RESPONSE OF GARLIC TO SILICON (Cv. PHULE NILIMA)

by

Miss Gade Pornima Rajendra.
Reg. No. 017/324

A Thesis submitted to the
MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI-413 722, DIST: AHMEDNAGAR,
MAHARASHTRA, INDIA.

In partial fulfilment of the requirements for the degree

of

MASTER OF SCIENCE (HORTICULTURE)

in

VEGETABLE SCIENCE

DEPARTMENT OF HORTICULTURE
POST GRADUATE INSTITUTE
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2019

CANDIDATE'S DECLARATION

I hereby declare that, this thesis or part
there of has not been submitted
by me or other person to any
other University or Institute
for a Degree or
Diploma

Place : MPKV, Rahuri (P. R. GADE)

Date : / / 2019

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CERTIFICATE

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The assistance and help received during the course of this investigation have been duly acknowledged.

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Date : / / 2019 Research Guide

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Place : MPKV, Rahuri (P. A. Turbatmath)

Date : / / 2019

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"Gratitude is the most exquisite form of memory"

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And last, I bow my head before Lord Ganesha for giving me wisdom and strength required to complete my post graduate programme successfully.

Place: M.P.K.V, Rahuri

Date: / /2019 *(Miss.P.R.Gade)*

CONTENTS

LIST OF TABLES

LIST OF FIGURE

LIST OF PLATES

LIST OF ABBREVATIONS AND SYMBOLS

%	:	Percent
(ºC)	:	Degree Centigrade
@	:	At the rate of
BA	:	Bagasse ash
C.D.	:	Critical difference
cm	:	Centimeter
CS	:	Calcium silicate
Cu	:	Copper
cv.	:	Cultivar
DE	:	Diatomaceous earth
dSm^{-1}	:	Deci Simen per meter
DTPA	:	Diethylene triamine
EC	:	Elecrical conductivity
et al	:	et alli (and others)
Fe	:	Ferrous (Iron)
Fig.	:	Figure
FYM	:	Farm Yard Manure
$g\ kg^{-1}$	:	Gram (s) per killo gram
g	:	Gram (s)
ha	:	Hectare
i.e.	:	That is
K	:	Potassium
Kg	:	Kilo gram
$Kg\ ha^{-1}$	:	Kilogram (s) per hectare
$Mg\ kg^{-1}$	:	Milligram per killo gram
Mn	:	Mangnese
N	:	Nitrogen

ºB	:	Degree brix
OC	:	Organic Carbon
P	:	Phosphorus
Ppm	:	Parts per million
q ha^{-1}	:	Quintal per hectare
RDF	:	Recommended dose of fertilizer
S.E±	:	Standard error
Si	:	Silicon
TSS	:	Total Soluble solids

ABSTRACT

RESPONSE OF GARLIC TO SILICON (Cv. PHULE NILIMA)

by

Miss Gade Pornima Rajendra

A Candidate for the degree

of

MASTER OF SCIENCE (HORTICULTURE)

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Mahatma Phule Krishi Vidyapeeth, Rahuri – 413 722

2019

Research Guide	:	**Dr. B. J. Shete**
Department	:	**Vegetable Science (Horticulture)**

The present investigation entitled "Response of Garlic to Silicon (cv. Phule Nilima)" was conducted during *Rabi*- 2017 -18 at All India Coordinated Research Project on vegetable crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri with a view to study the effect of sources and levels of silicon on nutrients and silicon uptake, growth, yield, disease and pest incidence of garlic. The present investigation was carried out in Factorial Randomized Block Design (FRBD) with control. Fifteen treatments comprised of five levels of silicon (0, 100, 150, 200, and 250 kg Si ha^{-1} through three sources of silicon viz.,Diatomaceous earth, Calcium silicate, and Bagasse ash with one absolute control treatment.

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 solids, yield per plot, total yield of bulbs and marketable yield of garlic significantly influenced due to application of different sources of silicon and their different levels. The source calcium silicate recorded significantly the highest plant height (52.95cm), number of leaves per plant (10.47), polar diameter (4.07cm), equatorial diameter (4.43cm), neck thickness (1.37cm), number of cloves per bulb (22.20), weight of 10 cloves (10.43g), weight of bulb (23.20g), yield of garlic per plot (8.94kg),total yield of garlic (148.96 qt ha^{-1}),marketable yield (92.33%).The source bagasse ash recorded significantly the highest TSS (37.35ºB).

In case of levels of Si @ 250 Kg ha^{-1} recorded significantly superior plant height (56.58cm), number of leaves per plant (10.89), polar diameter (4.12cm), equatorial diameter (4.92cm), neck thickness (1.45cm), number of cloves per bulb (22.44), weight of 10 cloves (11.93g), weight of bulb (23.67g), yield of garlic per plot (10.41kg),total yield of garlic (173.55qt ha^{-1}), marketable yield (96.86%) and TSS (38.17ºB).

The chemical properties viz., pH, EC significantly influenced due to application of different sources. In case of source calcium silicate application significant increase in soil pH (8.16) and EC (0.45dSm^{-1}) and the source diatomaceous earth recorded significant increase in organic carbon (0.52%) content in soil.

The available nutrient at harvest viz. N, P, K, Si, Mn, Zn, Fe, were significantly influenced due to application of different sources. In case of source calcium silicate recorded significantly superior N (175.29 kg ha^{-1}), P (16.48 kg ha^{-1}), K (284.51 kg ha^{-1}), Si (53.59 mg kg^{-1}), Fe (4.50 mg kg^{-1}). Mn (8.47 mg kg^{-1}) at harvest. In case of source A_1 (DE) recorded significantly highest Zn and Cu (0.67 and 1.40 mg kg^{-1}, respectively) at harvest.

In case of levels of silicon @ 250 kg ha^{-1} found significant increase in available N (183.07kh ha^{-1}), P(17.98kg ha^{-1}), K(294.09 kg ha^{-1}), Si(62.31mg kg^{-1}), Fe (4.48mg kg^{-1}), Mn (8.78mg kg^{-1}), Zn (0.69 mgkg^{-1})and Cu(1.46mg kg^{-1}) content in soil over all other levels of Si application.

The total uptake of N, P, K and Si were increased significantly with application of different silicon sources. In case of source calcium silicate was significantly superior uptake of N (40.12khg ha^{-1}), P (13.44 kg ha^{-1}), K (29.74 kg ha^{-1}) and Si (4.82 Kg ha^{-1}) by garlic.

The pest infestation and disease incidence was significantly influenced by application of silicon. Application of calcium silicate recorded lowest infestation of thrips (5.08) and mites (7.34) on the basis of average survival per plant, while the incidence of purple blotch was (5.00%).The pest infestation and disease incidence was decreased with increased levels of silicon.

From the above result, it can be concluded that, the application of silicon @ 250 kg ha^{-1} through calcium silicate proved as good source of silicon for increasing the growth and yield of garlic.

Pages 1 to 74

1. INTRODUCTION

The word silicon is derived from the latin word ‘Silex’, meaning flint. Silica refers to a compound in which each molecule of silicon is chemically bound to two oxygen molecules (SiO_2; Silicon dioxide). Silicon (Si) is the second most abundant element (27.72 %) after oxygen (46.60 %) in the earth crust. Silicon dioxide comprises 50 – 70 % of the soil mass, the earth crust contain large proportion of silicon, this silicon is mostly in the form of silicates. Although Si is abundant in the earth`s crust, its availability in the soil is very low because of its low solubility from soil source. In soil solution, silicon is found mostly in the form of silicic acid ($Si(OH)_4$). (Lindsay and Norvell, W.A.1978; Epstein 1994) and in plants, silicon is found mostly as silicon dioxide. The accumulation of Si in the plant varies considerably from 1 to 10 % of dry weight according to the species (Currie and Perry 2007). This wide range of Si concentration is mainly due to Si uptake and transport characteristics of each species. The majority of species accumulate Si via passive diffusion, i.e the element moves from xylem to shoots following the water flux driven by transpiration.

In the past 20 years, the scientific documentation on the benefits of Si to crops has helped establish Si fertilization as an agronomic practice in many agricultural lands worldwide. All plants grown in the soil contain some Si which is primarily deposited on the cell walls of epidermis and vascular tissues conferring strength, rigidity and resistant to pests and diseases. Under field condition, Si fertilization is widely used to enhance production as well as improving resistance to lodging and increasing the erectness of leaves; these effects allow better light transmittance through plant canopies and thus indirectly improve whole plant photosynthesis. Many studies have shown that leaf transpiration of some plants is reduced considerably by Si application. It was postulated that this effect might be due to reduction in transpiration rate through cuticular layers thickened by silica deposits. The Si absorbed by roots is transported to the shoots and deposited either inside or outside the plant cell as hydrated silica

Also effect of Si on the greater tolerance of higher plant to drought could be associated with an increase action of antioxidant defenses a reduction in the oxidative damage of functional molecule and membranes, and maintenance of many physiological as well as photosynthetic processes, under water deficit conditions. Silicon fertilizers can improve calcium content, nitrogen, and ratio of sugar to nicotine in tobacco and makes the quality higher. Si fertilizer can improve the sugar content in grape, watermelon. Si fertilizer can increase the vitamin C content in eggplant , cabbage, green Chinese onion garlic and ginger , it also increase the protein content in soybean and peanut . Si fertilizers can improve quality of tea. The usual carrier for Si is calcium silicate and this material also supply Ca to a Ca deficient soil. Silicon fertilizers improve the quality of Horticultural product. (Matichenkov and Bocharnikova, 2004) 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.

Garlic contains approximately 33 sulfur compound .Garlic (*Allium sativum L.*) member of Alliaceae or Lilliaceae family is the important bulb crop next to onion. Garlic originated in central Asia where it was extended to the Mediterranean region in the prehistoric dates (Thompson and Kelly, 1957). The cloves of garlic bulb used in flavoring of various vegetarian and non-vegetarian dishes.

Garlic has higher nutritive value as compared to other bulbous crops. In Ayurveda garlic is considered as "Nectar of life." It is rich source of carbohydrates (29.0%), proteins (6.3%), minerals (0.3%), essential oils (0.1– 0.4%) and also contain appreciable quantities of fats and vitamin C. It has antibacterial, antifungal, antiviral and antiprotozoal properties. It is beneficial to cardiovascular, and immune system and has antioxidant and anticancer properties (Harris *et al.*, 2001). In addition to this, garlic has several medicinal properties and its reputation as a medicine has increased to such an extent that garlic oil capsules are now marketed through pharmacies and health food stores (Rahim and Fordham, 1994) allicin is the active constituent of garlic.

India rank second after China world in area (274 thousand hectare) and second in production (1271 thousand MT) of garlic with an average productivity of 5.09 metric tons per ha. India contributes 14% of world area and 5 % of production. The major garlic producing states of India are Madhya Pradesh, Orissa, Rajasthan, Karnataka, U.P and Gujarat.

Garlic is cultivated in India in the plains during the month of October to March. In northern hills it is grown during September to June and in southern from May to October. Garlic production requires a growing period of 4.5 – 6 months and the amount of rainfall ranges between 600 mm to 700 mm during its production season. The optimum temperature for garlic growing lies between 12 -14 ºc. Garlic withstands moderate of frost and produced during the cold season, in rotation with pulses that have contributed in breaking the life cycle of pest problem and improve soil fertility. It is propagated only vegetatively. In India large amount of dehydrated garlic product are exported to Japan, UK, Italy, Turkey.

Garlic is important crop in Rabi season. In this season pests like mites, thrips and dominant disease like purple blotch are attack on garlic and decrease the yield and quality of crop. This attack may be controlled by using different fungicides and insecticides however, by using the different sources and levels of silicon application through soil controls the pests, diseases as well as improve the quality and yield of garlic. Garlic bulbs supplied with N, P, K to improve bulb quality and nutrient. Nitrogen showed a direct positive effect on pungency and total soluble solids (TSS) content. The lack of experimental evidence on the response of garlic to silicon to achieve its productivity potential. The present experiment was therefore, undertaken to assess the efficiency of different sources and levels of silicon on growth and yield of garlic as well as insect, pest and disease resistance adoptable in garlic cultivars by different sources of Si with different levels silicon treatment to be applied in the study area.

Objectives:–

1. To study the effect of sources and level of silicon on total NPK and silicon uptake in garlic.
2. To study the effect of sources and levels of silicon on growth, yield and quality of garlic.
3. To study the effect of sources and levels of silicon on pest infestation and disease incidence in garlic.

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2. REVIEW OF LITERATURE

Garlic is one of the important edible Allium crop grown and used as a spice or a condiment throughout India. Garlic has higher nutritive value than other Alliums. A production of Garlic has been long continued as a specialized and commercial farming system. The bulb yield and quality of garlic largely depends on different factor like climate, soil, proper dose and time of application of fertilizers, irrigation schedule, cultivar season of planting and planting density. Among these, effect of different sources and different levels of silicon on growth, yield, quality and incidence of pest and disease.

A good deal of research work has been done in India to evaluate the response of garlic to applied silicon. This has encouraged generating information for farmer and vegetable growers. In view of these facts, the literature available on these aspect has been reviewed in this chapter on following heads.

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

2.1.1 pH

Yasuto Miyake and Eiichi (1983) reported that successive application of silicon fertilizer in cucumber plant, resulted in the increase soil pH.

Gu *et al*. (2011) reported that application of silicon rich material (fly ash) resulted in an increase in the soil pH, which decrease the phytoavaibility of Cb and reduced the uptake of heavy metals in rice.

Tavakkoli *et al.* (2011) reported that application of silicon element for rice then it significantly increases pH of the soil.

Pichel and Hayer. (2013) also experimented increase in pH with addition of silicon source (fly ash). It also been well understood that uptake of silicon by rice would tend to raise the pH .also reported that, there was a significant increase in soil pH from its initial value of 5.40 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 Co_2 and produced hydroxyl and other ionic forms in the soil solution and thereby carbonate are precipitated. These reactions and the presence of Na, would responsible for the high pH value

Durgude *et al.* (2014) experimented 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.

Kadlag *et al*. (2014) experimented 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.

Agostinho F.B. *et.al* (2017) reported that there was a significant increase in soil pH in rice with the application of different sources of silicon.

2.1.2 Electrical conductivity

Pichel and Hayer (2013) experimented that, the application of silicon fertilizer slowly increased EC values of soil. But no significant difference was observed in EC between 150 – 200 kg Si per ha. Increasing EC of soil because of applying 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.

Durgude *et al*. (2014) experimented that, the use of different sources of silicon in garlic crop uptake of silicon would tends to rise in EC of soil.

Kadlag *et al*. (2014) concluded that, the dose of different silicon sources with different levels, in sugarcane crop rise in EC and increasing the EC value of soil due to the addition of diatomaceous earth as a source of silicon.

2.1.3 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 when fly ash was applied alone in comparison to fly ash integrated with RDF and FYM.

Durgude *et al*. (2014) experimented that, the application of DE did not show distinguish variation in chemical properties after harvest of garlic. The application of DE @ 400 kg /ha + full POP recorded significantly highest organic carbon.

2.1.4 Nitrogen

Kono, (1969) & Ho *et.al* reported that, rice yields are declining due to excessive application of nitrogenous fertilizers. But application of Si has the potential to raise the optimum N rate due to synergistic effect, thus enhancing the productivity of lowland rice soil.

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.

Ma *et al*. (2001) reported that nitrogen is the most common nutrient that limits rice production. Deficiency symptoms are frequently characterized by general chlorosis (yellowing) of leaves and areduction in overall plant vigor and growth. At flowering. N deficient plants are stunted and have fever 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.

Prabhu *et al.* (2001) reported that, the effect of Si on pre – infection and post infection physiological plant response has unlimited prospect for blast control at the vegetative phase. The ratio of N / Si plays an important role in incidence of rice blast, leaf scald and sheath blight.

Mauad *et al.* (2003) evaluated the effects of nitrogen and silicon fertilization on vegetative and yield components of rice and concluded that, nitrogen fertilization increased the number of stems and panicles per square meter and the total number of spikelets, reflecting on grain productivity. Excessive tillering caused by inadequate nitrogen fertilization reduced the percentage of fertile stalks, spikelet fertility and grain mass. Si fertilization reduced the number of blank spikelets per panicles and increased grain mass.

Mongia *et al. (*2003) showed that, the fly ash could be potential source of silica and plant nutrients, silicon was found to be synergistic and positive interaction with the applied nitrogenous fertilizers and increased yield in rice.

Munir *et al.* (2003). Application of N fertilizers is an important practice for increasing rice yields. However, when applied in excess may limit yield because of lodging, promote shading and susceptibility to insects and diseases. These effects could be minimized by the use of Si.

Bin *et al.* (2004) investigated the effect of nitrogen application combined with silicon on the yield and growth of rice and soil nutrient status. The results showed that either nitrogen or silicon application could increase yield and growth of rice, with the effect of nitrogen being better than that of silicon.

Durgude *et al.* (2014) experimented that use of different levels of different sources of silicon in garlic crop improve the uptake of silicon would tends to rise in available nitrogen

2.1. 5 Phosphorous

Dean and Rubins (1947) reported the ability of silicate ion to displace the phosphate ion from the adsorbed conditions in the soil, thus increase in availability of phosphorus.

Vyas and Motiramani (1971) concluded that application of organic matter @ 1. 0 g (10000 ppm) and silicate at 0. 1 g (10000) and 0.3 g per 100 g of soil proved effective in increasing the available phosphorus from native as well as added phosphorus.

Smyth and Sanchez (1980) reported that, when silicate fertilizers are applied to the soil, silicate is specifically adsorbed by soil colloids thus releasing previously adsorbed phosphate. This could cause an increase in the concentration of phosphate in soil solution and stimulate phosphate in soil solution and stimulate phosphate uptake and translocation by plant.

Gladkova (1982) reported that, various Si fertilizer (amorphous dioxide of Si, silicates of calcium) can increase the quantity of mobile phosphate in soil.

Subramanian and Gopalswamy (1990) application of Si fertilizers decreased in phosphorus retention capacity of soil, and the increased solubility of P, leading to increase efficiency of phosphatic fertilizer.

Ma and Takahashi (1991) silicate application to soil not only supply Si, but may also produce beneficial effects on the growth of plants especially in acid soils deficient in phosphorus, increase the quantity of phosphate in soil.

Savant et al. (1999) reported that, application of silicate increased the water soluble phosphorus 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.

Matichenkov *et al.* (2000) reported that, silicon fertilizer applied into the soil initiates two process. The first process involves increases in the concentration of mono silicic acids resulting in the transformation of slightly soluble phosphates into plant available phosphate.

Ma *et al.* (2001) Silicon has been reported to improve the availability of phosphorus in the soil by acting as a liming material, thus raising pH and increasing desorption of previously fixed phosphorus.

Singh , Singh , Singh (2005) in rice phosphatic fertilizer use efficiency increased from 24 – 34 % when it was applied with the Si fertilizer , as its application reduced phosphorus (P) retention capacity of soil leading to increased level of water soluble phosphorus.

Phonde *et.al* (2009) reported that availability of P and K in soil after 120 days silicon application appears to be raised under silicon applied plots. Significant increase in phosphate availability was observed under Calcium silicate, fly ash, bagasse ash applied plots.

2.1.6 Potassium

Mohanthy *et al.* (1982) noticed that, an exchangeable potassium displaced from cation exchange sites into the soil solution due to competition for exchange sites from Fe and Mn might have increased the solution potassium concentration.

Sikka and Kansal (1995) studied that pH and available nutrient status of soil after harvest of rice and wheat crop were not affected by the application of fly ash. However, the mean DTPA extractable Fe content in soils increase significantly from 12 ppm in control to 18.1 ppm in soils amended with 8 % fly ash.

Sadgrove (2006) studied that reductions in leaching of N by 60 % for sandy soil and 10 % for potting mix, P by 30 % for sandy soil and by 95 % for clay, K by 60 % for sandy soil and 15 % for potting mix due to application of diatomaceous earth as a source of silicon, The potassium levels were improved for all soil types amended with 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.

2.1.7 Micronutrient

Singh *et al.* (2005) studied that with the application of 180 kg Si / ha increased nutrient uptake of Zn (0.45 kg / ha) , Fe (3.05 kg /ha) , Mn (2.66 kg /ha) 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 potassium.

Durduge *et.al.* (2014) observed in onion crop. Increase in micronutrient by soil application of diatomaceous earth.

2.1.8 Silicon

Savant *et al*. (1997) rice growing soils of India are becoming deficient in Si because of intensive cultivation without addition of Si fertilizers particularly when the rice straw is not incorporated in the field. As a result Si depletion occurred, which has been highlighted as one of the reason for stagnation of rice yield.

Balasubramaniam *et .al* (2011) studied 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 15 th to 60 th 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) studied in onion crop. The application of diatomaceous earth increased the availability of silicon in soil through different levels.

2.2 Effect of sources and level of silicon on plant nutrient uptake by crop

2.2.1 Nitrogen

Egrinya *et.al* (2008) studied that, nitrogen uptake also varied highly according to soil moisture and plant species but was not much affected by Si source. The uptake in the dry treatment (8.4 g / kg) was about half that in the dry treatment (16.2 g/ kg). Again the uptake was highest in rhodes grass (20.9 g /kg) and lowest in timothy grass (8.8 g /kg).

2.2.2 Phosphorus

Siva (1971) reported that, application of silicon fertilizer stimulate phosphate uptake and translocation by plant.

Subramanian and Gopalswamy (1990) found that, the uptake of phosphorus was also greater with higher dose of Si (600 kg DE / ha along with full SFP. The results, therefore indicated that, better response of rice crop with respect to phosphorus nutrition was observed in Si fertilized soil, which might be due to increase in root growth and enhanced soil P, availability with Si application.

Rani and Narayan (1994) noticed that, silicon application increased silicon and Phosphorous uptake. Silicon increased P in grain and straw in rice grown without p and the enhanced p was attributed to enhanced translocation of P from roots to shoots.

Mongia *et al.* (2003) noticed significantly higher uptake of P at each level of fulvic acid application over the control and the increase was from 4.6 to 13.6 kg ha^{-1}.

Yang *et al.* (2008) showed that appropriate Si application to the low P solution could enhance absorbability and utilization ability of phosphorus in maize seedling roots, increase content and accumulation of phosphorus and silicon.

2.2.3 Potassium

Kaya *et al.* (2006) concluded that, Potassium concentration in leaf tissue was much lower in the water stressed plants than in those under the well watered treatments. Potassium concentration increased in the presence of Si under water stressed conditions.

Mali and Aery (2008) studied that, silicon application has been observed to rise plant yield by reducing the absorption of sodium and increasing uptake of potassium in wheat.

Egrinya *et al.* (2008) studied that, the mean uptake of K was only 1.4 g /kg in the dry treatment compared with 3.7 g / kg in the wet treatment. K uptake varied from 1.8 g / kg in the control to 3.8 Kg in K2SiO3. Rhodes grass had the highest K uptake (5 g / kg)

2.2.4 Silicon

Jones and Handreck (1967) plant take up different amount of silica according to their species also Si uptake by plant is controlled not only by the level of soluble Si but also, by the concentration of other ions.

Ma *et al*. (1989) reported that effect of addition and removal of 100 ppm SiO_2 as silicic acid during vegetative, reproductive and ripening stages on plant growth. About 66% of Si in whole plant and 70-75 per cent of that in the leaf and blades was absorbed during the reproductive stage. About 75 per cent of the Si in the panicle was absorbed during the vegetative and reproductive stages was present in the leaf blades, whereas only 20-30 per cent of that absorbed during the ripening stage was present in the leaf blades.

Uptake of silicon has been examined, in both accumulating and non-accumulating species, by examining the plant absorption of silicon over the entire growth period and proposed three modes of silicon uptake in plants, active (in strong accumulators such as rice) , passive (in accumulator such as cucumber) and exclusive (in non-accumulators such as tomato), based on the Si/ Ca ratios of these species . Silicon uptake is related to the development stages of the plant and in the soil system, the silicate ion can replace and release the phosphate ion fixed in the soil, thus increasing the amount of phosphate available to the plant, and helps to promote the translocation of phosphorus (Takahashi *et al*., 1990)

Deren *et al*. (1994) noticed increased Si concentration in plant tissue with increasing rate of Si fertilization, but within each Si treatment and control, cultivar varied for Si concentration and its uptake.

Kanto *et al*. (2004) with their hydroponic study noticed that, addition of liquid potassium silicate into the hydroponic medium increased the amount of silicon absorption by plants. Although silicon exists in great quantities in soil, the degree of foliar absorption of silicon by plants is unclear even in high silicon-accumulator plants such as rice.

Liang *et al.* (2005) reported that , uptake and xylem loading of Si in *Cucumis sativus* along with *Vicia faba* at three levels of SI (0.085 , 0.17 , and 1.70 mM)showed that, the Si uptake in *Cucumis sativus* was more than twice calculated from the rate of transpiration assuming no discrimination between silicic acid and water uptake , but Si uptake in *Vicia faba* was significantly lower than the calculated uptake . Concentration of Si in xylem exudates was several – fold higher in *Cucumis sativus* but was significantly lower in *Vicia faba* compared with the Si concentration in external solutions, regardless of Si levels. It can be concluded that Si uptake and transport in *Cucumis sativus* is active and independent of external Si concentrations, in contrast to the process in *Vicia faba.*

Prakash *et al.* (2011) reported that, foliar spray of silicic acid 2 and 4 ml L^{-1} alone increased the percent silicon and its uptake in both straw as well as grain in both hilly and coastal zones of Karnataka.

2.3 Effect of sources and level of silicon on growth, yield and quality of garlic.

2.3.1 Effect of silicon on growth parameter

Miyaka and Eiichi (1983) studied the effect of silicon on the growth of solution – cultured cucumber plant. The crop which was supplied with silicon had shown minimum curling percentage with positive effect on growth and yield of cucumber.

Matichenkov *et al.* (2001) studied on response of citrus to silicon soil amendments they reported that improving silicon nutrition aids in the initiation of root and fruit formation in higher plants.

Aziz *et al.* (2001) observed that, 100 mM silicon application to the growth media significantly improve the growth of melon plant.

Seome *et al.* (2008) reported that, application of silicon increase the plant growth leaf area and yield in potato plant.

Hattori *et al.* (2008) investigated the effects of silicon application on photosynthesis of solution – cultured cucumber seedlings were under osmotic stress and unstressed conditions. The results suggested that, the silicon induced alleviation of growth reduction under osmotic stress in cucumber was due to amelioration of stress – induced damage of leaf tissues rather than to improvement of leaf water status.

The application of calcium silicate fertilizer improve the lettuce nutritional status for silicon and increased the percentage of healthy leaves (Ferreira *et al.* 2010)

Sivanesan *et.al* (2011) reported that height was significantly increased by application of silicate. Application of silicon also increased the mean number of flowers diameter, fresh and dry weight of flower as compared with the control in chrysanthemum.

Ahmad *et al.* (2012) reported that combine application of both the nutrients at 1.5 % silicon and 1 % boron performed well. Silicon (1 % silicon level) produced the maximum plant height resulted best in rice crop.

Miyake and Eiichi (2012) studied the effect of silicon on reproductive growth of tomato plant. The plant which is supplied with 100 ppm of silicon showed maximum reproductive growth as compared to that of control.

Tesfagiorgis *et al.* (2013) studied on effects of silicon level in nutrient solution on the uptake and distribution of silicon in Zucchini and zinnia, and its interaction with the uptake of selected elements and they reported that when Si was added into the nutrient solution at 50 to 100 mg / L, the growth of both plants appeared to be improved in zucchini and zinnia plant.

Raquel de Castro Salmao Chagas *et al*. (2014) reported that calcium silicate and wollastonite produced linear increase in soluble silicon and in silicon uptake by rice pearl millet. Increases in shoot dry weight were observed in rice and pearl millet calcium silicate level were higher than wollastonite in the dry weight of both plant.

Meena *et al.* (2014) studied on silicon fertilization to improve crop yields in tropical soils and reported that the application of silicon may be one of the available pathways to improve crop growth and its production in arid or semiarid areas.

Mathew *et al.* (2017) studied on impact of silicates on the growth of coconut seedlings grown in a tropical entisol and reported that the highest percentage increase in plant height was recorded by the treatment which received calcium silicate @ 400 ppm per kg soil.

2.3.2 Effect of silicon on yield parameter

Ross *et al*. (1974) observed that there was marked increase in sugarcane yield with calcium silicate applications throughout the cycle.

Yoshida (1981) reported that 10 percent increase in the photosynthetic rate due to the improved erectness of leaves can be achieved through proper silicon management and consequently a similar increase in yield. Fertilizing with excessive N tends to make rice leaves droopy, whereas Si keeps them erect.

Korndorfer and Lepsch (2001) studied on effect of silicon on plant growth and crop yield and reported that silicon will enhance crop yield by promoting several desirable plant physiological processes. Silicon fertilization may increase and sustain crop productivity of different crops.

Matichenkov and Calvert (2002) studied on silicon as a beneficial element for sugarcane and reported that, field and greenhouse experiments conducted in the USA (Florida and Hawaii) and Mauritius, demonstrated that sugarcane productivity increase from 17 to 30 % whereas production of sugar increased from 23 to 58 % with increasing silicon fertilization.

Heckman *et al*. (2003) studied on pumpkin yield and disease response to amending soil with silicon and reported that the calcium Meta silicate as liming material needed for soil pH correction has the potential benefits of suppressing powdery mildew and increasing pumpkin yield without increasing the cost of production.

Gil Rodrigues dos Santos *et al.* (2011) studied the effect of silicon sources on rice diseases and yield in Tocantins, Brazil and reported that calcium silicate effectively reduced the brown spot and the panicle blast, which resulted in an increased rice yield.

Arab *et al.* (2011) studied on effects of silicon on yield components and quantity yield of rice. (Oryza sativa L.) in Iran and reported that, higher grain yield was obtained on application of silicon.

Dhamapurkar *et.al* (2011) studied on effect of calcium silicate slag on yield and silica uptake by rice and reported that application of calcium silicate slag (45 % silica) to rice beneficial for sustainable rice production.

Durgude *et al*. (2014) reported that application of silicon to the onion crop improve the all yield contributing characteristics i.e. 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.

Rahimi *et al*. (2012) reported that, the increase supply of Si enhanced the umbel number / plant and seed yield in fennel crop.

2.3.3 Effect of silicon on quality of garlic.

Liu (1997) showed that, application of silicate and calcium fertilizers increase fruit size and improve the flavoure of the tomato fruits by increasing sugar concentration in the fruit

Stamatakis *et al.* (2003) studied effects of silicon and salinity on fruit yield and quality of tomato grown hydroponically and reported that, B – carotene and lycopene contents of fruit were significantly increased by Si and nutrient – induced salinity. B other Si and EC enhanced the fruit firmness and the contents of total solid solutes and vitamin C in the tomato fruit.

Su *et a*l. (2011) studied the effects of silicon on quality of apple fruit on acid soils. The results indicated that silicon could significantly increase the content of soluble solid and vitamin C and reduce the titratable acid content in fruit, but had no obvious influence on fruit, hardness.

Magno *et al.* (2012) observed the modifications in leaf anatomy of banana plants cultivar Maca subjected to different silicon sources under in vitro condition. The addition of calcium silicate resulted in greater thickness of upper and lower epidermis, mesophyll, palisade parenchyma and increased photosynthetic rate. The use of silicon improved the micro propagated anatomy of banana plant cultivar Maca leaves.

Ahmad *et al.* (2013) reported that silicon (0. 50 % silicon solution) produced maximum grain diameter and grain protein in paddy crop.

Abd – Alkarim *et al* (2017) studied on silicon supplements affect yield and fruit quality of cucumber (*Cucumis sativus* L.) grown in net houses and reported that at all growth stages , application of Si showed significant differences among treatments.

2.4 Effect of sources and level of silicon on disease and pest incidence on garlic.

Datnoff *et al.* (1992) showed that, Si was as effective as conventional fungicides in controlling diseases such as leaf scald *(Monographella albescens)*, blast *(Magnaporthe grisea)*, sheath blight *(Thanatephoruscucu meris)*, brown spot *(Cochliobolusmiya beanus)* and grain discoloration in rice.

Yang *et al.* (2008) studied the effect of silicon on anthracnose occurrence, flower stalk formation, silicon uptake and accumulation in Chinese cabbage (*Brassica campestris* L. *spp. Chinensis var.* utilis Tsen Lee). The plant which was supplied with silicon had showed highest resistance to *Colletotrichum higginsianum*, with the lowest disease index and the highest flower stalk yield.

Buck *et al.* (2008) reported the effect of silicon absorption through the leaves on rice blast *(Pyricularia oryzae)* control using potassium silicate (K_2SiO_3) in different doses (0, 1, 2, 3, 4, 8 or 16 g Si L^{-1}) and number of spraying at two solution pH. The greatest reduction on blast incidence was observed at 4 g Si L^{-1}, regardless of solution pH. 10 and yellow stem borer resistance.

Adequate Si uptake also reduces the susceptibility of plants to chewing insects such as stem borer *(Chilo suppressalis)*, possibly by rendering plant tissue less digestible and by 11 Results obtained in study undertaken by (Zanao *et al.*, 2009) reported that Si has the potential to reduce the development of brown spot regardless of low or high Mn conditions. This information may prove to be invaluable in the field especially in areas where soils have toxic or deficient Mn levels.

Wagner *et al. (*2010) in their hydroponic study with orchids reported that one source of silica ($KSiO_3$) was used and treatments supplemented with 2% silica resulted in leaf tissue Si concentrations of 1.34 and 1.64 per cent.

Rogerio *et al.* (2012) studied the effect of silicon leaf application, in the form of stabilized Silicic acid, on the disease incidence, yield, and quality of potato. Silicon application reduced the severity of late blight and incidence of black leg, besides increasing tuber yield and tuber dry matter content.

3. MATERIAL AND METHODS

The present investigation entitled "Response of garlic to silicon. (Cv. Phule Nilima)" at, AII India Coordinated Research Project on Vegetable Crop, Department of Horticulture , Mahatma Phule Krishi Vidyapeet , Rahuri during season of *Rabi 2017 – 18.*

The details of material used and methods adopted during the course of present investigations were mentioned under suitable heading and sub -headings.

The details of materials used in experimental techniques are presented here as follow.

3.1 Details of experimental materials

3.1.1 Experimental site and location

The experiment was carried out at the All India Coordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar during *Rabi* season of 2017 – 18.

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.

3.1.2 Soil

The topography of experimental site was uniform, field was uniformly levelled flat, soil was medium black having good water holding capacity .The soil of experimental plot is grouped under the order vertisol and texture of soil was medium deep black.

3.1.3 Climatic condition

This region falls under semi – arid, subtropical zone with average rainfall is 520 mm, receiving during the monsoon months from June to September from South – West monsoon. The average rainfall, the minimum and maximum temperatures, relative humidity at morning and evening, pan evaporation and sunshine hours of meteorological weeks of crop growing season are given in the Appendix I.

3.2 Methods

3.2.1 Selection of crop

The Garlic (Cv. Phule Nilima) was selected as a test crop during rabi season of 2017 – 18

3.2.2 Experimental details

The experiment was laid out in Factorial Randomised Block Design (FRBD) with three replications having 16 treatments including one absolute control.

The details of present investigation conducted during year 2017 -18 are as below.

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) with control
6.	Number of treatments	:	16
7.	Replications	:	3
8.	RDF	:	100:50:50kg ha^{-1} N, P_2O_5 and K_2O, respectivly +20 t ha^{-1} FYM
9.	Date of sowing	:	6/11/2017
10.	Planting distance	:	15 x 10cm
11.	Plot size	:	Gross plot= 3m x 2m Net plot= 2.80m x 1.70m

B Treatment details

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	:	000 (control)
2.	B_2	:	100
3.	B_3	:	150
4.	B_4	:	200
5.	B_5	:	250

C Absolute control

Note:

Treatments comprised of five levels of silicon (0 , 100 , 150 ,200 , 250 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.

Table : 1 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
T_{16}	Absolute control

3.2.3 Field preparation and other cultural operations

The schedules of various cultural operations were carried out during the course of investigation according to need and time of operation.

3.2.3.1 Field preparation

The experimental field was prepared by a plough with mould board plough followed by cris cross cultivator operation and finally pulverized by the rotavator.

The layout of prepared field was prepared as per the experimental design. Field was divided into small plots according to treatments and replications. Proper irrigation channels were made for irrigation.

3.2.3.2 Cloves sowing

After completion of field preparation the cloves were dibbled according to their randomized plan at 2 to 3 cm depth. During dibbling of cloves, the growing point was kept in upward direction for proper germination.

3.2.3.3 Irrigation management

First irrigation was given immediately after clove dibbling .Further, irrigations were given at 10-15 days interval as per requirement of crop growth phases.

3.2.3.4 Weed management

Spraying of weedicide after planting but before germination was done and hand weeding was accomplished in respective treatments as per the requirement.

3.2.3.5 Plant protection

Different plant protection measures were undertaken as per the occurrence of pest and disease incidence.

3.2.3.6 Harvesting

The bulbs were harvested with the tops on the harvested bulbs were cured for three days in the field and then under shade.

3.2.3.7 Sampling techniques

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

3.2.3.8 Application of silicon sources and fertilizers

Different silicon sources as diatomaceous earth, calcium silicate, bagasse ash, were applied as basal dose 15 days before planting. 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 in equal two split doses at 30 and 45 days after planting.

3.2.4 Chemical analysis

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 during the 2017-18. The methods adopted for recording the observations of soil and plant are explained here under different sub - heads.

3.2.4.1 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 fluoride 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.

3.2.4.2 Soil analysis

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

Table 2. Standard analytical methods

Sr. No	**Parameter**	**Method**	**Reference**
I.	**Total silicon from various sources**	HCl (12.1 N) + HF (48%)	Korndorfer *et al.* (2004)
II.	**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)
III.	**Plant analysis**		
1.	Total N	Micro-kjeldahl method (H_2O_2+H_2SO_4)	Parkinson and Allen (1975)
2.	Total P	Vandomolybdate Yellow color 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)
V	**Pest and diseases incidence**	Square method	Mayee and Datar (1986)

II. Soil chemical properties

3.2.4.2.1 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).

3.2.4.2.2 Electrical conductivity

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

3.2.4.2.3 Organic carbon

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

3.2.4.2.4 Available nitrogen

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

3.2.4.2.5 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 wavelength by Watanabe and Olsen (1965).

3.2.4.2.6 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).

3.2.4.2.7 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.*, 2004).

3.2.4.2.8 Available micronutrients

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

3.2.4.3 Methods used for plant analysis

I. 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.

3.2.4.3.1 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).

3.2.4.3.2 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 color was developed with combined nitric acid vandatemolybdate reagent. Phosphorus was determined colorimetrically by using spectrophotometer at 420 nm wavelength as described by Jackson (1973).

3.2.4.3.3 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).

3.2.4.3.4 Silicon

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

I. 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 powdered in a stainless steel grinder and used for determining concentration of silicon by adopting standard methods of analysis.

II. 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).

III. 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 allowed 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 color developed after waiting 15 to 20 minutes was measured at 660 nm using spectrophotometer (Nayar *et al.*, 1975).

3.2.4.4 Observations recorded at harvest

The observation recorded while conducting this investigation were as under.

I. Growth characters

3.2.4.4.1 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.

3.2.4.4.2 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.

II. Yield and quality attributes

3.2.4.4.3 Number of cloves per bulb

The cloves were separated from the bulbs which are selected for measuring diameters and the cloves were counted.

3.2.4.4.4 Average weight of 10 cloves (g)

Ten cloves were taken from each of the ten randomly selected bulbs and average weight of 10 cloves was calculated, therefore it was recorded as average weight of 10 cloves in gram.

3.2.4.4.5 Polar diameter (cm)

The ten bulb of garlic were selected randomly from each net plot at harvesting to measure the polar diameter with the help of Vernier's calliper. The mean value was calculated and expressed in centimeters.

3.2.4.4.6 Equatorial diameter (cm)

The ten bulb of garlic are selected randomly from each net plot at harvesting to measure equatorial diameter with the help of Vernier's calliper. The mean value was calculated and expressed in centimeters.

3.2.4.4.7 Neck thickness (cm)

Neck thickness was measured by Vernier's calliper from the ten randomly selected bulbs.

3.2.4.4.8 Average weight of bulb (g)

The ten bulbs of garlic were selected randomly from each net plot at harvesting. Weight of ten bulbs was undertaken done with the help of digital weighing balance. The mean weight was calculated and expressed in grams.

3.2.4.4.9 Yield of bulbs (kg plot^{-1})

The bulb from each net plot are separated from leaves to weigh with the help of weighing balance and expressed in kilogram.

3.2.4.4.10 Marketable yield (%)

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 and was less than 3 cm.

3.2.4.4.11 Total soluble solids (^{0}B)

The selected bulbs were sliced and pressed to remove juice for placing on hand refractometer for recording TSS.

3.2.4.4.12 Pest infestation and disease incidence

The infestation of pest (average survival per plant) and disease incidence for each treatment was recorded during crop growth period by adopting standard procedure.

Formula:

$$\text{Disease incidence (\%)} = \frac{\text{Number of affected plants}}{\text{Total number of plants}} \times 100$$

3.2.4.4.13 Dry matter per plot

The plant material (bulbs and leaves) from each plot first cutted into the pieces and then kept in perforated brown paper bags, suitably labelled and dried to constant weight in thermo statistically controlled oven at 60^0C ± 2^0C temperature. The mean dry weight per plot from respective treatments are worked out.

3.3 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).

4. RESULTS AND DISCUSSION

An investigation was carried out by conducting a field experiment entitled, "Response of Garlic to Silicon (Cv. Phule Nilima)", at All India Coordinated Research Project on Vegetable Crops, Department of Horticulture, MPKV, Rahuri.

The observations of plant growth and yield were recorded. Soil samples of each treatment were analyzed for their chemical properties and plant samples were analyzed for nutrient concentration and uptake of garlic were calculated. The results obtained from the statistical analysis of generated data in present investigation are discussed in this chapter under following sub heads.

4.1 Effect of sources and levels of silicon on chemical properties of soil.

4.2 Effect of sources and levels of silicon on growth, yield and quality of garlic.

4.3 Effect of sources and levels of silicon on total uptake of N, P, K and Si by garlic.

4.4 Effect of sources and levels of silicon on pests and disease incidence on garlic.

4.1 Effect of sources and levels of silicon on chemical properties of soil.

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 tables.

4.1.1 Soil pH

The data in respect of effect of sources and levels of silicon on soil pH at harvest are presented in table 3.

The soil pH was significantly influenced due to sources of silicon. The mean source A_2 (CS) recorded the significantly highest pH (8.16) over all the sources. However, it was at par with silicon sources A_1 (8.04).

The levels of silicon significantly influenced the pH. Application of Si level @ 250 kg ha^{-1} (B_5) recorded significantly the highest (8.33) pH.

The interaction effect of sources and levels of silicon was non- significant. However, treatment combination of A_2B_5 (8.45) recorded highest pH at harvest.

The pH was found to be significantly increased (8.04) with increasing levels of silicon application in garlic. However, the minimum (7.67) soil pH was observed with control treatment.

Table3: Effect of sources and level of silicon on soil pH

Effect of sources and level of silicon on soil pH						
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	7.92	7.98	7.84	8.08	8.38	8.04
A_2 : CS	8.08	8.05	8.07	8.15	8.45	8.16
A_3 : BA	7.92	7.62	7.92	7.91	8.17	7.91
Mean	7.97	7.88	7.94	8.17	8.33	8.04
Control	**7.67**					
	S.E. $\pm$			CD at 5%		
A	0.04			0.19		
B	0.08			0.25		
(A × B)	0.15			NS		
Treat Vs C	0.15			0.44		
Initial	7.84					

There was slight increase in soil pH with increase in levels of silicon. This might be due to electrochemical change 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 at harvest. This was in agreement with the findings of Pichel and Hayer (2013) and Durgude *et al.* (2014).

4.1.2 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 4.

The electrical conductivity of soil was significantly influenced by sources of silicon. The mean source of A_2 (CS) recorded significantly the highest EC (0.45 dSm^{-1}). However, it was at par with A_1 (0.42 dSm^{-1}) and A_3 (0.42 dSm^{-1}).

The levels of silicon significantly influenced on soil EC at harvest. The application of Si @ 250 kg ha^{-1} (B_5) recorded significantly the highest electrical conductivity (0.47 dSm^{-1}) over all the levels of silicon.

The interaction effect of sources and levels of silicon was non - significant. However, the treatment combination of A_2B_5 (0.48dSm^{-1}) recorded highest EC.

The EC was significantly increased with treated (0.43 dSm^{-1}) over control (0.35 dSm^{-1}).

Table 4: Effect of sources and level of silicon on electrical conductivity (dSm^{-1})

Electrical conductivity (dSm^{-1})						
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	0.37	0.44	0.40	0.40	0.47	0.42
A_2 : CS	0.44	0.45	0.43	0.43	0.48	0.45
A_3 : BA	0.40	0.41	0.42	0.43	0.46	0.42
Mean	0.40	0.43	0.42	0.42	0.47	**0.43**
Control	**0.35**					
	S.E. ±			CD at 5%		
A	0.008			0.023		
B	0.010			0.030		
(A × B)	0.017			NS		
Treat Vs C	0.018			0.053		
Initial	0.40					

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).

4.1.3 Organic carbon

The data in respect to effect of sources and levels of silicon on soil organic carbon at harvest presented in table 5.

The organic carbon content in soil was significantly influenced by different sources of silicon. The mean source of A_1 (DE) recorded significantly the highest organic carbon content in soil at harvest (0.52 %) over all the sources. However, it was at par with A_2 (0.50 %)

The levels of silicon significantly influenced on soil organic carbon. Application of Si @ 250 kg ha^{-1} (B_5) recorded significantly the highest organic carbon content in soil at harvest (0.53 %). However, it was at par with B_4 (0.51 %).

The interaction effect of sources and levels of silicon on organic carbon content in soil at harvest was not significant. However, the treatment combination of A_1B_5 (0.55%) recorded highest OC at harvest.

The organic carbon was significantly increased with treated (0.50%) over control (0.46%).

Table 5: Effect of sources and levels of in soil organic carbon (%)

	Organic carbon (%)					
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	0.49	0.50	0.51	0.53	0.55	0.52
A_2 : CS	0.48	0.49	0.49	0.49	0.52	0.50
A_3 : BA	0.49	0.48	0.49	0.50	0.51	0.49
Mean	0.49	0.49	0.50	0.51	0.53	**0.50**
Control	**0.46**					
	S.E. $\pm$			CD at 5%		
A	0.006			0.017		
B	0.007			0.02		
(A × B)	0.013			NS		
Treat Vs C	0.014			0.041		
Initial	0.48					

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.

4.1.4 Available nitrogen in Soil

The data in respect of effect of different sources and levels of silicon on soil available nitrogen at harvest presented in table 6.

The available nitrogen in soil was significantly influenced due to sources of silicon. The source A_2 (CS) recorded significantly the highest available nitrogen in soil at harvest (175.29 kg ha^{-1}) than all other sources.

The levels of silicon significantly influenced on soil available nitrogen. Application Si @ 250 kg ha^{-1} (B_5) for all sources recorded significantly the highest available nitrogen in soil (183.07 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 non - significant. However, the treatment combination of A_2B_5 (185.07 kg ha^{-1}) recorded highest nitrogen in soil at harvest.

The available nitrogen in soil was significantly increased with treated (171.80 kg ha^{-1}) over control (156.72 kg ha^{-1}).

Table 6: Effect of sources and level of silicon on available nitrogen in soil (kg ha^{-1})

	Available nitrogen in soil (kg ha^{-1})					
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	160.11	165.43	168.12	173.96	182.93	170.11
A_2 : CS	162.88	175.50	172.94	180.07	185.07	175.29
A_3 : BA	160.65	165.92	168.32	173.95	181.22	170.01
Mean	161.21	168.95	169.79	175.99	183.07	**171.80**
Control	**156.72**					
	S.E. ±			CD at 5%		
A	1.51			4.38		
B	1.96			5.66		
(A × B)	3.39			NS		
Treat Vs C	3.50			10.12		
Initial	192.65					

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. 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).

4.1.5 Available phosphorous in Soil

The data in respect of effect of different sources and levels of silicon on available phosphorus at harvest presented in table 7.

The available phosphorus in soil was significantly influenced due to sources of silicon. The source A_2 (CS) recorded significantly the highest available phosphorus in soil at harvest (16.48 kg ha^{-1}) than all other sources.

The levels of silicon significantly influenced the available phosphorus. Application of Si @ 250 kg ha^{-1} (B_5) recorded significantly the highest available phosphorus (17.98 kg ha^{-1}).

The interaction effect of sources and levels of silicon on available phosphorus in soil at harvest was significant. Application of Si @ 250 kg ha $^{-1}$ (B_5) through CS was significantly registered the highest A_2B_5 (19.26 kg ha^{-1}) available phosphorus in soil than rest of the treatment combinations.

The available phosphorus in soil was significantly increased with treated (15.77 kg ha^{-1}) over control (14.12 kg ha $^{-1}$).

Table 7: Effect of sources and level of silicon on available phosphorus in soil (kg ha^{-1})

	Available phosphorus in soil (kg ha^{-1})					
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	14.90	14.68	14.60	14.83	18.16	15.44
A_2 : CS	14.87	14.94	16.32	17.00	19.26	16.48
A_3 : BA	15.80	14.57	14.18	14.97	16.53	15.41
Mean	15.19	15.06	15.04	15.60	17.98	**15.77**
Control	**14.12**					
	S.E. $\pm$			CD at 5%		
A	0.26			0.77		
B	0.34			1.00		
(A × B)	0.60			1.73		
Treat Vs C	0.62			1.79		
Initial	20.10					

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).

4.1.6 Available potassium in Soil

The data in respect of effect of different sources and levels of silicon on available potassium at harvest presented in table 8.

The available potassium of soil was significantly influenced by sources of silicon. The source A_2 (CS) recorded significantly the highest potassium (284.51 kg ha $^{-1}$). However, it was at par with A_1 (271.75 kg ha^{-1}).

The levels of silicon significantly influenced available potassium at harvest. The application of Si @ 250 kg ha^{-1} (B_5) recorded significantly the highest potassium (294.09 kg ha^{-1}) over all the levels of silicon. However it was at par with B_3 (274.50 kg ha^{-1})

The interaction effect of sources and levels of silicon was non - significant. However, the treatment combination of A_2B_5 (297.33 kg ha^{-1}) recorded highest potassium.

The available potassium was significantly increased with treated (273 kg ha^{-1}) over control (254.56 kg ha^{-1}).

Table 8: Effect of sources and level of silicon on available potassium in soil (kg ha^{-1})

	Available potassium in soil (kg ha^{-1})					
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	277.99	250.07	286.29	247.79	296.61	271.75
A_2 : CS	258.41	289.06	282.87	294.86	297.33	284.51
A_3 : BA	280.07	251.33	254.32	251.57	288.32	265.12
Mean	272.16	263.48	274.50	264.74	294.09	**273.79**
Control	**254.56**					
	S.E. ±			CD at 5%		
A	5.30			15.32		
B	6.84			19.77		
(A × B)	11.86			NS		
Treat Vs C	12.25			35.38		
Initial	298.12					

Increase in the soil available potassium content may be due to optimum nitrogen and potassium rates and more availability of silicon in soil due to soil application of Si, and this might be due to positive interaction of silicon with potassium and reduction in its leaching. Similar results reporded by Durgude *et al*. (2014).

4.1.7 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

4.1.7.1 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 9.

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 significantly influenced due to sources of silicon. The source A_2 (CS) recorded significantly the highest available silicon in soil (62.05 mg kg^{-1}) than other sources. However, it was at par with A_3 (61.76 mg kg^{-1}).

The levels of silicon was significantly influenced on available silicon in soil at 50 days after planting. The application of Si @ 250 kg ha^{-1} (B_5) recorded significantly the highest silicon in soil (70.17 mg kg^{-1}) over all the levels of silicon. However, it was at par with B_4 (67.49

mg kg^{-1})

The interaction effect of sources and levels of silicon on available silicon at 50 days after planting was significant. Application of Si @ 250 kg ha^{-1} (B_5) through A_2 (CS) was significantly registered the highest A_2B_5 (73.87 mg kg^{-1}) available silicon in soil than rest of treatment combinations. However, it was at par with A_2B_4 (71.03 mg kg^{-1}), A_3B_4 (71.60 mgkg^{-1}) and A_3B_5 (69.97 mg kg^{-1}).

The available silicon at 50 days after planting was significantly increased with treated (59.78mg kg^{-1}) over control (39.40 mg kg^{-1}).

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.

Table 9: Effect of sources and level of silicon on available silicon at 50 days after planting ($mg\ kg^{-1}$)

	Available silicon at 50 days after planting ($mg\ kg^{-1}$)					
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	41.13	52.87	57.23	59.83	66.67	55.55
A_2 : CS	41.57	60.57	63.20	71.03	73.87	62.05
A_3 : BA	42.20	59.93	65.10	71.60	69.97	61.76
Mean	41.63	57.79	61.84	67.49	70.17	**59.78**
Control	**39.40**					
	S.E. ±			CD at 5%		
A	0.61			1.78		
B	0.79			2.30		
(A × B)	1.38			3.99		
Treat Vs C	1.42			4.12		
Initial	55.47					

4.1.7.2 Silicon at harvest

The data in respect of effect of different sources and levels of silicon on available silicon at harvest are presented in table 10.

The soil available silicon in soil found significantly influenced due to sources, levels and their interactions.

The source A_2(CS) significantly recorded the highest available Si (53.59 mg kg^{-1}) over all other sources of silicon, however it was at par with A_3 (53.27 mg kg^{-1}).

The levels of silicon was significantly influenced on soil available silicon. Application of Si @ 250 kg ha^{-1} (B_5) recorded significantly the highest available silicon in soil (62.31mg kg^{-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. Application of Si @ 250 kg ha^{-1} (B_5) through A_2 (CS) was significantly registered the highest A_2B_5 (64.03 mg kg^{-1}) available silicon in soil than rest of treatment combinations. However, it was at par with A_3B_5 (62.90 mg kg^{-1})

The available silicon at harvest was significantly increased with treated (52.63mg kg^{-1}) over control (32.73 mg kg^{-1}).

Table 10: Effect of sources and level of silicon on available silicon in soil at harvest (mg kg^{-1})

	Available silicon in soil at harvest (mg kg^{-1})					
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	37.00	45.97	55.00	57.17	60.00	51.03
A_2 : CS	36.03	51.63	56.23	60.00	64.03	53.59
A_3 : BA	34.80	51.43	55.83	61.37	62.90	53.27
Mean	35.94	49.68	55.69	59.51	62.31	**52.63**
Control	**32.73**					
	S.E. ±			CD at 5%		
A	0.41			1.19		
B	0.53			1.54		
(A × B)	0.92			2.67		
Treat Vs C	0.95			2.76		
Initial	55.47					

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

4.1.8 DTPA Fe content of soil

The data in respect of effect of different sources and levels of silicon on available Fe at harvest presented in table 11.

The soil available Fe in soil found significantly influenced due to sources, levels and their interaction.

The source A_2 (CS) significantly recorded the highest available Fe (4.50 mg kg $^{-1}$) over all other sources of silicon.

The levels of silicon was significantly influenced on soil available Fe. Application of Si @ 250 kg ha^{-1} (B_5) recorded significantly the highest available Fe in soil (4.48 mg kg^{-1}) over rest of the levels of silicon. However, it was at with B_4 (4.35 mg kg-^{1}) and B_3 (4.46 mg kg^{-1})

The interaction effect of sources and levels of silicon on an available Fe in soil at harvest was non - significant. However the treatment combination of A_2B_5 (4.70mg kg $^{-1}$) recorded the highest Fe at harvest.

The available Fe at harvest was significantly increased with treated (4.30mg kg^{-1}) over control (3.70 mg kg^{-1}).

Similar results were also noticed by Okuda and Takahashi (1962) and Das *et al*. (2013)

Table 11: Effect of sources and level of silicon on available Fe in soil at harvest (mg kg $^{-1}$)

	Available Fe in soil at harvest (mg kg^{-1})					
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	4.18	4.00	4.31	4.26	4.51	4.25
A_2 : CS	4.15	4.58	4.58	4.49	4.70	4.50
A_3 : BA	3.92	3.84	4.48	4.13	4.23	4.16
Mean	4.08	4.14	4.46	4.35	4.48	**4.30**
Control	**3.70**					
	S.E. ±			CD at 5%		
A	0.07			0.22		
B	0.10			0.29		
(A × B)	0.17			NS		
Treat Vs C	0.18			0.52		
Initial	3.94					

4.1.9 DTPA Mn content of soil

The data in respect of effect of different sources and levels of silicon on available Mn at harvest are presented in table 12.

The soil available Mn in soil found significantly influenced due to sources, levels and their interaction.

The source A_2 (CS) significantly recorded the highest available Mn (8.47mg kg $^{-1}$) over all other sources of silicon. However, it was at bar with A_1 (8.20 mg kg^{-1})

The levels of silicon was significantly influenced on soil available Mn. Application of Si @ 250 kg ha^{-1} (B_5) recorded significantly the highest available Mn in soil (8.78 mg kg^{-1}) over rest of the levels of silicon. However, it was at with B_4 (8.67 mg kg^{-1}) and B_1 (8.11 mg kg-^{1}).

The interaction effect of sources and levels of silicon on an available Mn in soil at harvest was non - significant. However, the treatment combination A_2B_5 (9.67 mg kg $^{-1}$) recorded highest Mn at harvest.

The available Mn at harvest was significantly increased with treated (8.09mg kg^{-1}) over control (6.67 mg kg^{-1}). Similar results were also noticed by Okuda and Takahashi (1962), Das *et al*. (2013) and Durgude *et al.* (2014)

Table 12: Effect of sources and level of silicon on available Mn in soil at harvest (mg kg $^{-1}$)

Available Mn in soil at harvest (mg kg^{-1})						
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	9.00	8.00	7.00	8.67	8.33	8.20
A_2 : CS	7.67	7.67	8.00	9.33	9.67	8.47
A_3 : BA	7.67	7.33	6.67	8.00	8.33	7.60
Mean	8.11	7.67	7.22	8.67	8.78	**8.09**
Control	**6.67**					
	S.E. $\pm$			CD at 5%		
A	0.21			0.62		
B	0.27			0.80		
(A × B)	0.48			NS		
Treat Vs C	0.49			1.43		
Initial	8.90					

4.1.10 DTPA Zn content of soil

The data in respect of effect of different sources and levels of silicon on available Zn at harvest are presented in Table13.

The soil available Zn in soil found significantly influenced due to sources, levels and their interaction.

The source A_1 (DE) significantly recorded the highest available Zn (0.67mg kg $^{-1}$) over all other sources of silicon. However, it was at bar with A_2 (0.65 mg kg^{-1})

The levels of silicon was significantly influenced on soil available Zn Application of Si @ 250 kg ha^{-1} (B_5) recorded significantly the highest available Zn in soil (0.69 mg kg^{-1}) over rest of the levels of silicon. However, it was at with B_3 (0.63 mg kg-^{1}) and B_4 (0.67mg kg^{-1})

The interaction effect of sources and levels of silicon on an available Zn in soil at harvest was non - significant. However, the treatment combination of A_1B_5 (0.73 mg kg $^{-1}$) recorded highest Zn at harvest.

The available Zn at harvest was significantly increased with treated (0.64 mg kg^{-1}) over control (0.57 mg kg^{-1}).

The application of silicon significantly increased DTPA – Zn content in soil at harvest. These findings recorded by Okuda and Takahashi (1962), Das *et al.* (2013) and Durgude *et al* (2014)

Table 13: Effect of sources and levels of silicon on available Zn in soil at harvest (mg kg $^{-1}$)

	Available Zn in soil at harvest (mg kg^{-1})					
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	0.65	0.66	0.61	0.69	0.73	0.67
A_2 : CS	0.59	0.60	0.66	0.68	0.69	0.65
A_3 : BA	0.54	0.58	0.61	0.63	0.64	0.60
Mean	0.60	0.61	0.63	0.67	0.69	**0.64**
Control	**0.57**					
	S.E. ±			CD at 5%		
A	0.016			0.04		
B	0.020			0.060		
(A × B)	0.03			NS		
Treat Vs C	0.03			0.10		
Initial	0.69					

4.1.11 DTPA Cu content of soil

The data in respect of effect of different sources and levels of silicon on available Cu at harvest are presented in table 14.

The soil available Zn in soil found significantly influenced due to sources, levels and their interaction.

The source A_1 (DE) significantly recorded the highest available Cu (1.40 mg kg $^{-1}$) over all other sources of silicon. However, it was at par with A_2 (1.38 mg kg^{-1}) and A_3 (1.32mg kg^{-1})

The levels of silicon was significantly influenced on soil available Cu Application of Si @ 250 kg ha^{-1} (B_5) recorded significantly the highest available Cu in soil (1.46 mg kg^{-1}) over rest of the levels of silicon. However, it was at with B_4 (1.40 mg kg^{-1})

The interaction effect of sources and levels of silicon on an available Cu in soil at harvest was non - significant. However, the treatment combination of A_1B_5 (1.48 mg kg $^{-1}$) and A_2B_5

(1.48 mg kg-1) recorded highest Cu at harvest.

The available Cu at harvest was significantly increased with treated (1.37 mg kg^{-1}) over control (1.26mg kg^{-1}).

These findings recorded by Okuda and Takahashi (1962), Durgude *et al.* (2014) and Das *et al.* (2013).

Table 14: Effect of sources and level of silicon on available Cu in soil at harvest (mg kg $^{-1}$)

	Available Cu in soil at harvest (mg kg^{-1})					
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	1.34	1.36	1.38	1.43	1.48	1.40
A_2 : CS	1.29	1.33	1.40	1.41	1.48	1.38
A_3 : BA	1.24	1.25	1.34	1.36	1.41	1.32
Mean	1.29	1.31	1.37	1.40	1.46	**1.37**
Control	**1.26**					
	S.E. ±			CD at 5%		
A	0.014			0.04		
B	0.019			0.054		
(A × B)	0.03			NS		
Treat Vs C	0.03			0.09		
Initial	1.40					

4.2 Effect of sources and levels of silicon on growth, yield and quality of garlic

The data in respect of plant height, number of leaves per plant, number of cloves per bulb, weight of 10 cloves, polar diameter, equatorial diameter, neck thickness, weight of bulb, TSS of bulbs influenced by sources and levels of silicon are presented in tables

4.2.1 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 sources A_2 (CS) was recorded significantly the highest plant height (52.95cm) over all other sources.

The levels of silicon significantly influenced plant height. Application of Si @250 kg ha^{-1} (B_5) recorded significant the highest plant height (56.58 cm) over all other the levels of silicon.

The interaction effect of sources and levels of silicon was non - significant. However, the treatment combination of A_2B_5 (58.53 cm) recorded highest plant height at harvest.

The plant height was significantly increased with treated (51.15) over control (45.30).

Increase in plant height with increased levels of silicon. This might be due to dissolution of silicon from sources of silicon as well as from soil and become available to plant. The silicon gets deposition in the plant tissues causing erectness of leaves and stem. These result corroborate those obtained by Singh *et.al.* (2005)

Table 15: Effect of sources and level of silicon on plant height (cm)

	Plant height (cm)					
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	46.78	46.13	49.20	52.67	56.57	50.27
A_2 : CS	47.73	49.27	54.33	54.87	58.53	52.95
A_3 : BA	48.35	49.07	48.40	50.73	54.63	50.24
Mean	47.62	48.16	50.64	52.76	56.58	**51.15**
Control	**45.30**					
	S.E. ±			CD at 5%		
A	0.73			2.12		
B	0.95			2.74		
(A × B)	1.64			NS		
Treat Vs C	1.70			4.91		

4.2.2 Number of leaves per plant

The number of leaves per plant was found significantly influenced due to sources and different levels of silicon were presented in table 16.

The source A_2 (CS) was recorded significantly the highest number of leaves per plant (10.47) over all other sources.

The levels of silicon significantly influenced number of leaves per plant. Application of Si @ 250 kg ha^{-1} (B_5) recorded significant the highest number of leaves per plant (10.89) over all other levels of silicon. However, it was at par with B_4 (10.67).

The interaction effect of sources and levels of silicon was non - significant. However, the treatment combination of A_2B_5 (11.67) recorded highest number of leaves at harvest.

The number of leaves per plant was significantly increased with treated (9.89) over control (7.67).

Table16: Effect of sources and level of silicon on number of leaves per plant

	Number of leaves per plant					
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	8.33	9.33	9.00	10.67	10.67	9.60
A_2 : CS	9.67	9.67	10.00	11.33	11.67	10.47
A_3 : BA	9.67	9.33	8.67	10.00	10.33	9.60
Mean	9.22	9.44	9.22	10.67	10.89	**9.89**
Control	**7.67**					
	S.E. ±			CD at 5%		
A	0.25			0.74		
B	0.33			0.96		
(A × B)	0.57			NS		
Treat Vs C	0.59			1.72		

4.2.3 Polar diameter (cm)

The polar diameter of bulb was found significantly influenced due to sources and levels of silicon were presented in table 17.

The source A_2 (CS) was recorded significantly the highest polar diameter (4.07 cm) over all other sources. However, it was at par with A_1 (3.95).

The levels of silicon significantly influenced the polar diameter. Application of Si @ 250 kg ha^{-1} (B_5) recorded significant the highest polar diameter (4.12 cm) over all other the levels of silicon. However, it was at par with B_3 (3.88cm) and B_4 (4.00cm)

The interaction effect of sources and levels of silicon was non - significant. However the treatment combination of A_2B_5 (4.68cm) recorded highest polar diameter at harvest.

The polar diameter was significantly increased with treated (3.94 cm) over control (3.13 cm).

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 it more size. This effect of other factors responsible for increase in polar diameter. Similar finding were also reported by Durgude *et al*. (2014).

Table17: Effect of sources and level of silicon on Polar diameter (cm)

Polar diameter (cm)						
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	3.82	3.64	3.96	3.91	4.42	3.95
A_2 : CS	3.75	3.89	3.90	4.14	4.68	4.07
A_3 : BA	3.56	3.46	3.80	3.96	4.15	3.79
Mean	3.71	3.66	3.88	4.00	4.12	**3.94**
Control	**3.13**					
	S.E. ±			CD at 5%		
A	0.077			0.22		
B	0.099			0.28		
(A × B)	0.17			NS		
Treat Vs C	0.17			0.51		

4.2.4 Equatorial diameter (cm)

The data related to equatorial diameter of bulb was significantly influenced due to sources and different levels of silicon were presented in table 18.

The source A_2 (CS) recoded significantly the highest equatorial diameter (4.43cm).

The levels of silicon significantly influenced by application of Si @ 250 kg ha^{-1} (B_5) and recorded significantly the highest equatorial diameter (4.92 cm).

The interaction effect of sources and levels of silicon was non - significant in respect of equatorial diameter. However, the treatment combination of A_2B_5 (5.03 cm) recorded the highest equatorial diameter at harvest.

The equatorial diameter was significantly increased with treated (4.17cm) over control (3.01cm).

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).

Table 18: Effect of sources and level of silicon on equatorial diameter (cm)

	Equatorial diameter (cm)					
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	3.53	3.91	3.79	4.16	5.01	4.08
A_2 : CS	4.13	4.21	4.49	4.27	5.03	4.43
A_3 : BA	3.48	3.89	3.97	4.03	4.71	4.02
Mean	3.71	4.00	4.08	4.15	4.92	**4.17**
Control	**3.01**					
	S.E. ±			CD at 5%		
A	0.11			0.34		
B	0.15			0.44		
(A × B)	0.26			NS		
Treat Vs C	0.27			0.79		

4.2.5 Neck thickness (cm)

The neck thickness of bulb showed significantly influenced due to application through different sources and levels of silicon were presented in table 19.

The source A_2 (CS) recoded significantly the highest neck thickness (1.37cm) over all other sources. However, it was at par with A_1 (1.34 cm). The source A_3 (BA) recorded significantly the lowest neck thickness (1.31cm). However, it was at par with A_1 (1.34cm)

The levels of silicon significantly influenced due to application Si @ 250 kg ha^{-1} (B_5) for achiving highest neck thickness (1.45 cm). However, it was at par with B_4 (1.39cm). The neck thickness was showed minimum for without application of silicon

The interaction effect of sources and levels of silicon were non - significant. However, the treatment combination of A_2B_5 (1.49 cm) recorded the highest neck thickness at harvest and the combination A_3B_1 (1.23cm) recorded the minimum neck thickness. The neck thickness was significantly decreased with control (1.22 cm) over treated (1.34 cm). However, the storage life of garlic increases with decrease in neck thickness.

The availability of nutrients to the crops at growth stages through silicon source might have increased neck thickness. Similar results for effect of sources and levels of silicon on neck thickness of garlic bulb reported by Durgude *et al*. (2014).

Table 19: Effect of sources and level of silicon on neck thickness (cm)

	Neck thickness (cm)					
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	1.27	1.32	1.23	1.41	1.46	1.34
A_2 : CS	1.28	1.32	1.38	1.40	1.49	1.37
A_3 : BA	1.23	1.24	1.33	1.35	1.40	1.31
Mean	1.26	1.29	1.31	1.39	1.45	**1.34**
Control	**1.22**					
	S.E. ±			CD at 5%		
A	0.014			0.040		
B	0.018			0.052		
(A × B)	0.031			NS		
Treat Vs C	0.03			0.09		

4.2.6 TSS (^{0}B)

Total soluble solids. (TSS ^{0}B)

The data in respect of effect of different sources and levels of silicon on TSS (^{0}B) of garlic were presented in table 20.

The TSS (^{0}B) of garlic found significantly influenced due to application of Si through different sources, levels and their interactions.

The source A_3 (BA) recorded significantly the highest TSS (37.35^{0}B). However, it was at par with A_2 (37.31^{0}B)

The levels of silicon significantly influenced due to TSS of garlic bulb. The application of Si @ 250 kg ha^{-1} (B_5) recorded significantly the highest TSS (38.17^{0}B), However, it was at par with B_4 (37.63 ^{0}B) and B_3 (37.22 ^{0}B).

The interaction effect of sources and levels of silicon were non -significant. However, the treatment combination of A_3B_5 (38.52^{o}B) recorded highest TSS at harvest.

The TSS was significantly increased with treated (36.84 ^{0}B) over control (32.33^{0}B).

The similar findings were also reported by Pharande *et al*. (2014).

Table 20: Effect of sources and level of silicon on TSS (^{o} B)

	Total soluble solids (^{o} B)					
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	32.47	33.80	37.27	37.74	37.93	35.84
A_2 : CS	36.16	37.46	37.40	37.51	38.04	37.31
A_3 : BA	36.20	37.40	37.00	37.64	38.52	37.35
Mean	34.94	36.22	37.22	37.63	38.17	**36.84**
Control	**32.33**					
	S.E. $\pm$			CD at 5%		
A	0.40			1.16		
B	0.52			1.50		
(A × B)	0.90			NS		
Treat Vs C	0.91			2.64		

4.2.7 Number of cloves bulb^{-1}

The number of cloves per bulb was found significantly influenced due to sources and levels of silicon were presented in table 21.

The source A_2 (CS) was recorded significantly the highest number of cloves per bulb (22.20) over all other sources.

The levels of silicon significantly influenced Number of cloves per bulb. Application of Si @ 250 kg ha^{-1} (B_5) recorded significant the highest number of clove per bulb (22.44) over all other levels of silicon. However, it was at par with B_4 (22.00)

The interaction effect of sources and levels of silicon was non - significant. However, the treatment combination of A_2B_5 (23.33) recorded highest number of cloves per bulb.

The number of cloves per bulb was significantly increased with treated (20.78) over control (17.00).

Table 21: Effect of sources and level of silicon on number of cloves per bulb

Number of cloves bulb^{-1}						
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	17.33	19.67	20.67	21.67	22.00	20.27
A_2 : CS	22.33	20.00	22.33	23.00	23.33	22.20
A_3 : BA	18.33	21.00	16.67	21.33	22.00	19.87
Mean	19.33	20.22	19.89	22.00	22.44	**20.78**
Control	**17.00**					
	S.E. ±			CD at 5%		
A	0.51			1.47		
B	0.65			1.90		
(A × B)	1.14			NS		
Treat Vs C	1.18			3.40		

4.2.8 Weight of 10 cloves (g)

The Weight of 10 cloves of bulb was found significantly influenced due to sources and levels of silicon were presented in table 22.

The source A_2 (CS) was recorded significantly the highest weight of 10 cloves (10.43 g) over all other sources.

The levels of silicon significantly influenced weight of cloves. Application of Si @ 250 kg ha^{-1} (B_5) recorded significant highest weight of 10 cloves (11.93 g) over all other levels of silicon.

The interaction effect of sources and levels of silicon was significant. Application of Si @ 250 kg ha^{-1} (B_5) through CS was significantly registered the highest A_2B_5 (12.52 g) weight of 10 cloves than rest of treatment combination. However, it was at par with A_1B_5 (11.94g)

The Weight of 10 cloves (g) was significantly increased with treated (9.91 g) over control (7.83 g).

Table 22: Effect of sources and level of silicon on weight of 10 cloves (g)

	Weight of 10 cloves (g)					
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	8.91	9.11	9.28	9.63	11.94	9.77
A_2 : CS	8.48	9.98	10.13	11.03	12.52	10.43
A_3 : BA	8.81	9.15	9.03	9.28	11.32	9.52
Mean	8.73	9.41	9.48	9.98	11.93	**9.91**
Control	**7.83**					
	S.E. ±			CD at 5%		
A	0.11			0.34		
B	0.15			0.44		
(A × B)	0.26			0.76		
Treat Vs C	0.27			0.79		

4.2.9 Average weight of bulb (g)

The average weight of garlic bulb was significantly influenced due to sources presented in table 23.

The source A_2 (CS) recorded significantly the highest weight of bulb (23.20g) over all sources. However, it was at par with A_1 (21.87 g).

The levels of silicon significantly influenced on bulb weight. Application of Si @ 250 kg ha^{-1} (B_5) recorded higher bulb weight (23.67 g). However, it was at par with B_4 (23.00g) and B_2 (21.89g).

The interaction effect of sources and levels of silicon was non - significant. However, the treatment combination of A_2B_5 (24.33 g) recorded highest bulb weight at harvest.

The Weight of bulb (g) was significantly increased with treated (22.07g) over control (18.67 g).

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).

Table 23: Effect of sources and level of silicon on average weight of bulb (g)

	Average weight of bulb (g)					
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	19.00	22.00	22.00	23.00	23.33	21.87
A_2 : CS	23.67	21.33	23.33	23.33	24.33	23.20
A_3 : BA	19.00	22.33	18.33	22.67	23.33	21.13
Mean	20.56	21.89	21.22	23.00	23.67	**22.07**
Control	**18.67**					
	S.E. ±			CD at 5%		
A	0.50			1.44		
B	0.64			1.86		
(A × B)	1.11			NS		
Treat Vs C	1.15			3.33		

4.2.10 Yield of garlic (kg $plot^{-1}$)

The data in respect of effect of different sources and levels of silicon on yield of garlic bulbs were presented in table 24.

The yield of garlic was found significantly influenced due to different sources, levels and their interactions. The source A_2 (CS) recorded significantly the highest bulb yield (8.94 kg $plot^{-1}$) over all other sources.

The levels of silicon showed significantly influenced due to the application of Si @ 250 kg ha^{-1} (B_5) for gaining the highest garlic bulb yield (10.41kg $plot^{-1}$) over all the levels of silicon.

The interaction effect of sources and levels of silicon on yield of garlic was non - significant, However, the treatment combination of A_2B_5 (11.01 kg $plot^{-1}$) recorded highest yield per plot at harvest.

The yield of bulb per plot (kg) was significantly increased with treated (8.61 kg) over control (6.98 kg).

Improved 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 @ 250 kg ha^{-1}. These results resembled to the findings reported by Korndorfer *et al.* (2001), Singh *et al*. (2005a) and Durgude *et al.* (2014).

Table 24: Effect of sources and levels of silicon on yield of garlic (kg $plot^{-1}$)

	Yield of garlic (kg $plot^{-1}$)					
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	7.30	7.82	8.23	8.91	10.56	8.36
A_2 : CS	8.10	8.07	8.33	9.18	11.01	8.94
A_3 : BA	7.78	7.44	7.90	8.90	9.67	8.34
Mean	7.73	7.78	8.15	9.00	10.41	**8.61**
Control	**6.98**					
	S.E. ±			CD at 5%		
A	0.14			0.42		
B	0.18			0.54		
(A × B)	0.32			NS		
Treat Vs C	0.33			0.97		

4.2.11 Yield of garlic (qt ha^{-1})

The data in respect of effect of different sources and levels of silicon on total yield of garlic bulbs were presented in table 25.

The source A_2 (CS) recorded significantly the highest bulb yield (148.96 qt ha^{-1}) over all other sources. However, it was at par with A_1 (142.50 qt ha^{-1})

The levels of silicon showed significantly influenced due to the application of Si @ 250 kg ha^{-1} (B_5) for gaining the highest garlic bulb yield (173.55qt ha^{-1}) over all the levels of silicon.

The interaction effect of sources and levels of silicon on yield of garlic was non - significant. However, the treatment combination of A_2B_5 (183.44 qt ha^{-1}) recorded highest total yield at harvest.

The yield of bulb qt ha^{-1} was significantly increase with treated (143.49 qt ha^{-}) over control (116.33 qt ha^{-1}).

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 silicon. These results resemble to the findings reported by Korndorfer *et al* (2001), Singh *et al.* (2005) and Durgude *et al.* (2014)

Table 25: Effect of sources and level of silicon on yield of garlic (qt ha $^{-1}$)

	Yield of garlic (qt ha^{-1})					
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	120.60	130.27	137.10	148.55	175.99	142.50
A_2 : CS	135.05	134.49	138.77	153.05	183.44	148.96
A_3 : BA	129.66	124.05	131.72	148.38	161.22	139.01
Mean	128.44	129.61	135.86	149.99	173.55	**143.49**
Control	**116.33**					
	S.E. ±			CD at 5%		
A	2.42			7.01		
B	3.13			9.05		
(A × B)	5.42			NS		
Treat Vs C	5.60			16.39		

4.2.12 Marketable yield (%)

The data in respect of effect of different sources and levels of silicon on marketable yield of garlic was presented in table 26.

The marketable yield of garlic bulb significantly influenced due to application through different sources and levels of silicon.

The source A_2 (CS) recorded significantly the highest marketable yield (92.33%). However, it was at par with A_1 (90.19%).

The levels of application of Si @ 250 kg ha^{-1} (B_5) recorded significantly the highest marketable yield (96.86 %) over all the levels of silicon.

The interaction effect of sources and levels of silicon were non - significant. However, the treatment combination of A_2B_5 (98.21%) recorded the highest marketable yield at harvest. The marketable yield of garlic was significantly increase with treated (90.75 %) over control (85.70%).

There was significant increase in the marketable yield of garlic grown on vertisols. 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)

Table 26: Effect of sources and level of silicon on marketable yield of garlic (%)

	Marketable yield of garlic (%)					
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	88.64	90.82	86.85	88.09	96.55	90.19
A_2 : CS	89.08	89.53	90.58	94.27	98.21	92.33
A_3 : BA	87.14	88.17	88.86	88.68	95.81	89.73
Mean	88.29	89.50	88.76	90.34	96.86	**90.75**
Control	**85.70**					
	S.E. ±			CD at 5%		
A	0.74			2.14		
B	0.96			2.77		
(A × B)	1.66			NS		
Treat Vs C	1.71			4.96		

4.3 Effect of sources and levels of silicon on uptake of nutrients by garlic

The data pertaining to effect of sources and levels of silicon on nutrient uptake of N, P, K and Si by garlic are presented in tables.

4.3.1 Nitrogen uptake (kg ha^{-1})

The data in respect of effect of different sources and levels of silicon on uptake of nitrogen by garlic plant presented in table 27.

The nitrogen uptake was significantly influenced due to sources of silicon. The A_2 (CS) recorded the significantly the highest total nitrogen uptake (40.12 kg ha^{-1}).

The levels of silicon was significantly influence due to the application Si @ 250 kg ha^{-1} (B_5) and recorded significantly the highest uptake of nitrogen (52.89 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 the highest due to application of Si @ 250 kg ha^{-1} A_2B_5 (58.95 kg ha^{-1}) over all other interactions.

The uptake of nitrogen was significantly increased with treated (37.54 kg ha^{-1}) over control (24.59 kg ha^{-1}).

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 Savant *et al.* (1997), Talashikar *et al*. (2000), Egrinya *et al.* (2008),

Table 27: Effect of sources and level of silicon on available silicon on nitrogen uptake (kg ha^{-1}

Nitrogen uptake (kg ha^{-1})						
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	25.21	29.23	33.51	42.86	52.57	36.71
A_2 : CS	31.51	34.26	35.55	40.33	58.95	40.12
A_3 : BA	29.91	29.72	32.30	39.78	47.15	35.77
Mean	28.94	31.07	33.79	40.99	52.89	**37.34**
Control	**24.59**					
	S.E. ±			CD at 5%		
A	0.59			1.72		
B	0.77			2.22		
(A × B)	1.33			3.86		
Treat Vs C	1.38			3.98		

4.3.2 Phosphorus uptake (kg ha^{-1})

The data in respect of effect of different sources and levels of silicon on total uptake of phosphorus by plant from soil are presented in table 28.

The phosphorus uptake was significantly influenced due to sources of silicon. The A_2 (CS) recorded the significantly the highest total phosphorus uptake (13.44 kg ha^{-1}). However, it was at with A_1 (13.12 kg ha^{-1}).

The levels of silicon showed significantly influenced on P uptake. Application of Si @ 250 kg ha^{-1} (B_5) recorded significantly the highest phosphorus uptake (17.60 kg ha^{-1}).

The interaction effect of sources and levels of silicon on phosphorus uptake was found non - significant. However, the treatment combination of A_2B_5 (19.11kg ha-1) recorded the highest phosphorus uptake harvest.

The uptake of phosphorus was significantly increased with treated (12.89 kg ha^{-1}) over control (8.12 kg ha^{-1}).

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 Rani and Narayan (1994) , Mongia *et al.* (2003) ,Gerroh and Gascho (2005) and Yang *et al.* (2008).

Table 28: Effect of sources and level of silicon on available silicon on phosphorus uptakes ($kg\ ha^{-1}$)

Phosphorus uptake ($kg\ ha^{-1}$)						
Silicon sources (A)	**Levels of silicon (B) $kg\ ha^{-1}$**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	10.78	11.30	12.43	13.99	17.08	13.12
A_2 : CS	11.23	11.91	10.69	14.26	19.11	13.44
A_3 : BA	10.96	10.52	10.43	12.03	16.61	12.11
Mean	10.99	11.24	11.18	13.43	17.60	**12.89**
Control	**8.12**					
	S.E. ±			CD at 5%		
A	0.26			0.76		
B	0.34			0.98		
(A × B)	0.59			NS		
Treat Vs C	0.61			1.76		

4.3.3 Potassium uptake ($kg\ ha^{-1}$)

The data in respect of effect of different sources and levels of silicon on total uptake of potassium by plant from soil were presented in table 29.

The potassium uptake was significantly influenced due to sources of silicon. The source A_2 (CS) recorded the highest potassium uptake (29.74 $kg\ ha^{-1}$).

The levels of silicon significantly increased by application of Si and level of Si @ 250 $kg\ ha^{-1}$ (B_5) recorded significantly the highest total potassium uptake (36.14 $kg\ ha^{-1}$) over all other levels of silicon.

The interaction effect of sources and levels of silicon on potassium uptake was found significant and recorded the highest due to application of Si @ 250 $kg\ ha^{-1}$ A_2B_5 (38.36 $kg\ ha^{-1}$) over all other interactions. However, it was at par with A_1B_5 (38.34 $kg\ ha^{-1}$)

The uptake of potassium was significantly increased with treated (27.66 $kg\ ha^{-1}$) over control (20.10kg 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 Schelhass and Muller (1977) and Kaya *et al*. (2006), Egrinya *et al*. (2008)

Table 29: Effect of sources and level of silicon on available silicon on potassium uptakes (kg ha[1])

Potassium uptake (kg ha^{-1})						
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	22.28	26.42	20.97	29.96	38.34	27.59
A_2 : CS	25.00	27.12	27.92	30.27	38.36	29.74
A_3 : BA	21.49	22.17	23.75	29.08	31.73	25.64
Mean	22.92	25.24	24.21	29.77	36.14	**27.66**
Control	**20.10**					
	S.E. $\pm$			CD at 5%		
A	0.58			1.55		
B	0.69			2.00		
(A × B)	1.20			3.47		
Treat Vs C	1.24			3.58		

4.3.4 Silicon uptake (kg ha^{-1})

The data in respect of effect of different sources and levels of silicon on uptake of silicon by plant from soil are presented in table 30.

The silicon uptake was significantly influenced due to sources of silicon. The source A_2 (CS) recorded significantly the highest total silicon uptake (4.82 kg ha^{-1}) over all other sources.

The levels of silicon significant influenced Si uptake. Application of Si @ 250 kg ha^{-1} (B_5) recorded significantly the highest silicon uptake (6.45 kg ha^{-1}) over all the levels of silicon.

The interaction effect of sources and levels of silicon on silicon uptake was found non - significant. However, the treatment combination of A_2B_5 (6.96 kg ha^{-1}) recorded highest silicon uptake at harvest.

The uptake of silicon was significantly increased with treated (4.48 kg ha^{-1}) over control (2.10 kg ha^{-1}).

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. 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).

Table: 30 Effect of sources and level of silicon on available silicon on silicon uptakes (kg ha^{1})

Silicon uptake (kg ha^{-1})						
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	2.77	3.50	3.77	5.09	6.53	4.33
A_2 : CS	3.61	3.88	3.93	5.74	6.96	4.82
A_3 : BA	3.26	3.54	3.60	5.18	5.84	4.28
Mean	3.21	3.64	3.77	5.34	6.45	**4.48**
Control	**2.10**					
	S.E. $\pm$			CD at 5%		
A	0.13			0.39		
B	0.17			0.51		
(A × B)	0.30			NS		
Treat Vs C	0.31			0.91		

4.4 Effect of sources and levels silicon on pest infestation and disease incidence on garlic

4.4.1 Effect of sources and levels of silicon on mites infestation on garlic

The sources of silicon found significantly influenced due to pest infestation work out by average survival per plant are presented in table 31.

The result recorded that source A_2 (CS) was significantly minimum mites infestation (7.34) over all sources.

The levels of silicon showed minimum pest infestation (mites) was significantly influenced due to the application of @ 250 kg ha^{-1} (B_5) recorded significantly the lowest number of mites (6.65) over all the levels of silicon. However, it was at par with B_4 (7.14)

The interaction effect of sources and levels of silicon on pest infestation (Mites) on garlic was found non - significant. The result recorded the lowest infestation of pest at treatment A_2B_5 (6.51). There was significant decreased in the percent of mites with increased levels of silicon

The pest infestation (Mites) on garlic was significantly decreased with treated (7.77) over control (9.12).

The decrease in the infestation of mites might be due to silicification of the epidermis. Silicon compounds are likely to be deposited in different cellular parts such as cell lumens, cell walls and intercellular spaces. Its deposition below and above of the cuticle layer has also been reported. The deposited silicon increases the hardness of plant tissue, which negatively impacts insect feeding ability due to inbuilt resistance developed in garlic. Similar results were also reported by salim and Saxena (1992), Talashilkar (2000) and Ranganathan *et al.* (2006)

Table 31. Effect of sources and levels of silicon on pest infestation (mites) on garlic

Pest infestation (mites) on garlic						
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	9.10	8.67	8.50	6.97	6.69	7.99
A_2 : CS	8.24	7.80	7.29	6.85	6.51	7.34
A_3 : BA	8.52	8.57	8.46	7.60	6.76	7.98
Mean	8.62	8.35	8.08	7.14	6.65	**7.77**
Control	**9.12**					
	S.E. $\pm$			CD at 5%		
A	0.19			0.55		
B	0.24			0.72		
(A × B)	0.43			NS		
Treat Vs C	0.44			1.29		

4.4.2 Effect of sources and levels of silicon on thrips infestation on garlic

The data presented in Table showed that effect of sources and levels of silicon significantly influenced the infestation was worked out by average survival per plant of thrips presented in table 32.

The source of silicon A_2 (CS) significantly recorded the lowest infestation of thrips (5.08) than other source of silicon.

The levels of silicon also significantly recorded the lowest infestation of thrips (4.13) with 250 kg ha^{-1}. However, it was at par with B_4 (4.76)

The interaction effect between sources and levels of silicon found non - significant and lower infestation was recorded by A_2B_5 (3.82).

The pest incidence was significantly decreased with treated (5.45) over control

(6.82).

Table 32. Effect of sources and levels of silicon on pest infestation (thrips) on garlic

Pest infestation (thrips) on garlic						
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	6.79	6.53	5.78	4.67	4.22	5.60
A_2 : CS	6.32	5.53	5.24	4.49	3.82	5.08
A_3 : BA	6.34	6.44	6.08	5.11	4.37	5.67
Mean	6.48	6.17	5.70	4.76	4.13	**5.45**
Control	**6.82**					
	S.E. ±			CD at 5%		
A	0.17			0.49		
B	0.22			0.64		
(A × B)	0.38			NS		
Treat Vs C	0.39			1.14		

It has been observed that sucking pests having low preference for the silicified tissue than low silica containing succulent parts. Silicon reduce the food intake, growth longitivity, fecundity of sucking pests. Increase the levels of silicon to decrease the incidence of pests.

The decrease in the infestation of thrips might be due to silicification of the epidermis. Silicon compounds are likely to be deposited in different cellular parts such as cell lumens, cell walls and intercellular spaces. Its deposition below and above of the cuticle layer has also been reported. The deposited silicon increases the hardness of plant tissue, which negatively impacts insect feeding ability due to inbuilt resistance developed in garlic. Similar results were also reported by salim and Saxena (1992), Ranganathan *et al.* (2006).

4.4.3 Effect of sources and levels of silicon on disease (purple blotch %) incidence on garlic

The data in respect of effect of different sources and levels of silicon on disease incidence on garlic presented in table 33.

The source of silicon A_2 (CS) significantly recorded the lowest incidence of purple blotch (5.00 %) than other source of silicon. However, it was at par with A_1 (5.30 %).

The levels of silicon also significantly recorded lowest incidence of purple blotch (4.41%) with 250 kg ha^{-1}. However, it was at par with B_4 (4.88 %)

The interaction effect between sources and levels of silicon found non - significant and lower incidence was recorded by A_2B_5 (4.15%).

The pest incidence (purple blotch %) on garlic garlic was significantly decreased with treated (5.41 %) over control (6.82 %).

Silicon in plant might form complexes with the organic compounds of cell walls of epidermal cells, thus increases resistance to enzymes elaborated by the pathogen. The soluble Si can produce phenolics and phytoalexins in response to infection by pathogen. The antifungal compounds like momilactones were known to accumulate in Si amended rice plants. Similar findings had also reported by Buck *et al.* (2008) and Patil and Patil (2011).

Table 33: Effect of sources and levels of silicon on disease incidence (purple blotch %) on garlic

Disease incidence (purple blotch %) on garlic						
Silicon sources (A)	**Levels of silicon (B) kg ha^{-1}**					
	B_1 0	**B_2 100**	**B_3 150**	**B_4 200**	**B_5 250**	**Mean**
A_1 : DE	5.87	5.87	5.78	4.67	4.39	5.30
A_2 : CS	5.98	5.20	5.18	4.49	4.15	5.00
A_3 : BA	6.34	6.78	6.41	5.47	4.70	5.94
Mean	6.04	5.95	5.79	4.88	4.41	**5.41**
Control	**6.82**					
	S.E. ±			CD at 5%		
A	0.24			0.70		
B	0.31			0.90		
(A × B)	0.54			NS		
Treat Vs C	0.56			1.61		

5. SUMMERY AND CONCLUSIONS

A field experiment was conducted in garlic (*Allium sativum* L.) Cv. Phule Nilima at All India Coordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri , Dist. Ahmednagar in *rabi* season of 2017 – 18, to find out the response of garlic to silicon by using different sources and levels of silicon on growth, yield and quality characters in garlic. The objectives of experiment were, to study the effect of sources and levels of silicon on total NPK and Si uptake in garlic and also to study the effect of sources and levels of silicon on incidence of pest and disease.

The experiment was conducted in Factorial Randomised Block Design (FRBD) with control. Fifteen treatment combinations were formed by three sources of fertilizer silicon (viz., diatomaceous earth, calcium silicate, bagasse ash) with five levels of silicon (viz., 0,100,150, 200 and 250 kg ha^{-1}) and one absolute control, were tried and each replicated three times. The basal dose of fertilizer 100 N, 50 P_2O_5 and 50 K_2O kg $ha^{-1}$was applied before planting.

The application of silicon fertilizers was done as per treatments @ 0,100, 150, 200 and 250 kg ha^{-1} before 15 days of planting. Cloves of garlic Cv. Phule Nilima was obtained from Senior Vegetable Breeder and was sown in the experimental field. It was followed by irrigation. Further irrigations were given as and when required. The various recommended cultural operations like hand weeding, plant protection measures etc. were taken to raise healthy crop of garlic.

Biometric observations were recorded at the time of harvesting viz., height of plant (cm) and number of leaves per plant by using five plants selected at random from each plot for this purpose. These five plants were harvested separately for assessment of individual bulb weight (g), number of cloves per bulb, weight of 10 cloves (g), equatorial and polar diameter of bulbs (cm) used for estimation of silicon.

After harvesting of crop with sample plants separately, the bulk of crop was harvested at maturity on 27 th March 2018. The weight of field cured bulbs was recorded in kg / plot. The total yield of bulbs in qt $ha^{-1}$was computed by addition of bulb yield with sampled plants. The bulk bulbs harvested plot wise were classified into three grades on the basis of size. Percentage of each grade was computed plot wise on weight basis and taken as marketable yield.

Silicon contents of bulbs at harvest were estimated and the total uptake in kg ha^{-1} was calculated. Three garlic bulbs were selected at random from each plot and used to determine the silicon uptake in garlic bulbs and leaves and total uptake was calculated.

Data obtained on basis of various variables were analysed, and interpretation was done. The results obtained are summarized as below.

5.1 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 were significantly influenced due to application of different sources and levels of silicon. In case of source A_1 (DE) recorded significantly highest OC, while source A_2 (CS) recorded significantly highest pH and EC (dsm^{-1})

In case of levels (B_5) application of Si @ 250 kg ha^{-1} recorded significantly highest pH, EC, and OC in soil.

The available nutrient viz. N, P, K and Si at harvest of garlic were significantly influenced due to application of different sources. In case of sources, the source A_2 (CS) recorded significantly highest N, P, K and Si at harvest in garlic

The availability of nutrients viz. N, P, K and Si was significantly influenced due to application of levels of silicon. In case of levels (B_5) application of Si @ 250 kg ha^{-1} recorded significantly highest N, P, K and Si.

The available nutrients like P and Si significantly influenced due to interaction of sources and levels of silicon. In case of interaction of silicon (A_2B_5) were recorded significantly highest P and Si at harvest.

The available micro nutrients viz., Fe, Mn, Zn, Cu was significantly influenced due to application of sources .The source A2 (CS) recorded significantly highest Fe and Mn .and source A1 (DE) recorded significantly highest Zn and Cu in soil.

In case of levels of silicon the available micronutrients Fe, Mn, Zn, and Cu was showed significant influence due to application of silicon @ 250 kg ha $^{-1}$.

5.2 Effect of sources and levels of silicon on growth, yield and quality of garlic

The yield attributing characteristics of garlic viz. plant height, number of leaves per plant, polar diameter , equatorial diameter , total soluble solids (TSS), number of cloves per bulb, weight of 10 cloves, weight of bulb $^{-1,}$ total yield as well as marketable yield of garlic bulbs, was significantly influenced due to the application of different sources of silicon. In case of source A_2 (CS) recorded significantly highest plant height, number of leaves per plant, polar diameter , equatorial diameter, number of cloves per bulb, weight of 10 cloves, weight of $bulb^{-1}$, yield $plot^{-1}$, total yield as well as marketable yield of garlic and The source A_3 (BA) recorded significantly lowest neck thickness and highest Total Soluble solids (TSS).

The plant height (cm), number of leaves per plant, polar diameter(cm), equatorial diameter(cm), total soluble solids (TSS), number of cloves per bulb, weight of 10 cloves(g), yield $plot^{-1}$(kg) , total yield (kg ha^{-1}) 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 @ 250 kg ha^{-1} was significantly highest in these respect. The neck thickness was minimum at control and at level B_1. i.e without silicon.

The weight of 10 cloves was significantly influenced due to interaction effect of sources and levels of silicon. The interaction (A_2B_5) recorded significantly highest weight of 10 cloves of garlic.

5.3 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 of different sources. In case of source A_2 (CS) recorded significantly highest N, P and K and Si uptake

In levels of silicon the nutrient uptake N, P, K and Si was significantly influenced due to application of Si @ 250 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_2B_5) recorded significantly highest N and K uptake.

5.4 Effect of sources and levels of silicon on pest infestation and disease incidence of garlic

The pest infestation and disease incidence was showed significantly influenced due to application of different sources. The source A_2 (CS) recorded minimum pest infestation.

The pest infestation and disease incidence was significantly influenced due to application of different levels. The level (B_5) Si @ 250 kg ha^{-1} recorded significantly minimum pest infestation

Conclusions :

1. Application of silicon through Calcium silicate @ 250 kg ha^{-1} along with recommended dose of fertilizer (100:50:50 kg ha^{-1} and FYM) was found beneficial for increase in plant height, number of leaves per plant, polar diameter, equatorial diameter, yield per plat, total yield, marketable yield of garlic as well as significant reduction of pest infestation and disease incidence of garlic in medium deep black soil. Considering the easy availability of calcium silicate proved as good source of silicon for garlic. The minimum neck thickness was recorded at control over treated.

2. There was significant increase in plant height, number of leaves per plant, polar diameter, equatorial diameter, number of cloves per plant, weight of 10 cloves, weight of bulb, Total Soluble Solid, yield $plot^{-1}$, total yield and marketable yield due to silicon application, however there were significant difference between levels of silicon and sources of silicon.

3. The uptake of N, P, K and Si was significantly increased over absolute control and no application of silicon sources, levels and their interaction.
4. The pest infestation and disease incidence was observed significantly minimum due to application of different sources and levels of silicon for garlic crop.

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7. APPENDICES

APPENDIX-I: Details of meteorological data during experimental period.

Met. Week	Temperature (^0C)		Humidity (%)		Sun Shine (hrs)	Rain Fall (mm)	No. Rainy days	Eva. (mm)
	Max	Min	Morning	Evening				
November, 2017								
45	30.30	13.3	63.00	36.00	9.7	0.0	0.0	5.5
46	30.00	12.2	66.00	34.00	9.0	0.0	0.0	5.7
47	30.20	16.6	74.00	35.00	6.2	0.0	0.0	4.2
48	29.80	11.4	66.00	34.00	8.3	0.0	0.0	4.3
December, 2017								
49	28.5	17.6	71.00	49.00	4.6	0.0	0.0	3.8
50	29.8	14.6	73.00	39.00	6.6	0.0	0.0	4.4
51	28.2	10.8	70.00	31.00	6.7	0.0	0.0	4.1
52	28.8	9.4	59.00	31.00	8.9	0.0	0.0	4.5
January, 2018								
1	28.51	10.65	67.14	36.42	7.95	0.0	0.0	3.84
2	28.11	12.22	62.57	34.57	7.47	0.0	0.0	3.90
3	29.88	12.84	70.42	31.85	8.57	0.0	0.0	4.41
4	28.40	9.5	55.57	27.14	9.40	0.0	0.0	4.77
5	30.31	10.65	59.42	21.57	9.52	0.0	0.0	5.00
February, 2018								
6	31.20	13.85	53.42	22.85	7.37	0.0	0.0	5.05
7	30.45	13.54	66.42	33.85	8.98	0.0	0.0	5.30
8	33.74	14.97	53.57	24.00	8.77	0.0	0.0	6.00
9	34.6	17.05	43.71	20.28	8.54	0.0	0.0	6.62
March, 2018								
10	34.65	18.25	44.42	20.28	7.44	0.0	0.0	5.94
11	33.08	18.88	47.85	25.28	5.94	0.0	0.0	7.04
12	35.00	16.40	43.85	19.14	8.81	0.0	0.0	7.25
13	37.62	17.97	40.57	14.71	9.22	0.0	0.0	8.54

8. VITAE

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MASTER OF SCIENCE (HORTICULTURE)

IN

VEGETABLE SCIENCE

2019

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