Norvell (1978)

for analysis of physical and chemical properties of soils. Soil samples for available Si estimation were collected at 50 days after planting. These soil samples were analyzed by adopting standard methods given in Table 3.

Soil physical properties

Soil textur: Soil texture was determined by international pipette method given by Black (1965).

Bulk density: Bulk density was determined by Core method by Blake and Hartage (1986).

pH: The soil pH was measured with the help of pH meter having glass electrode and calomel electrode using 1:2.5, soil : water ratio as described by Jackson (1973).

Electrical conductivity: It was determined with the help of conductivity meter using soil water ratio of 1: 2.5 as described by Jackson (1973).

Organic carbon: Organic carbon in soil (0.5 mm sieved) was determined as per wet oxidation method by Nelson and Sommer (1982).

Available nitrogen: It was determined by alkaline permanganate method as described by Subbiah and Asija (1956).

Available phosphorus

The soil: extractant ratio was 1:20 and the shaking time was 5 minutes. Phosphorus in the extract of (available phosphorus) was determined colorimetrically by using spectrophotometer at 660 nm wave length by Watanabe and Olsen (1965).

Available potassium: It was extracted with neutral normal ammonium acetate (NH_4OAc, pH 7.0) the soil : extractant ratio was 1:5 and shaking time was 5 minutes. Potassium in soil was determined flame photometrically as described Jackson (1973).

Available silicon in soil: The silicon in the extracting solution was determined by transferring 0.25 ml of filtrate into a plastic centrifuge tube and then adding 10.50 ml of distilled water, plus 0.25 ml of 1:1 hydrochloric acid (HCl), and 0.50 ml of 10 % ammonium molybdate [(NH_4) 6M $7O_2$] solution (pH 7-8). After 5 minutes, 0.50 ml of 20% tartaric acid solution was added and after two minutes, 0.50 ml of the reducing agent amino napthol n-sulphonic acid (ANSA) was added. Then after five minutes, but not later than 30 minutes after addition of the reducing agent, absorbance was measured at 630 nm using spectrophotometer. Simultaneously, Si standards (0.2, 0.4, 0.8 and 1.0 mg L^{-1}) were prepared in the same matrix and measured using spectrophotometer (Korndorfer *et al.,* 2001).

Available micronutrients: Micronutrient in soil was determined by atomic absorption spectrophotometer using DTPA extractant as described by Lindsay and Norvell (1978).

RESULTS

Effect of sources and levels of silicon on chemical properties of soil at harvest: The data on effect of sources, levels of silicon and their interactions on chemical properties and soil available nutrient at harvest of garlic under field experiment are presented in the following Table 4-12. An investigation was carried out by conducting a field experiment entitled, "Effect of sources and levels of silicon on Chemical Properties and Nutrient availability of Soil at Harvest of Garlic" at All India Co-ordinated Research Project on Vegetable Crop, Department of Horticulture, MPKV., Rahuri. The Soil samples of each treatment were analyzed for their chemical properties and nutrient concentration and nutrients available at harvest calculated. The results obtained from the statistical analysis of generated data in present investigation are discussed in this chapter.

Effect of sources and levels of silicon on chemical properties of soil at harvest: The data on effect of sources, levels of silicon and their interactions on chemical properties and soil available nutrient at harvest of garlic under field experiment are presented in the following Table 4 to 12.

Soil pH (1:2.5): The data in respect of effect of sources and levels of silicon on soil pH at harvest presented in Table 4. The soil pH was significantly influenced due to sources of silicon. The source A_1 (DE) recorded the significantly the highest pH (8.40) over all the sources. The levels of silicon significantly influenced the pH. Application of Si level @ 200 kg ha^{-1} (B_5) recorded significantly highest (8.39). However, it was at par with silicon level B_4 and B_3 (8.35 and 8.30 respectively). The interaction effect of sources and levels of silicon was nonsignificant. There was slight increase in soil pH with increase in levels of silicon. This might be due to electrochemical changes that take place under moist condition of garlic crop. Also might be due to profuse root growth which leads to production of significant amount of CO_2 and release of mild organic acids tended to increase pH of soil

Table 4. Effect of sources and levels of Si on soil pH

Silicon sources (A)	Levels of silicon (B) kg ha^{-1}					
	B_1 0	B_2 50	B_3 100	B_4 150	B_5 200	Mean
A_1 : DE	8.15	8.40	8.43	8.47	8.53	8.40
A_2 : CS	8.13	8.20	8.29	8.34	8.37	8.27
A_3 : BA	8.12	8.14	8.17	8.23	8.26	8.19
Mean	8.13	8.25	8.30	8.35	8.39	8.28
	A		B		(A×B)	
S.E. ±	0.03		0.04		0.06	
CD at 5%	0.08		0.10		NS	
Initial	8.02					

Table 5. Effect of sources and levels of on soil electrical conductivity (dSm^{-1})

Silicon sources (A)	Levels of silicon (B) kg ha^{-1}					
	B_1 0	B_2 50	B_3 100	B_4 150	B_5 200	Mean
A_1 : DE	0.43	0.45	0.46	0.48	0.49	0.46
A_2 : CS	0.42	0.47	0.48	0.51	0.47	0.48
A_3 : BA	0.44	0.46	0.51	0.53	0.54	0.49
Mean	0.43	0.46	0.48	0.50	0.52	0.47
	A		B		(A×B)	
S.E. ±	0.004		0.006		0.01	
CD at 5%	0.013		0.017		NS	
Initial	0.45					

at harvest. This was in agreement with the findings of Pichel and Hayer (2013) and Durgude *et al*. (2014).

Electrical conductivity of soil: The data in respect of effect of different sources and levels of silicon on soil EC at harvest presented in Table 5. The electrical conductivity of soil was significantly influenced by sources of silicon. The source A_3 (BA) recorded significantly highest EC (0.49 dSm^{-1}). However, it was at par with A_2 (0.48 dSm^{-1}). The levels of silicon significantly influenced on soil EC at harvest. The application of Si @ 200 kg ha^{-1} (B_5) recorded significantly the highest electrical conductivity (0.52 dSm^{-1}) over all the levels of silicon. The interaction effect of sources and levels of silicon was non significant. The electrical conductivity of soil was slightly increased with levels of silicon. The variability in dissolution of soluble salts from soil and silicon sources under moist soil. There by increased the ionic concentration of the soil solution. Similar findings were reported by Pichel and Hayer (2013) and Durgude *et al.* (2014).

Available nitrogen: The data in respect of effect of different sources and levels of silicon on soil available nitrogen at harvest presented in Table 7. The available nitrogen in soil was significantly influenced due to sources of silicon. The calcium silicate source (A_2) recorded significantly highest available nitrogen in soil at harvest (164.09 kg ha^{-1}) than all other sources. The levels of silicon significantly influenced on soil available nitrogen. Application Si @ 200 kg ha^{-1} (B5) recorded significantly highest available nitrogen in soil (171.90 kg ha^{-1}) over rest of levels of silicon. The interaction effect of sources and levels of silicon on available nitrogen in soil at harvest was significant. Application of Si @ 200 kg $ha^{-1.}$ through CS was significantly registered the highest (180.0 kg ha^{-1}) available nitrogen in soil than rest of treatment combinations. The available nitrogen in soil at harvest of garlic was decreased over initial. This might be due to its uptake by crop. But with increased levels of silicon available nitrogen found to be increased. This might be due to synergistic effect of nitrogen and silicon.

Table 6. Effect of sources and levels of in soil organic carbon (%)

Silicon sources (A)	Levels of silicon (B) kg ha^{-1}					
	B_1 0	B_2 50	B_3 100	B_4 150	$B_5$200	Mean
A_1 : DE	0.55	0.56	0.58	0.60	0.62	0.58
A_2 : CS	0.53	0.54	0.55	0.56	0.58	0.55
A_3 : BA	0.54	0.54	0.55	0.56	0.57	0.55
Mean	0.54	0.54	0.56	0.57	0.59	0.56
	A		B		(A×B)	
S.E. ±	0.003		0.004		0.01	
CD at 5%	0.010		0.012		NS	
Initial	0.63					

Table 7. Effect of sources and levels of silicon on available nitrogen in soil (kg ha^{-1})

Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 50**	**$B_3$100**	**B_4 150**	**B_5 200**	**Mean**
A_1 : DE	150.93	154.80	161.37	168.47	172.77	161.67
A_2 : CS	143.53	156.00	163.49	177.43	180.00	164.09
A_3 : BA	145.65	151.33	153.67	156.00	162.93	153.92
Mean	146.70	154.05	159.51	167.30	171.90	159.89
	A		B		(A×B)	
S.E. ±	0.45		0.58		1.00	
CD at 5%	1.31		1.69		2.92	
Initial	195.47					

Table 8. Effect of sources and levels of silicon on available phosphorus in soil (kg ha^{-1})

Silicon sources (A)	Levels of silicon (B) kg ha^{-1}					
	B_1 0	B_2 50	B_3 100	B_4 150	B_5 200	Mean
A_1 : DE	20.385	22.807	22.733	21.000	21.033	21.592
A_2 : CS	20.293	21.633	22.530	22.310	21.333	21.620
A_3 : BA	20.660	22.433	22.167	22.850	21.500	21.922
Mean	20.446	22.29	22.477	22.053	21.289	21.711
	A		B		(A×B)	
S.E. ±	0.20		0.26		2.93	
CD at 5%	NS		0.76		NS	
Initial	24.12					

Organic carbon: The data in respect to effect of sources and levels of silicon on soil organic carbon at harvest presented in Table 6. The organic carbon content in soil was significantly influenced by different sources of silicon. The source (A_1) DE recorded significantly highest organic carbon content in soil at harvest (0.58 %) over all the sources. The levels of silicon significantly influenced on soil organic carbon. Application of Si @ 200 kg ha^{-1} (B_5) recorded significantly highest organic carbon content in soil at harvest (0.59 %). However, it was at par with B_4 (0.57 %). The interaction effect of sources and levels of silicon on organic carbon content in soil at harvest was not significant. The results obtained are in agreement with the results of Pichel and Hayer (2013) who reported non-significant correlation between silicon content and organic carbon in soil.

The application of silicon reduces leaching losses of nitrogen also reported by Kono (1969) and Ho *et al.* (1980), Kono and Takahashi (1958), Idris *et al.* (1975), Snyder *et al.* (1986). Ma *et al.* (2001) and Munir *et al.* (2003).

Available phosphorus: The data in respect of effect of different sources and levels of silicon on available phosphorus at harvest presented in Table 8. The available phosphorus content in soil was non significantly influenced due to sources of silicon. The levels of silicon significantly influenced available P. Application of Si @ 100 kg ha^{-1} (B_3) and recorded significantly highest available phosphorus (22.47kg ha^{-1}) followed by Si levels $B_{2,}$ and $B_{4,}$ (22.291 and 22.053 kg ha^{-1} respectively). The interaction effect of Si sources and levels was non significant.

Table 9. Effect of sources and levels of silicon on available potassium in soil (kg ha^{-1})

Silicon sources (A)	Levels of silicon (B) kg ha^{-1}					
	B_1 0	B_2 50	B_3 100	B_4 150	B_5 200	Mean
A_1 : DE	221.86	220.40	219.91	219.43	218.73	220.06
A_2 : CS	222.13	221.86	220.60	220.06	219.66	220.86
A_3 : BA	223.46	223.23	222.33	222.80	224.80	223.32
Mean	222.48	221.83	220.94	220.76	221.06	221.42
	A		B		(A×B)	
S.E. ±	0.79		1.02		2.93	
CD at 5%	2.29		NS		NS	
Initial	288					

Table 10. Effect of sources and levels of silicon on available silicon at 50 days after planting (kg ha^{-1})

Silicon sources (A)	Levels of silicon (B) kg ha^{-1}					
	B_1 0	B_2 50	B_3 100	B_4 150	B_5 200	Mean
A_1 : DE	68.71	76.89	97.80	117.31	125.93	97.33
A_2 : CS	69.73	88.86	94.87	103.70	111.45	93.72
A_3 : BA	66.49	71.60	86.80	96.97	101.46	84.66
Mean	68.31	79.12	93.16	105.99	112.95	91.90
	A		B		(A×B)	
S.E. ±	0.65		0.84		1.45	
CD at 5%	1.88		2.43		4.22	
Initial	68.88					

Table 11. Effect of sources and levels of silicon on available silicon in soil at harvest (kg ha^{-1})

Silicon sources (A)	Levels of silicon (B) kg ha^{-1}					
	$B_1$0	$B_2$50	$B_3$100	$B_4$150	$B_5$200	Mean
A_1 : DE	42.03	63.83	76.30	87.14	98.79	73.62
A_2 : CS	43.37	64.23	77.80	86.78	90.37	72.51
A_3 : BA	42.90	66.05	78.34	80.25	90.53	71.62
Mean	42.77	64.71	77.48	84.73	93.23	72.58
	A		B		(A×B)	
S.E. ±	0.65		0.84		1.45	
CD at 5%	1.88		2.43		4.22	
Initial	68.88					

The application of silicon significantly increased available phosphorus in soil at harvest of garlic. The silicon application decreases the phosphorus retention capacity of soil and thus increases the water soluble phosphorus in soil leading to increase efficiency of phosphatic fertilizers. The silicon in solution renders phosphorus available to plants reversing its fixation as silicon itself competes for phosphorus fixation sites in the soil. Similar findings are reported by Kawaguchi (1966), Anon (1997), Prakash *et al*. (2010), Gerroh and Gascho (2005).

Available potassium: The data in respect of effect of different sources and levels of silicon on available potassium at harvest presented in Table 9. The available potassium content in soil was found significantly influenced due to different sources of silicon. The source BA (A_3) recorded significantly highest available potassium in soil (223.327 kg ha^{-1}) over all the sources. The effect between levels and interaction of sources and levels of silicon were non significant. Increase in the soil available potassium content in soil may be due to optimum nitrogen and potassium rates and more availability of silicon in soil due to soil application of Si. The applied Si is responsible for release of native potassium due to secretion of root exudates. Similar finding reported by Phonde *et al*. (2009), Mali and Aery (2008) stated that by the application of calcium silicate in sugarcane, increased the soil available potassium.

Available silicon in soil : The data on effect of sources, levels of silicon and their interactions on soil available silicon at harvest of garlic are presented in the following Tables 10 and 11.

Available silicon at 50 days after planting: The data in respect of effect of different sources and levels of silicon on available silicon at 50 days after planting presented in Table 10. The soil available silicon was found significantly influenced due to application of Si sources, levels and their interaction of silicon.

The available silicon at 50 days after planting in soil was significant influenced due to sources of silicon. The source DE (A_1) recorded significantly highest available silicon in soil (97.33 kg ha^{-1}) than other sources. The levels of silicon was significant influenced on available silicon in soil at 50 days after planting. The application of Si @ 200 kg ha^{-1} (B_5) recorded significantly highest silicon in soil (112.95 kg ha^{-1}) over all the levels of silicon. The interaction effect of sources and levels of silicon significant. Interaction of A_1B_5 (125.93 kg ha^{-1}) was the highest in respect to available Si (200 kg ha^{-1}) over all other combinations. The available silicon increase with increase in levels of silicon in soil, but Si decrease with increase in duration of crop due to uptake of crop. Similar results reporded by Durgude *et al*. (2014) and Dhammapurkar *et al*. (2011) in different crop.

Silicon at harvest : The data in respect of effect of different sources and levels of silicon on available silicon at harvest presented in Table 11. The soil available silicon in soil found significantly influenced due to sources, levels and their interaction. The source (A_1) DE significantly recorded highest available Si (73.62 kg ha^{-1}) over all other sources of silicon however it was at par with A_2 (72.51 kg ha^{-1}) The levels of silicon was significantly influenced on soil available silicon. Application of Si @ 200 kg ha^{-1} (B_5) recorded significantly highest available silicon in soil (93.23 kg ha^{-1}) over rest of the levels of silicon. The interaction effect of sources and levels of silicon on an available silicon in soil at harvest was significant. Interaction of A_1B_5 was highest in available Si (98.79 kg ha$^{-1)}$ over all other interactions. The available silicon increased with increase in levels of silicon on soil, but average Si content was decreased slightly as increase of crop duration. These results in accordance with Balsubramanium *et al.* (2011) in rice crop.

DTPA Fe content of soil: The data in respect of effect sources and levels of silicon on available Fe at harvest presented in Table 12. Available Fe content in soil after harvest was non significantly influenced by sources of silicon.

Table 12. Effect of sources and levels of silicon on available micronutrient in soil at harvest (mg kg^{-1})

Treatments	Fe	Mn	Zn	Cu
	mg kg^{-1}			
A. Sources (A)				
A_1 : DE	4.317	8.113	0.636	1.729
A_2 : CS	4.436	8.209	0.657	1.728
A_3 : BA	4.432	8.319	0.641	1.678
S.E. ±	0.04	0.05	0.003	0.012
CD at 5%	NS	0.01	0.008	0.036
B. Levels (B)				
B_1 : 0	4.222	7.874	0.622	1.688
B_2 : 50	4.349	8.184	0.632	1.709
B_3 : 100	4.433	8.303	0.646	1.711
B_4 : 150	4.444	8.338	0.657	1.713
B_5 : 200	4.526	8.369	0.665	1.736
S.E. ±	0.03	0.07	0.004	0.016
CD at 5%	0.08	0.20	0.010	NS
C. Interaction (A×B)				
S.E. ±	0.05	0.12	0.006	0.028
CD at 5%	NS	NS	NS	NS
Initial	3.94	8.90	0.69	1.72

The levels of silicon significantly influenced in soil available Fe at harvest. The application of Si @ 200 kg ha^{-1} (B5) recorded significantly highest Fe in soil (4.526 mg kg^{-1}) over all the levels of silicon. The interaction effect of sources and levels of silicon was showed non significant. Similar findings reporded by Okuda and Takahashi (1962).

DTPA Mn content of soil: The data in respect of effect of different sources and levels of silicon on available Mn at harvest presented in Table 12. Available Mn in soil at harvest was significantly influenced due to application of different sources of silicon. The source (A_3) BA recorded significantly highest available Mn in soil at harvest (8.319 mg kg^{-1}) over all other sources. The levels of silicon significantly influenced on soil available Mn. Application of Si @ 200 kg ha^{-1} (B_5) recorded significantly highest available Mn (8.369 mg kg^{-1}) in soil at harvest. The lower level of silicon B_4, B_3 and B_2 (8.338, 8.303 and 8.184 mg kg^{-1} respectively). The interaction effect of sources and levels of silicon on available Mn content in soil at harvest was non significant. There was decreased in the DTPA-Mn content in soil at harvest of garlic. This might be due to efficient utilization of Mn by crop. The DTPA-Mn content in soil increased significantly with levels of silicon. Similar results were also noticed by Okuda and Takahashi (1962) and Durgude *et al.* (2014).

DTPA-Cu content in soil: Available DTPA-Cu content in soil was significantly influenced by sources of silicon. The source (A1) DE recorded significantly highest available Cu in soil at harvest (1.729 mg kg 1). However, it was at par with A2 (1.728 mg kg^1). However, effects were non significant in case of levels of Si and their interactions with sources. There was slight reduction in the DTPA-Cu content in soil at harvest. This might be due to uptake of Cu by crop. The application of silicon significantly increased DTPA-Cu content in soil at harvest. These results recorded by Okuda et al. (1962) and Durgude et al. (2014).

DISCUSSION

Effect of sources and levels of silicon on chemical properties and nutrient availability of garlic: The chemical properties of soil viz. pH, EC and OC was significantly influenced due to application of different sources and levels of silicon. In case of sources A1 (DE) recorded significantly highest pH and OC, while source As (BA) recorded significantly highest EC. The available nutrient viz. N, P and Si at harvest of garlic were significantly influenced due to application of different sources. In case of sources, the source A3 (CS) recorded significantly highest N and Si and source A3 (BA) recorded significantly highest available K at harvest. The avaialble micro nutrients viz. Mn. Zn and Cu was significantly influenced due to application of sources. The source A3 (BA) recorded significantly highest Mn and source A2 (CS) recorded significantly highest Zn and source A_1 (DE) recorded significantly highest Cu. In case of levels of silicon the available micronutrients Fe, Mn and Zn was showed significant influence due to application of silicon @200 kg ha -1.

CONCLUSION

Application of silicon through bagasse ash @ 200 kg ha^{-1} along with recommended dose of fertilizer (100:50:50 kg ha^1 and FYM) was found beneficial for highest Electrical conductivity, nitrogen and potassium availability of soil at harvet of garlic.

REFERANCES

Anon. 1997. Soluble silicates and their applications. *Cross field Publication*, Crossfield, Warrington, UK, Issue No. 2.

Arnon, D.I. and Stout, P.R. 1939. The essentiality of certain elements in minute quantity for plants with special reference to copper. Plant Physio., 14 : 371–375.

Balasubramaniam, Pedda Ghouse Peera, Mahendran, S.K. and Tajuddin, A. 2011. Release of silicon from soil applied with graded levels of fly ash with silicate solubilizing bacteria and farm yard manure. *Proceedings of the 5th Int. Conference on Silicon in Agriculture, Beijing,* p. 5.

Black, C.A. 1965. Methods of soil analysis, Part II, chemical and Mineralogical properties. *J. of American soc. Agronomy,* Wiscosin, USA.

Blake, G.R. and Hartage, K.H. 1986. Bulk density *In Methods* Incidence *of soil analysis, part-I*, Klute, A. (Ed.) II edition*, American Society of* Agronomy and Soil Sci. Soc. American. Inc., Madison, USA. pp. 371-373.

Chinnasami, K.N. and Chandrasekaran, S. 1978. Silica status in certain soils of Tamil Nadu. Madras Agricultural J. 65 : 743-746.

Dhamapurkar, V.B. 2011 Effect of calcium silicate slag with UB-DAP on the yield and nutrient uptake by rice and change in chemical properties of lateritic soil of Konkan. M.Sc. (Agri.). Thesis submitted to Dr. B.S.K. K.V. Dapoli (MS).

Durgude, A.G., Pharande, A.L., Kadlag, A.D., Kadam, S.R. and Patil, A.A. 2014. Silicon nutrition on onion, book-novel innovation and stratigies for boosting production and productivity in agriculture. Editor Ratan Kumar Rao. pp. 217-224.

Epstein, E. 1994. The anomaly of silicon in plant biology. Procedure of National Acadamy of Science. Department of Land, Air and Water Resources, Soils and Biogeochemistry, University of California, Davis USA. 91 : 11-17.

Epstein, E. and Bloom, A.J. 2005. Mineral Nutrition of Plants: *Principles and Perspectives*. 2nd Edn., Sunderland, MA : Sinauer.

Gascho, G.J. 2001. Silicon sources for agriculture. In: L.E. Datnoff, G.H. Snyder, G.H. Korndorfer, eds. *Silicon in Agriculture*. Amsterdam : Elsevier, pp. 197–207.

Gerroh, C.O. and Gascho, G.J. 2005. Effect of silicon on low pH soil phosphorus absorption and on uptake and growth of maize. *Community of Soil Science Plant Analysis*. 35(15 & 16) : 2369–2378.

Haysom, M.B.C. and Chapman, L.S. 1975. Some aspects of the calcium silicate trials at Mackay. Procedure of Australian Sugarcane Technology. 42 : 117-121.

Ho, D.Y., Zhang, H.L. and Zhang, X.P. 1980. The silicon supplying ability of some important paddy soils of South china. In Proc. of the symposium on paddy Soil. Naying China. 19-24, pp. 95.

Horiguchi, T. 1988. Mechanism of manganese toxicity and tolerance of plants. *Soil Sci. and Plant Nutri*. 34 : 65-73.

Idris, M.D., Hossain, M.H., and Choudhary. F.A. 1975. The effect of Silicon on lodging of rice in presence of added nitrogen. Plant and Soil. 43 : 691-695.

Iler, R.K. 1979. The chemistry of Silica. Wiley and Sons, New York, p: 621.

Imaizumi, C.K. and Yoshida, R.V. 1958. Edopological studies on silicon supplying power of paddy soils. *Bulletin of the National Institute of Agricultural Science, Ibaraki,* B. 8 : 261-304.

Jackson, M.L. 1973. Soil chemical analysis, Prentice Hall of India, Pvt. Ltd., New Delhi.

Jones, L.H.P. and Handreck, K.A. 1967. Silica in soils, plants, and animals. Adv. Agro. 19 : 107- 149.

Kadlag, A.D., Durgude, A.G., Pharande, A.L., Kadam, S.R., Kale, S.D. and Todmal, S.M. 2014 Silicon nutrition on onion, book-novel innovation and strategies for boosting production and productivity in agriculture. Editor Ratan Kumar Rao. pp. 369-371.

Kawaguchi, K. 1966 Tropical paddy soils. *Japan Agriculture Res*., 1 : 711.

Kono, M. 1969. Effectiveness of silicate fertilizer to japonica varieties, Tropical. Agriculture Research Center. 3 : 241 - 247.

Kono, M. and Takahashi, J. 1958. Selective absorption of silica and calcium by rice and tomato plants. *J. of Society of Soil Science, Tokyo.* 29 : 63 - 66.

Korndorfer, G.H., Snyder, G.H., Ulloa, M., Powell, G.D. and Datnoff, L.E. 2001. Calibration of soil and plant silicon analysis for rice production. J. of Plant Nutri. 24 : 1071-1084.

Liang, Y.C., Ma, T.S., Li, F.J. and Feng, Y.J. 1994. Silicon availability and response of rice and wheat to silicon in calcareous soils. *Community of Soil Sci. and Plant Analysis.* 25 : 2285-2297.

Lindsay, W.L. and Norvell, W.A. 1978. Development of DTPA soil test for zinc, iron, manganese and copper. Soil Sci. Soc. of American J. 42 : 421-428.

Ma, J.F., Miyake, Y. and Takahashi, E. 2001. Silicon as a beneficial element for crop plants. In : Silicon in Agriculture. Ed. L. E. Datnoff, G. H. Snyder. and G. H. Korndorfer. Elsevier Science, Amsterdam. pp. 17-39.

Mali, M. 2012. Impact of herbal extract application on soil properties and yield of maize. M.Sc (Agri.) thesis, submitted to Mahatma Phule Krishi Vidyapeeth. Rahuri, Maharashtra State, India.

Mali, M. and Aery, N.C. 2008. Influence of silicon on growth, relative water contents and uptake of silicon, calcium and potassium in wheat grown in nutrient solution. *J. of Plant Nutri.* 31(11) : 1867-1876.

Marschner, S.T. 1995. Beneficial mineral elements. In: Mineral Nutrition of Higher Plants. Academic Press Inc. Sandiego. USA.

Matychenkov, I.V., Pakhnenko, E.P., Bocharnikova, E.A. and Matichenkov, V.V. 2011. Detoxification of heavy metals in industrial and municipal wastes by activated Si. Proceedings of the 5th Int. Conference on Silicon in Agriculture, Beijing, p. 123.

Miyake, Y. 1993. Silica in soils and plants. Science of Research. Faculty Okayanam University. 81 : 61–79.

Mohanthy, S.K., Patnaik, S., Ranga Reddy, P. and Sridhar, R. 1982. Effect of submergence on the chemical changesin different rice soils. *Acta Agriculture Acadamy Science Hungary*. 26 :187-191.

Munir, M., Carlos, A.C.C., Heilo, G.F. and Juliano, C.C. 2003. Nitrogen and silicon fertilization of upland rice. Science of Agricola. 60(4) : 1-10.

Nayar, P.K., Misra, A.K. and Patnaik, S. 1977. Evaluation of silica - supplying power of soils for growing rice. Plant and Soil. 47 : 487-494.

Nelson, D.W. and Sommers, L.E. 1982. Total carbon, organic carbon and Organic matter. Methods of Soil Analysis, Part II, Page A.L. (Ed), Soil Science American Inc. Madison, Wisconsin, USA. pp. 539-579.

Obihara, C.H. and Russell, E.W. 1972. Specific adsorption of silicate and phosphate by soils. European Journal of Soil Science. 23(1) 105-117.

Okuda, A. and Takahashi, E. 1962. Effect of silicon supply on the growth of rice plant under various phosphorus supply levels. Part 7. J. of soil Sci. Soil and Manure, Japan. 33 : 65-69.

Phonde, D.B., Zende, N.A., Mali, V.S., Ghogake, P.V., Pawar, B.H., Yadav, R.G., Vasekar, V.S. and Undre, B.V. 2009. Response of sugarcane to levels and sources of silicon in medium deep black soils. Silicon Research Project in Vasantdada Sugar Institute, Pune (MS).

Pichel, A. and Hayer, M. 2013. A review of silicon and its benefits for plant. pp. 34-38

Prakash, N.B., Narayanswami, C. and Hanumantharaju, T.H. 2010. Effect of calcium silicate as a silicon source on growth and yield of rice in different acid soils of Karnataka, southern India IRRN. (0117-4185).

Sadgrove, N. 2006. Nutrient and moisture economics in diatomaceous earth amended growth media. Southern Cross University.

Savant, N.K., Korndorfer, G.H., Datnoff, L.E. and Snyder, G.H. 1999. Silicon nutrition and sugarcane production: A Review. *J. of Plant Nutri.* 22(12) : 1853-1903.

Schelhass. R.M. and Muller. A. 1977. Internal Report. Royal Tropical Institute, Amsterdam, No. AO-BO. pp. 77-212.

Sikka, R. and Kansal, B.D. 1995. Effect of fly-ash application on yield and nutrient composition of rice, wheat and on pH and available nutrient status of soils. Bioresource-Tech. 51(2-3) : 199-203.

Silva, J.A. 1971. Possible mechanisms of crop response to silicate applications. Process of International Soil Fertilizer Evalution. 1 : 805-814.

Singh, A.K., Singh, R. and Singh, K. 2005a. Growth, yield and economics of rice (*Oryza sativa*) as influenced by level and time of silicon application. Indian J. of Agronomy. 50(3) : 190-193.

Snyder, G.H., Jones, D.B. and Gascho, G.J. 1986. Silicon fertilization of rice on Everglades Histosols. *Soil Sci. Soc. of Amerika* J. 50 : 1259-1263.

Subbaih, B.V. and Asija, G.L. 1956. A rapid procedure for the estimation of available nitrogen in Soils. Current Sci. 25 : 259-260.

Takahashi, E., Ma, J.F. and Miyake, Y. 1990. The possibility of silicon as an essential element for higher plants. Comments Agric. Food Chemistry. 2 : 99-122.

Watanabe, F.S. and Oslen, S.R. 1965. Test of ascorbic acid methods for phosphorus in water and sodium bicarbonate extract of soil. *Procedure of Soil Science of American Society*. 21 : 677-678.

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