



Effect of Silicon Fertilization on Agro-Morphological Traits of Grand Naine Banana Grown in Typic Ustifluent Soil

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Authors' contributions

This work was carried out in collaboration among all authors. Authors VA designed and conducted the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors MVS and RM managed the analyses of the study and finalized the manuscript. 'Arumugam Shakila' managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Banana is the fifth largest agricultural commodity in the world trade after cereals, sugar, coffee and cocoa and second largest fruit crop in the world. The main objective of the study is to know the performance of banana to silicon fertilization grown in typic ustifluent soil.

Study Design: The experiment was conducted in randomized block design. The test crop banana var Grand Naine.

Place and Duration of Study: Rajagopalapuram village under Kuttallam taluk, Tamilnadu, India Between July to October 2016

Methodology: The experiment consisted of ten treatments viz., T₁-NPK (RDF), T₂-NPK+Potassium silicate (FS)- 0.25%, T₃-NPK+Potassium silicate (FS)-0.50%, T₄-NPK+Potassium silicate (FS)-

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1.00%, T₅-NPK+Potassium silicate (FS)-0.25%, T₆-NPK+ Potassium silicate (FS)-0.50%, T₇-NPK+ Potassium silicate (FS)-1.00%, T₈-NPK+Potassium silicate (SA)-50kg ha⁻¹, T₉-NPK + Potassium silicate (SA)-100 kg ha⁻¹ and T₁₀-NPK + Potassium silicate (SA)-150 kg ha⁻¹. T₂ to T₄ foliar spray was done at 3rd and 5th month and from T₅ to T₇, foliar spray was done at 3rd, 5th and 7th month. Growth, yield parameters and banana yield were recorded.

Results: The outcome was that soil application of silicon recorded higher growth and yield compared to foliar application. Pseudo stem height, Pseudo stem girth, LAI, chlorophyll content, sucker production and leaf dry matter weight, fruit characters viz., bunch weight and length, number of hands/ bunches, number of fingers / hands, total number of fingers/ bunches, finger weight, length and girth were highest with soil application of 50 kg Si ha⁻¹. Similarly, foliar application of silicon at 1% applied at 3rd and 5th recorded the highest morphological and fruit characters compared to 0.25 and 0.5% Si. The highest fruit yield (96.0 t ha⁻¹) was noticed with 50 kg Si ha⁻¹ followed by foliar spray of 1% Si applied at 3rd and 5th month (92.7 t ha⁻¹).

Conclusion: It is concluded that soil application of 50 kg Si ha⁻¹ through potassium silicate is best followed by foliar spray of 1.0% Si for realizing higher banana productivity.

Keywords: Banana; growth; yield; silicon; soil; foliar.

1. INTRODUCTION

Banana is perennial giant herb. Banana production plays a major role in food security for more than 400 million people in developing countries in tropical areas and is a source of income and employment for local populations [1]. At present, banana production in India is 270 million tons from an area of 0.77 Million ha and the productivity of 34.4 t ha⁻¹. Tamilnadu has the largest area of 0.12 Mha and the production of 6.4 MT [2]. Banana (*Musa spp.*) is widely cultivated in tropical regions because of their economic importance for the local market as the source of food for the regional population. Nutritionally, the banana has a fast-growing period, produces high quantity of vegetative biomass, and requires high amount of nutrients. In modern agriculture, silicon is considered to be a functional element for a number of plants, especially for gramineous species [3]. Role of silicon in the alleviation of the biological and non-biological stresses, as well as in the balance of nutrients in other plants, has been proven [4]. Foliar application of Si @ 4 ml and 2 ml/l/ plant at 15 days interval proved to be better in improving the quality parameters in banana cv. Neypooivan [5]. Kumbargire et al. [6] from their field study reported that soil application of diatomaceous earth (DE) as a source of silicon @ 750 kg/ha + Recommended dose of fertilizer registered higher banana fruit yield. In intensive agriculture, supplementary addition of silicon fertilizer is justified to achieve maximum production [7]. The availability of silicon varies with textures and coarse textured soil usually have low silicon status and crops usually remove large quantity of silicon and silicon deficiency are

often noticed. Previous studies have shown using all sources of silicon was very effective in improving yield and fruit characteristics of different fruit crops [8]. Potassium silicate is a source of highly soluble potassium and silicon. It is used in agricultural production systems primarily as a silica amendment and has the added benefit of supplying small amounts of potassium. With this background analysis, a field experiment was conducted in coarse textured soil to know the response of tissue cultured banana var grand naine to silicon fertilization.

2. MATERIALS AND METHODS

2.1 Location

The field experiment was conducted in Padugai series (*Typic Ustifluvent*) soil in farmers field located at Rajagopalapuram village under Kuttallam taluk, Tamilnadu, India. The experimental field is geographically situated 11.10°N and 79.67°E at an altitude of 16 m above mean sea level.

2.2 Physico-Chemical Properties

Texture-sandy loam (International Pipetted method -20), bulk density-1.53 Mg m⁻³ (measuring cylinder method) [9], pH- 7.39 (1:2.5 soil water ratio using pH meter) [9], EC-0.24 dSm⁻¹ (1:2.5 soil water ratio using conductivity meter) [9], organic carbon- 3.5 g kg⁻¹ (Chromic acid wet digestion method) [10], KMnO₄-N- 260 kg ha⁻¹ (low) (Alkaline permanganate method) [11], Olsen-P- 20.2 kg ha⁻¹ (medium) (Ascorbic acid method using spectrophotometer) [12],

$\text{NH}_4\text{OAc-K-}$ 251 kg ha^{-1} (medium) (1 N NH_4OAc extraction method using flame photometer) [13] and available silicon- 29 mg kg^{-1} (1N ammonium acetate buffer 1:10 (pH 4.0) -Imaizumi and Yoshida 1958).

2.3 Experimental Details

The treatments imposed for the study was T_1 -NPK (RDF), T_2 -NPK+Potassium silicate(FS)-0.25%, T_3 -NPK+Potassium silicate(FS)-0.50%, T_4 -NPK+Potassium silicate(FS)-1.00%, T_5 -NPK+Potassium silicate (FS)-0.25%, T_6 -NPK + Potassium silicate (FS)-0.50%, T_7 -NPK+Potassium silicate (FS)-1.00%, T_8 -NPK+Potassium silicate (SA)-50 kg ha^{-1} , T_9 -NPK + Potassium silicate (SA)-100 kg ha^{-1} and T_{10} -NPK + Potassium silicate (SA)-150 kg ha^{-1} . T_2 to T_4 foliar spray was done at 3rd and 5th month and from T_5 to T_7 , foliar spray was done at 3rd, 5th and 7th month. The experiment was conducted in RBD design. The test crop banana cv Grand Naine.

2.4 Data Collections

The observations on pseudo stem height, girth, LAI, sucker production, leaf DMP, yield characters viz., weight of the bunch, length of the bunch, number of hands per bunch, number of fingers per bunch, weight of the finger, length of the finger and fruit yield. The data on growth and yield of banana were analyzed by analysis of variance (ANNOVA), F test and regression to get meaningful expression on the treatment effect on banana.

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

Silicon administered through soil and foliar recorded significantly higher pseudo stem, pseudo stem girth, LAI, chlorophyll, sucker production and leaf dry matter over control is presented in the Table 1. Soil application of silicon recorded higher growth character compared to foliar application. Among the treatments, the tallest banana plant (230.6 cm), pseudo stem girth (74.8 cm), LAI (3.63), sucker production (7.66), chlorophyll (3.51 mg g^{-1}) and DMP (1000.2 g plant^{-1}) was noticed with soil application of 50 kg ha^{-1} . It was comparable with 100 and 150 kg Si/ha except with leaf dry matter. With respect to foliar application, plant height, pseudo stem girth, LAI, sucker production, chlorophyll and DMP increased with concentration of silicon from 0.25 to 1%. Foliar

spray of 1% Si applied twice (3rd and 5th month) registered the maximum growth among foliar application. These results are quite logical due to the role of silicon in the production of biomass by improving the availability of other elements for the plants and alleviating the deficiency of other nutrients [14]. Plants with thicker pseudo stem are desirable as they reflect on bunch size and other related characters besides, they also provide better anchorage to the plants. Silicon has been generally recognized to have a beneficial role in stimulating the various forms of growth and biochemical contents of many plant species. Concerning growth response, silicon was found to enhance stem elongation and strength [15]. Increased leaf area index is an important source in manufacturing photo assimilates through large light interception which determines DMP and yield. Foliar application of silicon increased LAI in rape seed (Nasri et al., 2012). Adibeh Ghasemi et al. [16] reported that addition of 30 kg Si ha^{-1} as sodium silicate improved leaf area index in broad bean. Role of silicon in increasing the chlorophyll level arises from maintenance of chloroplast ultra-structure concomitant with the enhancement of chlorophyll biosynthetic enzyme due to depression of chlorophyll degrading enzymes [17]. Adibeh Ghasami et al. [16] reported increased chlorophyll index in maize and broad bean on addition of 30 kg Si ha^{-1} . Abdella [18] reported increased chlorophyll content in broad bean through foliar spray of diatomite. The synergistic effect of silicon on photosynthesis and chlorophyll content improved markedly the carbohydrate biosynthesis, the supply of cell wall material e.g., cell wall polysaccharides and lignin polymers and eventually high DMP [19]. Maintenance of adequate amount of water-soluble silicon in soil solution and greater accumulation of silicon in plant is key for higher leaf dry weight of plant. Abdella [18] noticed that foliar spray of diatomite as silicon source increased DMP of broad bean.

3.2 Fruit Characters

Addition of silicon through soil and foliar as potassium silicate significantly improved various fruit characters viz., bunch weight, bunch length, number of hands / bunches, number of fingers/hands, total number of fingers / bunches, finger length and weight over control (Table 2). Soil application of silicon recorded higher fruit character compared to foliar application. Soil application of 50 kg Si ha^{-1} recorded the highest fruit character followed by foliar spray of 1% Si

applied twice. Impact of silicon treatments on various fruit characters in terms of percent increase over control is depicted in (Fig. 1). Increase in fruit character could be due to increase in morphological traits such as pseudo stem height, girth, LAI and also higher nutrient uptake by the plants. Increased leaf area index increased the photosynthetic efficiency leading to higher accumulation of carbohydrates. Relatively higher carbohydrates could have promoted the growth rate and in turn increased bunch weight. Silicon might help in cell division, more nutrient and water uptake and resulted in production of a greater number of fruits. Effect of silicon on fruit number was reported by Nesreen et al. [20] in bean, Stamatakis et al. [21] in tomato. Increase in fruit number increased the bunch weight.

Higher photosynthetic activity has resulted in more translocation of metabolites and thereby size of the fruit increased. Silicon plays an important role in protecting the plant against abiotic and biotic stress, improving root development, uptake of water and nutrient uptake and green pigments [22] resulted in higher fruit characters. Lalithya et al. [23] in sapota and El Kholy et al. [24] in Loquat tree reported foliar application of potassium silicate increased fruit characters over control. Roshdy [25] reported that foliar spray of 0.1% Si through potassium silicate increased bunch weight and fruit number of banana var Grand Naine. The present finding was in harmony with Abd-El Hameed [26] in Mango and Ahmad et al. [14] in tomato.

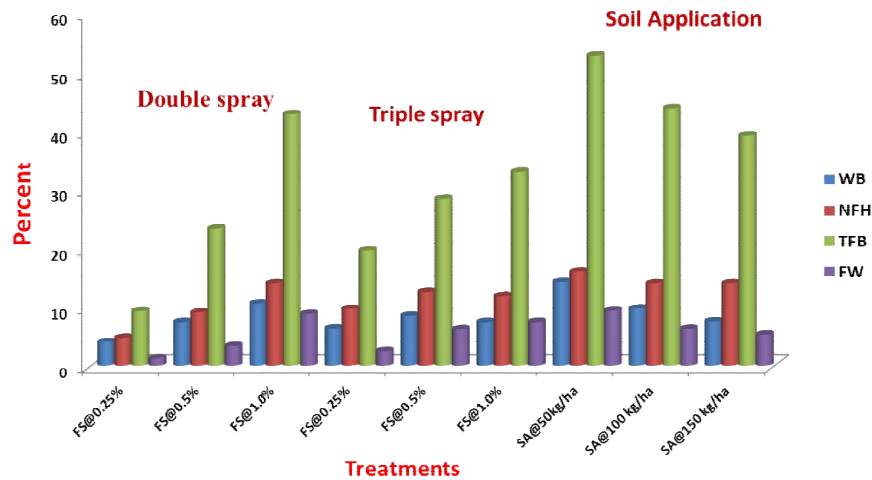


Fig. 1. Percent increase in bunch weight (BW), number of fingers/hand (NFB), total fingers/bunch (TFB) and finger weight due to silicon over control

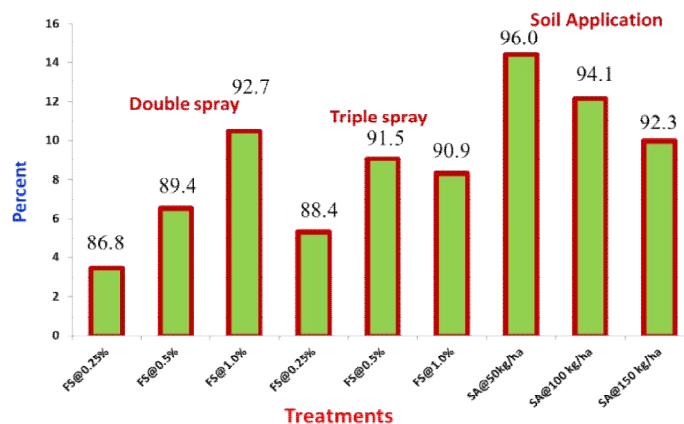


Fig. 2. Percent increase in fruit yield over control due to silicon treatments (absolute yield in t/ha shown in top of bar)

Table 1. Effect of potassium silicate on growth characters of banana var grand naine

Treatments	Plant height (cm)	Pseudo stem girth (cm)	LAI	Chl. (mg g ⁻¹)	Sucker production	Leaf DMP (g)
T ₁ - RDF (Control)	212.4	63.2	2.66	3.10	5.66	868.5
T ₂ - RDF + PS (FS) - 0.25% @ 3 rd & 5 th month	213.7	65.9	2.89	3.18	6.33	896.0
T ₃ - RDF + PS (FS) - 0.50% @ 3 rd & 5 th month	215.7	68.1	3.10	3.28	6.66	900.5
T ₄ - RDF + PS (FS) - 1.0% @ 3 rd & 5 th month	219.7	73.8	3.29	3.40	7.33	989.7
T ₅ - RDF + PS (FS) - 0.25% @ 3 rd , 5 th & 7 th month	216.1	66.5	2.95	3.24	6.50	932.6
T ₆ - RDF + PS (FS) - 0.5% @ 3 rd , 5 th & 7 th month	219.8	70.9	3.19	3.34	6.90	956.7
T ₇ - RDF + PS (FS) - 1.0% @ 3 rd , 5 th & 7 th month	218.2	71.5	3.15	3.32	7.00	968.2
T ₈ - RDF + PS (SA) - 50 kg ha ⁻¹	230.6	74.8	3.63	3.51	7.66	1000.2
T ₉ - RDF + PS (SA) - 100 kg ha ⁻¹	225.1	73.6	3.49	3.47	7.33	979.6
T ₁₀ - RDF + PS (SA) - 150 kg ha ⁻¹	222.6	72.2	3.41	3.42	7.30	960.6
SE _d	5.20	1.29	0.13	0.06	0.15	15.77
CD @ 5%	10.93	2.72	0.29	0.14	0.33	33.14

FS – Foliar spray; SA – Soil application; TS – Tillering stage; PI – Panicle initiation

Table 2. Effect of potassium silicate on fruit characters of banana var grand naine

Treatments	Weight of bunch (g)	Length of bunch (cm)	Number of hands/ bunches	Number of fingers /hand	Total number of fingers / bunches	Weight of the finger (g)	Length of the finger (cm)	Girth of the finger (cm)
T ₁ - RDF (Control)	23.14	65.6	7.0	14.3	105.3	160.2	18.1	7.9
T ₂ - RDF + PS (FS) - 0.25% @ 3 rd & 5 th month	24.10	66.2	7.6	15.0	115.2	162.3	18.2	7.39
T ₃ - RDF + PS (FS) - 0.50% @ 3 rd & 5 th month	24.87	67.9	8.0	15.6	130.0	165.7	18.6	7.79
T ₄ - RDF + PS (FS) - 1.0% @ 3 rd & 5 th month	25.61	68.5	9.0	16.3	150.5	174.4	19.6	7.80
T ₅ - RDF + PS (FS) - 0.25% @ 3 rd , 5 th & 7 th month	24.63	67.2	8.0	15.7	126.0	164.3	18.4	7.59
T ₆ - RDF + PS (FS) - 0.5% @ 3 rd , 5 th & 7 th month	25.12	68.7	8.3	16.1	135.3	170.3	18.7	7.98
T ₇ - RDF + PS (FS) - 1.0% @ 3 rd , 5 th & 7 th month	24.87	67.5	8.6	16.0	140.2	172.2	19.0	7.49
T ₈ - RDF + PS (SA) - 50 kg ha ⁻¹	26.43	69.5	9.6	16.6	161.0	175.4	19.9	8.95
T ₉ - RDF + PS (SA) - 100 kg ha ⁻¹	25.41	68.5	9.3	16.3	151.6	170.4	19.4	8.85
T ₁₀ - RDF + PS (SA) - 150 kg ha ⁻¹	24.90	67.2	9.0	16.3	146.7	168.9	19.3	8.70
SE _d	1.59	1.40	0.19	0.12	3.18	4.32	0.13	0.13
CD @ 5%	NS	2.94	0.40	0.26	6.69	9.08	0.28	0.28

FS – Foliar spray; SA – Soil application; TS – Tillering stage; PI – Panicle initiation

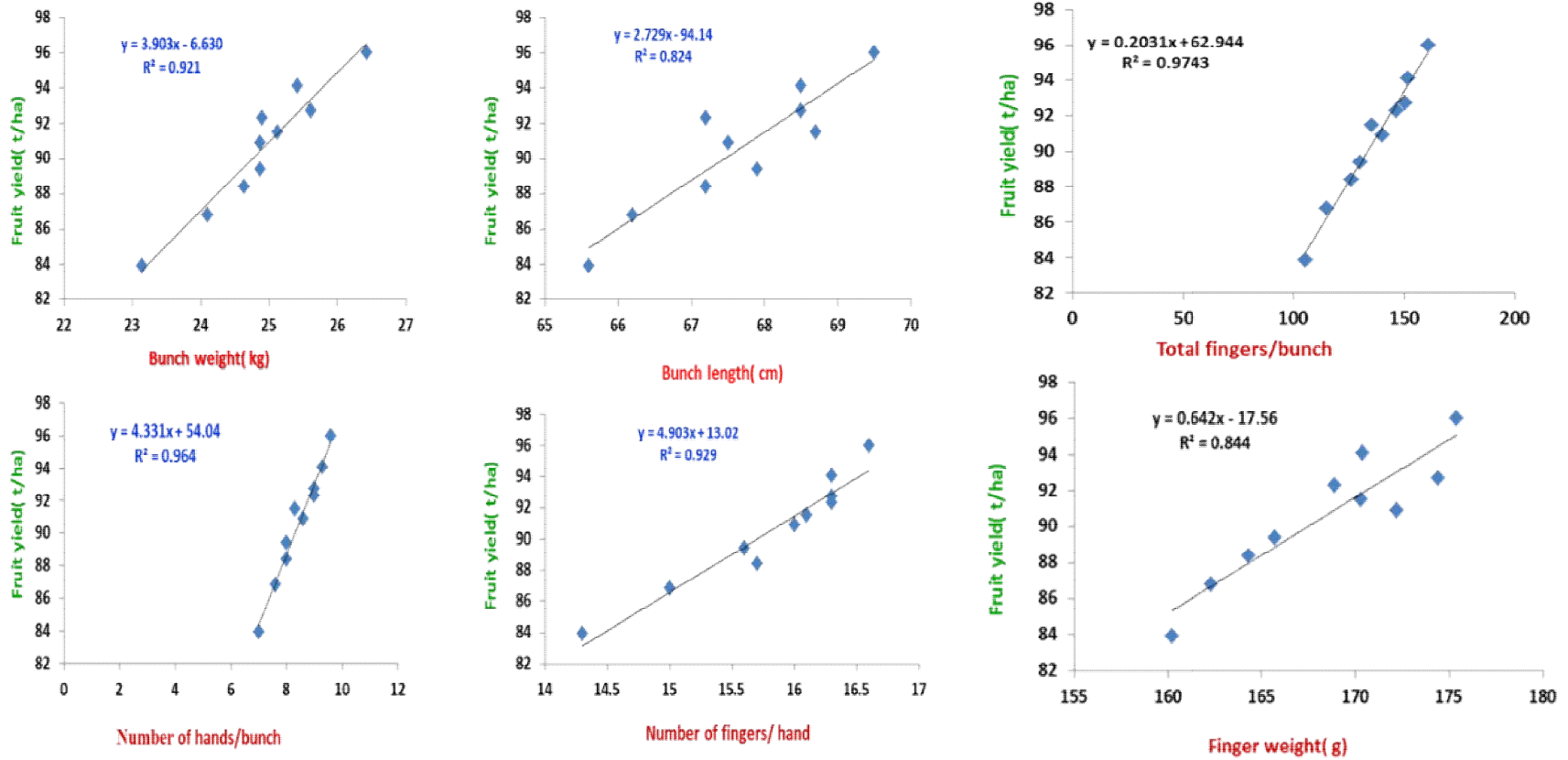


Fig. 3. Linear relationship between fruit yield with fruit characters

3.3 Fruit Yield

Fruit yield was significantly influenced by soil and foliar application of silicon applied through potassium silicate over control. Soil application of silicon recorded higher banana yield compared to foliar application. The per cent increase in fruit yield due to silicon treatments ranged from 3.34 to 14.62 (Fig. 2). Fruit yield was maximum with 50 kg Si ha⁻¹ and declined with increase in silicon rate. Similarly, fruit yield also increased with silicon concentration (0.25 to 1%). Foliar spray of 1% silicon applied at 3rd and 5th month after planting recorded the highest fruit yield compared to 0.25 and 0.5% Si. The frequency of foliar spray influenced fruit yield. When potassium silicate was sprayed thrice (3rd, 5th and 7th month) at 0.25% and 0.5%, fruit yield increased but at 1% Si fruit yield decreased. Increase in the productivity could be attributed to the beneficial effect of silicon in the plant as an improvement of architecture for showing more erect leaves, which intercept higher solar luminosity increasing the photosynthesis efficiency and higher chlorophyll content. In the present study, application of silicon increased LAI and chlorophyll and it was confirmed by significant positive correlation between fruit yield with LAI ($r=0.984^{**}$) and chlorophyll ($r=0.992^{**}$). Silicon increased the photosynthetic efficiency of the plant resulting in greater accumulation of

solids in the leaf tissues. This photo assimilates can be translocated to the fruits which are strong metabolic drains. It may be one of the factors, which increased the productivity. Fiori et al. (2006) reported increase in fruit yield is due to increase in fruit number and size of fruit which are attributed to increase in availability of silicon in soil. Regression analysis between fruit yield with fruit character shown in the (Fig. 3) revealed that 92.1 per cent, 82.4 per cent and 92.9 per cent, 97.4 per cent and 84.4 per cent variations in fruit yield was due to bunch weight, bunch length, number of hands/ bunches, number of fingers / hands, total fingers / bunch and finger weight respectively. Among the fruit character, total number of fingers / bunches, number of hands / bunch and number of fingers / hands is very important. Higher fruit yield could also be due to better availability of nutrients in the soil for increased uptake, which led to higher growth and fruit yield. Role of silicon in augmenting higher banana yield was further strengthened by regression analysis (Fig. 4), which showed that 86.0 per cent, 82.3 per cent and 85.3 per cent variation in banana yield was due to available silicon, silicon content and uptake respectively. Ahmed et al. [27] in date palm, Lalithya et al. [23] in sapota and Roshdy [28] in banana reported higher yield due to foliar spray of potassium silicate.

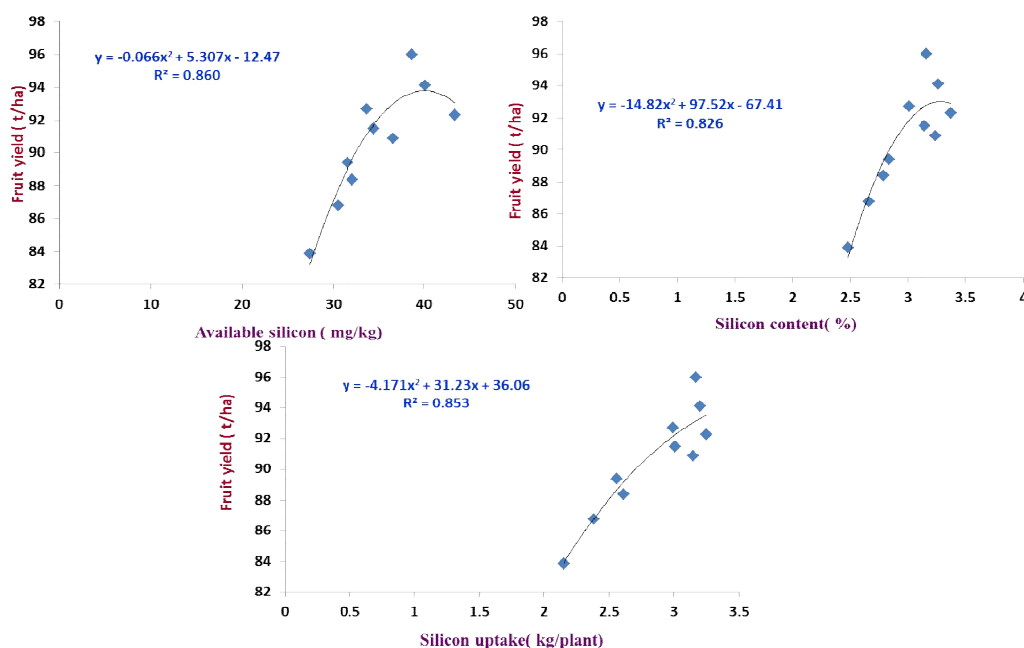


Fig. 4. Quadratic relationship between banana fruit yield with a) Available silicon b) Silicon content c) Silicon uptake

Decrease in banana yield beyond 50 kg Si ha⁻¹ probably because of the nutrient imbalance caused by silicon or by the accompanying ions (Ca, K, Na) that competes for the same adsorption site of other nutrients (Fernandez and Souza, 2006). Liang et al. [28] in tomato and Tesfagiorgis and Lang [29] in Zucchini and Zinnia reported maximum yield at 50 mg Si/ha but decreased at 100 mg Si/ha.

4. CONCLUSION

From the study, it is concluded addition of 50 kg Si/ha through potassium silicate is necessary to get higher banana yield in coarse textured soil followed by foliar spray of 1% potassium silicate twice (3rd and 5th month).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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