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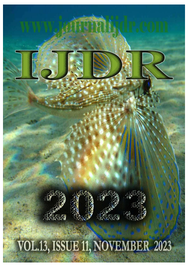

RESEARCH ARTICLE

OPEN ACCESS

EFFECT OF SOURCES AND LEVELS OF SILICON ON GROWTH AND YIELD OF GARLIC CV.PHULE NILIMA

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ABSTRACT

The field experiment entitled "Effect of sources and levels of silicon on growth and yield of garlic cv. Phule Nilima was conducted during *Rabi* with a view to study the effect of sources and levels of silicon on growth, and yield 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 plant height, number of leaves per plant, number of cloves per bulb, weight of 10 cloves, polar diameter, equatorial diameter, neck thickness, average weight of bulb, total soluble solid, total yield of bulbs and marketable yield of garlic were recorded significantly influenced due to application of different sources and their different levels. The source A_1 (DE) recorded significantly the highest TSS (38.71 ^{0}B). The source A_2 (CS) recorded significantly the highest number of leaves per plant (12.74), weight of 10 cloves (9.38 g), equatorial diameter (3.54 cm), average weight of bulb (19.23 g). The source A_3 (BA) found significantly superior in plant height (55.50 cm), polar diameter (3.39 cm), neck thickness (1.30 cm), total yield of garlic (16.36 t ha$^{-1)}$, than the overall other sources and the marketable yield of garlic significantly highest (14.90 t ha^{-1}). However, it was at par with source A_1 (DE) (14.64 t ha^{-1}). In case of levels B_5 (Si @ 200 kg ha^{-1}) recorded significantly superior plant height (55.54 cm), number of leaves per plant (13.22), number of cloves per bulb (18.89), weight of 10 cloves (9.37 g), polar diameter (3.45 cm), equatorial diameter (3.52 cm), neck thickness (1.19 cm) and average weight of bulb (19.33 g). The total uptake of N, P, K and Si was increased significantly with application of different silicon sources. In case of source A_1 (DE) was significantly superior uptake of Si (6.66 kg ha^{-1}) over all the sources. The source A_2 (CS) recorded significantly highest N, P and K (113.51, 28.33 and 99.63 kg ha^{-1} respectively). 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 increasing the growth and yield of garlic.

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INTRODUCTION

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 (SiO_2 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. An adequate supply of silica is essential if grasses and cereals are to give a good yield. Some crops are larger silicon accumulator. Si plays a very important role in increasing yield, disease and pest resistance of rice. Much of the work of Si nutrition has been done in respect of rice, sugarcane, wheat, maize and other cereals. But little work has been reported on vegetable and particularly cash crop like onion. Hence, it decided to study of Si nutrition aspect for garlic as the test crop. In view of this the present investigation was conducted to evaluate various indigenous sources of silicon (diatomaceous earth, calcium silicate, bagasse Ash) and levels of Si which influencing the garlic crop yield, quality of garlic bulbs, disease and pest resistance, uptake of nutrients and soil properties. Therefore the present investigation was carried out with,

1. To study the effect of sources and levels of silicon on NPK and silicon uptake by garlic.
2. To study the effect of sources and levels of silicon on yield and quality of garlic.

REVIEW

Effect of sources and levels of silicon on yield and quality of crop: Silicon is responsible for improved growth in rice (Lewin and Reimann, 1969). Ross *et al*. (1974) observed that there was marked increase in sugarcane yield with calcium silicate applications throughout the cycle. Pawar and Hegde (1978) also observed that foliar spray of 100-400 ppm Si applied twice per week to rice seeding up to the booting stage increased tillering, vegetative growth and photosynthetic efficiency. Silica in the soil increased dry matter yield and hastened heading. Fertilizing with excessive N tends to make rice leaves droopy, whereas Si keeps them erect. Yoshida (1981) reported that 10 per cent increase in the photosynthetic rate due to improved erectness of leaves by proper silicon management and consequently a similar increase in yield. According to Schnug and Franck (1984) under intensive systems of fertilization and plant protection, the possibilities of using the yield-promoting effect of Si are limited mainly to foliar application. Maximum dry matter yield was found at > 40 ppm Si with drooping leaves cultivar showed a greater response to Si than those with erect leaves (Kang, 1985). Ma *et al.* (1989) observed that addition of 100 ppm SiO_2 as silicic acid during the reproductive stage markedly increased straw yield. Addition of 100 mg Si kg^{-1} soil increased plant height, dry matter production and leaf area ratio (Rani *et al*. 1997). The photosynthetic activity is improved by more erectness of rice which is ultimately provided by silica. Silica nutrition has direct and indirect beneficial effects on rice growth largely due to its unique physiological role (Okuda and Takahashi, 1965; Yoshida, 1975 and Takahashi *et al*. 1990). Jayabad and Chockalingam (1990) recorded that when drought was imposed by irrigating only once a week during summer (May and June) they observed increased yields of sugarcane (var. CO-6304) due to spraying 2.5 % Sodium metasilicate. The effect was attributed to a reduced rate of transpiration. If the observation that a foliar spray of soluble Si improved plant growth and yield in sugarcane is confirmed, an appropriate Si management practice for alleviating the effect of drought could be developed for sugarcane. Plant grown with added Si also maintained or had enhanced photosynthesis, translocation of carbon to panicles/ seeds, water use efficiency, Transpiration and advanced from vegetative to reproductive growth (Savant *et al*., 1997). The maintenance of photosynthetic activity due to Si fertilization could be one of the reasons for the increased dry matter production (Agarie *et al*., 1992). The application of black to gray ash of rice hulls (at 0.5-2.0 kg m^{-1}) made rice seedling healthy and strong and increased their biomass (Savant *et al*., 1994).

Liang *et al*. (1994) reported that Si application increased the rice yields by 4.6-20.7 per cent. Hua *et al*. (1999) studied the influence of Si, Zn and Mn on high yielding maize plants grown under field conditions. The increase in average length of cob by 0.3, 0.8 and 0.5 cm and reduction in the length of sterile ear tip by 0, 0.3 and 0.2 cm due to Si, Zn and Mn treatments. Zhu *et al*. (1999) reported that effect of commercial silica fertilizer (25 % SiO_2, 35 % CaO) on the yield of hybrid rice. Yield increase of 8.52 and 14.72 per cent were achieved with 150 and 300 kg Si ha^{-1} respectively. Additional benefits are to be gained by amending soils with silicon as a standard production practice to increase rough rice yields (Lee *et al*., 1990). Korndorfer *et al.* (2001) reported that the effect of Si on reducing disease unquestionably contributes to increased yields, but Si has also been shown to increase yield in the absence of disease. There were significant increases in rice yield in their experiments. The predicted maximum yield ranged from 2804 to 8152 kg ha^{-1}. The maximum yield increase with calcium silicate application was 1625 kg ha^{-1}. When considering only sites with Si response, the average increase yield was 1007 kg ha^{-1}. Silica application significantly increased grain yield up to 150 kg Si ha^{-1} in rice (Singh *et al.* 2002). Mongia *et al.* (2003) also reported that the application of fly ash as Silica source was significantly increased the grain and straw yields in rice. Hwang *et al.* (2004) stated that combined application of N and Si enhanced growth parameters and reduced lodging index of both rice cultivars. It was thus concluded that the level of physiologically active GA_1 increased during vegetative and early reproductive stage, but starts declining at seed filling stage.

The dry matter accumulated at ripening stage of 30 rice genotypes, linearly increased with increased accumulation at both early and late season (Jiang *et al.* 2004). Nitrogen, Phosphorus, Potassium and Silicon accumulated at the rate of 3.76:1:4.55:7.10 at early stages and 2.88:1:4.54:8.09 at late stages of crop growth. Silicon was largely distributed in stem and leaf sheath at early season but distributed largely in panicle at late period. Singh and Singh (2005) reported that no significant increase in plant height and panicle length with the Si fertilization. Gong *et al*. (2003) observed that silicon increased plant height, leaf area and dry mass of wheat even under drought. Field experiments were conducted in the coastal zone soils of South India with application of calcium silicate as silicon source (Prakash *et al.,* 2011). Application of calcium silicate @ 3 to 4 t ha^{-1} as a Si source resulted in a significant increase in grain yield over the control and other treatments ($CaCO_3$) in the acid soils of Karnataka, southern India. Silicon and nitrogen interaction was found to be non-significant in obtaining higher yield of rice. But increased application of Si and N alone resulted in significant increase in yield attributes except test weight (Singh and Singh, 2005 and Singh *et al*., 2006). Abro *et al.* (2009) concluded that application of silicon levels of 0.25 and 0.50 per cent noticed positive effects while overdose was not only found un-advantageous but also reduced growth and yield in wheat crop. In a similar study by Guevel *et al*. (2007) the wheat plants fed with Silamol as foliar application showed an increased height. Phonde *et al*. (2009) found that the milliable cane height was increased at 400 kg ha^{-1} Si level, however they found increase in height beyond this level of Si was not significant. The different sources of Si viz. Bagasse ash, pond ash, and calcium silicate did not showed any significant difference in milliable cane height.

Ghanbari *et al.* (2011) concluded that in rice silicon application increases plant height because leaves become more erect, thus increasing photosynthesis rate, especially under conditions of high population densities and high doses of nitrogen. Prakash *et al*. (2011) reported that in rice the growth parameters *viz.* plant height (cm), panicle length (cm) and number of tillers were found to be increased with the foliar spray of silisic acid at 4 ml L^{-1} alone and along with half dose of pesticide over the control. Abro *et al.* (2009) found a positive response of all wheat varieties for spike length under low and moderate silisic acid concentrations while it significantly decreased as the levels of silisic acid increased. Durgude *et al*. (2014) reported that application of silicon to the onion crop to improve the all yield contributing characteristics. That is plant height, polar diameter, equatorial diameter, neck thickness of garlic bulb and yield of garlic bulbs. Pharande *et al.* (2014) observed that in sugarcane crop. The application of silicon source i.e. DE to rise the total solid sugar (^{0}B) in crop due to the different levels.

MATERIAL AND METHODS

An investigation was carried out by conducting a field experiment entitled, "Effect of sources and levels of silicon on growth and yield of garlic (cv. Phule Nilima)" at Department of Horticulture, All India Co-ordinated Research Project on Vegetable Crop, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri in *Rabi*. The details of material used in experimental techniques and analytical methods adopted during the investigation are presented. 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

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.	Date of sowing	:	21/10/2021
10.	Planting distance	:	15 x 10cm
11.	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.

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

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 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 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 texture: 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).

Silicon: The following method was adopted to determine Si content in plant samples.

Plant samples preparation: Plant samples were collected from experimental plots at the time of harvesting. Straw samples were initially washed in tap water followed by double glass distilled water, tapped with clean filter paper and then air dried. The garlic bulb samples were collected separately and air dried. Then straw and bulb samples were dried in oven at 65 ^{0}C till to get constant weight. The dried samples were powered in a stainless steel grinder and used for determining concentration of silicon by adopting standard methods of analysis.

Plant samples digestion for estimation of silicon: One gram oven dried plant sample was digested on a hot plate with 5 ml concentrated nitric acid; 1 ml perchloric acid (70 %) and 0.5 ml concentrated sulphuric acid in a 50 ml corning glass conical flask which was thoroughly cleaned with hot alkali followed by acids and distilled water. The digestion was continued till the brown fumes ceased and the volume of the acid was reduced to about 2 ml which took about 30 minutes. The resultant solution from digestion as then carefully transferred with repeated washings of solution 1 to 1.5 g of anhydrous AR sodium carbonate in suspension so that there was sufficient alkali in excess after neutralization of the acid. The resultant solution, after cooling, was made up to 250 ml and stored in polythene bottles (Nayar *et al.,* 1975).

Estimation of silicon from plant: A suitable aliquot (2 ml) was treated with 2 ml of 1:1 HCI followed by the addition of 2 ml of 10% ammonium molybdate and allwed to stand for 5 minutes. Addition of 0.5 ml of hydroxylamine hydrochloride (5 %) and l ml of oxalic acid (10 %) plus 2 ml of ascorbic acid (0.5 %) and the volume made up to 50 ml in corning flask. The blue colour developed after waiting 15 to 20 minutes was measured at 660 nm using spectrophotometer (Nayar *et al.,* 1975).

Table 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.	Plant analysis		
1.	Total N	Micro-kjeldahl method (H_2O_2+H_2SO_4)	Parkinson and Allen (1975)
2.	Total P	Vandomolybdate Yellow colour in Nitric Acid System. (Diacid digestion method)	Jackson (1973)
3.	Total K	Flame photometry (Diacid digestion method)	Chapman and Pratt (1961)
4.	Total Si	Triacid digestion method	Nayar *et al.* (1975)
IV	Bulb Analysis		
1.	TSS	Hand Refractometer	A.O.A.C. (1990)

Methods used for plant analysis

Uptake of nutrients by the Garlic: The uptake of nitrogen, phosphorus, potassium and silicon was worked out by multiplying the percentage of these nutrients in bulb and straw with the corresponding dry matter yields of the respective constituent**.**

Total Nitrogen: The silicon sources and plant samples (0.2 g each) were digested by using concentrated H_2SO_4 (5 ml) and H_2O_2 (5 ml). The volume was made by distilled water to 100 ml after digestion of sample. A suitable aliquot was taken for nitrogen distillation and nitrogen was determined by Micro kjeldahl method (Parkinson and Allen 1975).

Phosphorus: The plant samples (0.2 g each) were wet digested with nitric acid, sulphuric acid, and perchloric acid. The volume was made to 100 ml with distilled water after digestion and was used for determination of phosphorus. The total phosphorus was determined by using triacid extract and the yellow colour was developed with combined nitric acid vandatemolybdate reagent. Phosphorus was determined colorimetrically by using spectrophotometer at 420 nm wavelength as described by Jackson (1973).

Potassium: The plant samples (0.2 g each) were wet digested with sulphuric acid, nitric acid and perchloric acid. The volume was made to 100 ml with distilled water after digestion and was used for determination of potassium by flame photometer given by Chapman and Pratt (1961).

Observations recorded at harvest: The observation recorded while conducting this investigation were as under.

Growth characters

Plant height (cm): Ten plants from each treatment were selected randomly and labelled. The observations for plant height were recorded in centimeters at harvest. The height was measured from ground level to the tip of leaves.

Number of leaves per plant: Number of leaves per plant were counted and average was taken for same plants selected. The observations were recorded at harvest.

Yield and quality attributes

Number of cloves per bulb: The cloves were separated from the bulbs which are selected for measuring diameters and the cloves were counted and average was worked out.

Average weight of 10 cloves (g): Ten cloves were taken from each of the ten randomly selected bulbs and average weight of 10 cloves weighed and was averaged.

Polar diameter (cm): The ten bulb of garlic are selected randomly from each net plot at harvesting to measure the polar diameter with the help of Vernier caliper. The mean value was calculated and expressed in centimeters.

Equatorial diameter (cm): The ten bulb of garlic are selected randomly from each net plot at harvesting to measure equatorial diameter the with the help of Vernier caliper. The mean value was calculated and expressed in centimeters.

Neck thickness (cm): Neck thickness was measured by Vernier Calliper from the ten randomly selected bulbs.

Average Weight of bulb (g): The ten bulbs of garlic are selected randomly from each net plot at harvesting weight of ten bulbs done with the help of digital weighing balance. The mean weight was calculated and expressed in grams.

Yield of bulbs (t ha^{-1}): The bulb from each net plot are separated from leaves to weigh with the help of weighing balance and expressed in kilogram.

Marketable yield (t ha^{-1}): The harvested bulbs were sorted in two grades i.e. grade-I and grade-II. The grade-I garlic having good size (4-6 cm) and quality while, and grade-II bulb having no good size less than 3 cm.

Total soluble solid (^0B): The selected bulbs were sliced and pressed to remove juice for placing on hand refractometer for recording TSS.

Statistical analysis: The data generated after observations of soil, plant and pest and disease incidence from present experiment was statistically analyzed by methods suggested by Panse and Sukhatme (1985).

RESULTS

Plant height (cm): The data regarding mean plant height is influenced by different treatments at harvest are presented in Table 15. The Plant height was found significantly influenced due to sources and levels of silicon. The source (A_3) BA was recorded significantly highest plant height (55.50 cm) over all other sources. The levels of silicon significantly influenced plant height. Application of Si @ 200 kg ha^{-1} (B_5) recorded significant highest plant height (55.54 cm) over all other the levels of silicon. The interaction effect of sources and levels of silicon was non significant.

Number of leaves per plant: The number of leaves per plant was found significantly influenced due to sources and levels of silicon. The source (A_2) CS was recorded significantly highest number of leaves per plant (12.74) over all other sources. The levels of silicon significantly influenced number of leaves per plant. Application of Si @ 200 kg ha^{-1} (B_5) recorded significant highest number of leaves per plant (13.22) over all other the levels of silicon. The interaction effect of sources and levels of silicon was significant.

Number of cloves per bulb: The number of cloves per bulb was found significantly influenced due to sources and levels of silicon. The source (A_2) CS was recorded significantly highest number of cloves per bulb (19.46) over all other sources. The levels of silicon significantly influenced Number of cloves per bulb. Application of Si @ 200 kg ha^{-1} (B_5) recorded significant highest No. of leaves per plant (18.89) over all other the levels of silicon. The interaction effect of sources and levels of silicon was non significant.

Weight of 10 cloves (g): The Weight of 10 cloves of bulb was found significantly influenced due to sources and levels of silicon. The source (A_2) CS was recorded significantly highest weight of 10 cloves (9.38 g) over all other sources. The levels of silicon significantly influenced weight of cloves. Application of Si @ 200 kg ha^{-1} (B5) recorded significant highest weight of 10 cloves (9.37g) over all other the levels of silicon. The interaction effect of sources and levels of silicon was significant.

Table 4.Effect of sources and levels of silicon on yield attributing characters garlic

Treatments	Plant height (cm)	No. of leaves plant^{-1}	No. of cloves bulb^{-1}	Weight of 10 cloves (g)
A. Sources (A)				
A_1 : DE	54.97	12.00	17.92	8.75
A_2 : CS	54.39	12.74	19.46	9.38
A_3 : BA	55.50	12.20	17.43	8.68
S.E. $\pm$	0.13	0.02	0.08	0.02
CD at 5%	0.39	0.06	0.23	0.06
B. Levels (B)				
B_1 : 0	54.32	11.23	17.79	8.64
B_2 : 50	54.84	11.95	18.01	8.65
B_3 : 100	54.67	12.35	18.25	8.82
B_4 : 150	55.43	12.81	18.41	9.20
B_5 : 200	55.54	13.22	18.89	9.37
S.E. $\pm$	0.17	0.03	0.10	0.02
CD at 5%	0.51	0.08	0.30	0.08
C. Interaction (A×B)				
S.E. $\pm$	0.30	0.05	0.17	0.04
CD at 5%	NS	0.15	NS	0.13
Initial	3.94	8.90	0.69	1.72

Table 4 contd…..

Treatments	Polar diameter (cm)	Equitorial diameter (cm)	Neck thickness	Weight of bulb (g)
A. Sources (A)				
A_1 : DE	3.26	3.36	1.10	18.87
A_2 : CS	3.26	3.54	1.13	19.23
A_3 : BA	3.39^a	3.42	1.3	18.27
S.E. $\pm$	0.02	0.01	0.002	0.04
CD at 5%	0.07	0.04	0.007	0.12
B. Levels (B)				
B_1 : 0	3.12	3.36	1.11	18.18
B_2 : 50	3.25	3.39	1.14	18.35
B_3 : 100	3.30	3.44	1.16	18.85
B_4 : 150	3.39	3.48	1.16	19.25
B_5 : 200	3.45	3.52	1.19	19.33
S.E. $\pm$	0.03	0.01	0.003	0.09
CD at 5%	0.09	0.05	0.009	0.27
C. Interaction (A×B)				
S.E. $\pm$	0.05	0.03	0.005	0.09
CD at 5%	NS	NS	0.01	0.27
Initial	3.94	8.90	0.69	1.72

Polar diameter (cm): The polar diameter of bulb was found significantly influenced due to sources and levels of silicon. The source (A_3) BA was recorded significantly highest polar diameter (3.39 cm) over all other sources. The levels of silicon significantly influenced polar diameter. Application of Si @ 200 kg ha^{-1} (B_5) recorded significant highest polar diameter (3.45 cm) over all other the levels of silicon. The interaction effect of sources and levels of silicon was non significant. The polar diameter was significantly increase by application of silicon. Increase in polar diameter due to supply of nutrients from soil and beneficial effect of added silicon. The role of silicon for increase in cell division, elongation, expansion and deposition of silicon at cellular level make at more size. This effect of other factors responsible for increase in polar diameter. Similar finding were also reported by Durgude *et al*. (2014).

Equatorial diameter (cm): The data related to equatorial diameter of bulb was significantly influenced due to sources and levels of silicon

The source (A_2) CS recoded significantly highest equatorial diameter (3.54 cm). The levels of silicon significantly influenced by application of Si @ 200 kg ha^{-1} (B_5) and recorded significantly highest equatorial diameter (3.52 cm). However, it was at par with B_4 and B_3 (3.48 and 3.44 cm respectively). The interaction effect of sources and levels of silicon was not significant in respect of equatorial diameter. The equatorial diameter was significantly increased by application of silicon. It might be due to supply of nutrients from soil and beneficial effect of added silicon. The role of Si for increase in cell division, elongation, expansion and deposition of silicon at cellular level to make more size. This might be due to other factors responsible for increase in equatorial diameter. Similar results were also reported by Durgude *et al*. (2014).

Neck thickness (cm): The neck thickness of bulb showed significantly influenced due to application through different sources and levels of silicon (Table 16). The source (A_3) BA recoded significantly highest neck thickness (1.23 cm) over all sources. The levels of silicon significantly influenced due to application Si @ 200 kg ha^{-1} (B_5) for achiving highest neck thickness (1.19 cm). However, it was at par with B_4 (1.16 cm) and B_3 and B_4 (1.16 cm). The interaction effect of sources and levels of silicon were significant. The availability of nutrient to the crops at growth stages through silicon source might have increased neck thickness. Similar result for effect of sources and levels of silicon on neck thickness of garlic bulb reported by Durgude *et al*. (2014).

Average weight of bulb (g): The average weight of garlic bulb was significantly influenced due to sources. The source (A_2) CS recorded significantly highest neck thickness (19.23 g). over all sources The levels of silicon significantly influenced on bulb weight. Application of Si @ 200 kg ha^{-1} (B_5) recorded higher bulb weight (19.33 g). However, it was at par with B_4 (19.25 g). The interaction effect of sources and levels of silicon were significant. There was significant increase in the bulb weight with increased levels of silicon. This might be attributed to the better crop stand and enhanced photosynthesis. That's resulted into the availability and translocation of nutrients as well as photosynthates from source to sink. These findings are in accordance with similar by Durgude *et al.* (2014).

Yield: The data in respect of effect of different sources and levels of silicon yield of garlic bulbs presented in Table 5.The yield of garlic was found significant influence due to sources, levels and their interactions. The source (A_3) BA recorded significantly highest bulb yield (16.63 t ha^{-1}) over all other sources. The levels of silicon showed significantly influenced due to the application of Si @ 200 kg ha^{-1} (B_5) for gaining highest garlic bulb yield (17.43 t ha^{-1}) over all the levels of silicon. The interaction effect of sources and levels of silicon on yield of garlic was significant and recorded highest A_3B_5 (17.77 t ha$^{-1)}$ over all other interaction. Improved the crop stand by making leaves more erect due to Si that might have enhanced the photosynthetic activity and enabled plant to accumulate sufficient photosynthates. The accumulation of silicon in plant reduced its lodging as well as pest and disease incidence. These together coupled with efficient translocation of photosynthates towards sink. That ultimately resulted in more bulb yield. This might be the reason for higher yield of garlic bulb with application of Si @ 200 kg ha^{-1}. These results resembled to the findings reported by Korndorfer *et al.* (2001), Singh *et al*. (2005a) and Durgude *et al.* (2014).

Marketable yield: The data in respect of effect of different sources and levels of silicon on marketable yield of garlic presented in Table 6. The marketable yield of garlic bulb significantly influenced due to application through different sources and levels of silicon. The source (A_3) BA recorded significantly highest marketable yield (14.90 t ha^{-1}).The levels of application of Si @ 200 kg ha^{-1} (B_5) recorded significantly highest marketable yield (15.98 t ha^{-1}) over all the levels of silicon. The interaction effect of sources and levels of silicon were non significant. There was significant increase in the marketable yield of garlic grown on vertisols.

Table 5. Effect of sources and levels of silicon on yield of garlic (t 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	14.21	15.43	16.52	16.59	16.88	15.93
A_2 : CS	13.89	15.51	16.62	16.82	17.65	16.10
A_3 : BA	14.61	15.37	16.52	17.54	17.77	16.36
Mean	14.24	15.44	16.55	16.99	17.43	16.13
	A		B		(A×B)	
S.E. ±	0.01		0.01		0.02	
CD at 5%	0.03		0.04		0.08	

Table 6. Effect of sources and levels of silicon on marketable yield (t 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	13.19	14.48	14.52	15.93	15.63	14.64
A_2 : CS	12.44	13.42	14.24	15.47	16.21	14.36
A_3 : BA	12.83	14.34	15.54	15.69	16.09	14.90
Mean	12.82	14.08	14.77	15.52	15.98	14.63
	A		B		(A×B)	
S.E. ±	0.06		0.08		0.14	
CD at 5%	0.18		0.23		0.40	

Table7. Effect of sources and levels of silicon on total soluble sugar (^{0}B)

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	37.28	38.24	38.52	39.72	39.82	38.71
A_2 : CS	37.05	38.12	38.41	39.52	39.64	38.55
A_3 : BA	37.21	38.24	38.47	39.48	39.53	38.59
Mean	37.18	38.20	38.47	39.57	39.66	38.62
	A		B		(A×B)	
S.E. ±	0.01		0.02		0.03	
CD at 5%	0.04		0.05		0.10	

The adequate silicon supply might have attributed to higher yield reported by Singh *et al*. (2006), Prakash *et al.* (2011) and Durgude *et al.* (2014).

Total solid sugar (TSS ^{0}B): The data in respect of effect of different sources and levels of silicon on TSS (^{0}B) of garlic presented in Table 7. The TSS (^{0}B) of garlic found significantly influenced due to application of Si through different sources, levels and their interactions. The source (A_1) DE recorded significantly highest TSS (38.71^{0}B). The levels of silicon significantly influenced due to TSS of garlic bulb. The application of Si @ 200 kg ha^{-1} (B_5) recorded significantly highest TSS (39.66 ^{0}B) over B4 and B3 (39.57 and 38.47 ^{0}B respectively). The interaction effect of Si sources and levels significantly influenced on TSS of garlic. The application of Si @ 200 kg ha^{-1}(B_5) recorded significantly highest TSS (39.66 ^{0}B) over all their interactions followed by A_1B_4, A_2B_5, A_1B_3 and A_2B_4 (39.72, 39.64, 38.52, and 39.52 respectively). The similar findings were also reported by Pharande *et al*. (2014).

it was at par with (B_4) (31.27 kg ha^{-1}). The interaction effect of sources and levels of silicon was not significant. The increase in total uptake of P due to application of silicon might be attributed to role of silicon in increasing the availability of soil phosphorus which might have increase the biomass and root activity. The similar findings on increases in uptake of nutrients due to application of silicon were reported by Gerroh and Gascho (2005), Yang *et al.* (2008), Rani and Narayan (1994) and Mongia *et al*. (2003).

Potassium: The data in respect of effect of different sources and levels of silicon on total uptake of potassium by plant from soil presented in Table 10. The potassium uptake was significantly influenced due to sources of silicon. The source (A_2) CS recorded highest potassium uptake (99.63 kg ha^{-1}) and it was at par with A_3 (98.52 kg ha^{-1}). The levels of silicon significantly increased by application of Si and level of Si @ 200 kg ha^{-1} (B_5) recorded significantly highest total potassium uptake (113.02 kg ha^{-1}) over all other levels of silicon.

Table 8. Effect of sources and levels of silicon on nitrogen uptake (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	89.36	106.18	111.30	121.86	126.77	111.09
A_2 : CS	88.50	109.40	114.57	124.90	130.20	113.51
A_3 : BA	87.93	107.25	111.52	121.42	134.51	112.53
Mean	88.60	107.61	112.46	122.73	130.49	112.38
	A		B		(A×B)	
S.E. ±	0.46		0.60		1.045	
CD at 5%	1.35		1.74		3.02	

Table 9. Effect of sources and levels of silicon on phosphorus uptake (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	19.16	23.63	24.08	27.46	28.76	24.62
A_2 : CS	20.30	24.50	28.58	36.97	31.28	28.33
A_3 : BA	20.55	24.23	27.33	29.37	33.33	26.96
Mean	20.00	24.12	26.66	31.27	31.32	26.64
	A		B		(A×B)	
S.E. ±	0.69		0.89		1.53	
CD at 5%	1.99		1.99		NS	

Effect of sources and levels of silicon and their interaction on uptake of nutrients by garlic: The data pertaining to effect of sources and levels of silicon and their interactions on nutrient uptake of N, P, K and Si by garlic

Nitrogen: The data in respect of effect of different sources and levels of silicon on uptake of nitrogen by garlic plant presented in Table 8. The nitrogen uptake was significantly influenced due to sources of silicon. The calcium silicate source (A_2) recorded the significantly highest total nitrogen uptake (113.51 kg ha^{-1}) and it was at par with A_3 (112.53 kg ha^{-1}). The levels of silicon was significantly influence due to the application Si @ 200 kg ha^{-1} (B_5) and recorded significantly highest uptake of nitrogen (130. 49 kg ha^{-1}) over all other levels of silicon. The interaction effect of sources and levels of silicon on nitrogen uptake was found significant and recorded highest due to application of Si @ 200 kg ha^{-1} A_3B_5 (134.51 kg ha^{-1}) over all other interactions. This might be due to the proper crop stand, probable root growth, supply of nutrient and conducive physical environment created on account of addition of silicon. Such favourable situation might have facilitated better absorption of nitrogen by crop. Silicon fertilized plant gained maximum benefits of ample nitrogen availability. This result agrees with reports of Talashikar *et al*. (2000), Egrinya *et al.* (2008), Savant *et al*. (1997).

Phosphorus: The data in respect of effect of different sources and levels of silicon on total uptake of phosphorus by plant from soil presented in Table 9. The total phosphorus uptake was significantly influenced due to sources of silicon. The effect of source (A_2) CS was significantly highest for P uptake (28.33 kg ha^{-1}) and it was at par with A_3 (26.96 kg ha^{-1}). The levels of silicon showed significantly influenced on P uptake. Application of Si @ 200 kg ha^{-1} (B_5) recorded significantly highest phosphorus uptake (31.32 kg ha^{-1}) and

The interaction effect of sources and levels of silicon was significantly influenced on K uptake by plant. The application of Si through BA @ 200 kg ha^{-1} (A_3B_5) recorded significantly highest K uptake (115.30 kg ha^{-1}) it was followed by A_3B_5 (112.77 kg ha^{-1}). The application of chemical fertilizers in combination with silicon levels significantly increased total potassium uptake by upland paddy. The positive response of higher silicon application towards uptake of potassium can be linked to silicification process of cell walls. Increased in the potassium uptake possibly might be due to stimulating effect of silicon on activation of H+-ATPase in the membrane. Similar results were also noticed by Kaya *et al*. (2006), Egrinya *et al*. (2008) and Schelhass and Muller (1977).

Silicon: The data in respect of effect of different sources and levels of silicon on uptake of silicon by plant from soil presented in Table 11. The silicon uptake was significantly influenced due to sources of silicon. The source (A_3) BA recorded significantly highest total silicon uptake (6.66 kg ha^{-1}) over all other sources. The levels of silicon significant influenced Si uptake. Application of Si @ 200 kg ha^{-1} (B5) recorded significantly highest silicon uptake (8.56 kg ha^{-1}) over all the levels of silicon. The interaction effect of silicon source and level was significantly influenced. Application of Si @ 200 kg ha^{-1} (A_3B_5) recorded significantly highest Si uptake (11.97 kg ha^{-1}) over all the interactions. The higher silicon uptake was associated with increased levels of silicon. This might be due to increase in root growth and available form of silicon in soil.

The addition of silicate material to soil have increased in silicon availability might be the reason for higher silicon uptake. The application of silicon leads to improvement in crop stand, enhanced photosynthesis and resistance against biotic stress.

Table 10. Effect of sources and levels of silicon on potassium uptake (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	88.47	91.93	96.20	101.00	111.00	97.72
A_2 : CS	88.57	93.93	97.47	105.43	112.77	99.63
A_3 : BA	88.10	93.33	95.46	100.40	115.30	98.52
Mean	88.38	93.07	96.38	102.28	113.02	98.62
	A		B		(A×B)	
S.E. ±	0.46		0.60		1.03	
CD at 5 %	1.34		1.73		2.98	

Table 11. Effect of different sources and levels of silicon on silicon uptake (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	0.92	2.95	4.03	4.82	5.20	3.58
A_2 : CS	0.94	3.63	5.51	6.73	8.50	5.06
A_3 : BA	1.21	4.28	6.39	9.43	11.97[a]	6.66[a]
Mean	1.02	3.62	5.31	7.00	8.56[a]	5.10
	A		B		(A×B)	
S.E. ±	0.128		0.165		0.286	
CD at 5%	0.370		0.479		0.829	

This are the certain other factors might have responsible for higher silicon uptake by garlic. These results are in conformity with the findings of Nayar *et al.* (1982), Liang *et al*. (2006), Prakash *et al.* (2011).

DISCUSSION

Effect of sources and levels of silicon on yield and quality of garlic: The yield attributing characteristics of garlic viz. plant height, number of leaves per plant, number of cloves per bulb, weight of 10 cloves, polar diameter, equatorial diameter, neck thickness, total yield as well as marketable yield of garlic bulbs, total soluble solid (TSS) and average weight of bulb^{-1} was significantly influenced due to the application of different sources. In case of source A_2 (CS) recorded significantly highest plant height, number of leaves per plant, number of cloves per bulb, weight of 10 cloves, equatorial diameter, average weight of bulb^{-1} and source A_3 (BA) for significantly highest polar diameter, neck thickness, total yield as well as marketable yield of garlic bulbs. The source A_3 (DE) recorded significantly highest Total Soluble solid (TSS). The plant height, number of leaves per plant, number of cloves per bulb, weight of 10 cloves, polar diameter, equatorial diameter, neck thickness, total yield as well as marketable yield of garlic bulbs of garlic was significantly influenced due to application of different levels of silicon. The level (B_5) Si @ 200 kg ha^{-1} was significantly highest in these respect. The total yield and TSS of garlic bulbs was significantly influenced due to interaction effect of sources and levels of silicon. The interaction (A_3B_5) recorded significantly highest yield of garlic and interaction (A_1B_5) recorded significantly highest TSS.

Effect of sources and levels of silicon on total uptake of N, P, K and Si on *Garlic*: The nutrient uptake viz. N, P, K and Si was significantly influenced due to application different sources. In case of source A_2 (CS) recorded significantly highest N, P and K, while source A_3 (BA) recorded significantly highest Si. In levels of silicon the nutrient uptake N, P, K and Si was significantly influenced due to application of Si @ 200 kg ha^{-1}. The total nutrient uptake of garlic was significantly influenced due to interaction effect of sources and levels of silicon. The interaction (A_3B_5) recorded significantly highest N and K.

CONCLUSIONS

1. There was significant increase in plant height, number of leaves per plant, number of cloves per plant, weight of 10 cloves, polar diameter, equatorial diameter, neck thickness, weight of bulb, Total Soluble Solid, total yield and marketable yield due to silicon application, however there was significant difference between levels of silicon and sources of silicon.
2. 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 increase in polar diameter, total yield, marketable yield of garlic in medium deep black soil. Considering the availability and cost of material, bagasse ash proved as good source of silicon for garlic.
3. The uptake of N, P, K and Si was significantly increased over no application of silicon sources, levels and their interaction.

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