

**STUDY OF DIATOMACEOUS EARTH (AS A SOURCE
OF SILICON) ON GROWTH, YIELD AND QUALITY OF
BANANA cv. GRAND NAINÉ (*Musa* AAA)**

RAVI B.

**DEPARTMENT OF FRUIT SCIENCE
KITTUR RANI CHANNAMMA COLLEGE OF HORTICULTURE,
ARABHAVI – 591 218
UNIVERSITY OF HORTICULTURAL SCIENCES,
BAGALKOT- 587102**

JUNE, 2016

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OF SILICON) ON GROWTH, YIELD AND QUALITY OF
BANANA cv. GRAND NAINÉ (*Musa* AAA)**

*Thesis submitted to the
University of Horticultural Sciences, Bagalkot
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Master of Science (Horticulture)

in

Fruit Science

By

**RAVI B.
UHS12PGM218**

**DEPARTMENT OF FRUIT SCIENCE
KITTUR RANI CHANNAMMA COLLEGE OF HORTICULTURE,
ARABHAVI – 591 218
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ARABHAVI - 591 218
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587102**

CERTIFICATE

This is to certify that the thesis entitled “**STUDY OF DIATOMACEOUS EARTH (AS A SOURCE OF SILICON) ON GROWTH, YIELD AND QUALITY OF BANANA cv. GRAND NAINA (Musa AAA)**” submitted by **RAVI B. UHS12PGM218** for the degree of **MASTER OF SCIENCE (Horticulture)** in **FRUIT SCIENCE**, of the University of Horticultural Sciences, Bagalkot, is a record of research work carried out by him during the period of his study in this university, under my guidance and supervision, and the thesis has not previously formed the basis of the award of any degree, diploma, associateship, fellowship or other similar titles.

ARABHAVI

JUNE, 2016

(G. S. K. SWAMY)

Chairman

Professor and Head
Department of Fruit Science
College of Horticulture, Mysore

Approved by

Chairman:_____

(G. S. K. SWAMY)

Members: 1. _____

(N. THAMMAIAH)

2. _____

(N. B. PRAKASH)

3. _____

(PRAVEEN JHOLGIKAR)

4. _____

(G. J. SURESHA)

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**Affectionately Dedicated to
My Beloved Parents and
Family Members**

CONTENTS

Chapter No.	Chapter particulars	Page No.
	CERTIFICATE	iii
	ACKNOWLEDGEMENT	iv
	LIST OF ABBREVIATIONS	ix
	LIST OF TABLES	x
	LIST OF FIGURES	xi
	LIST OF PLATES	xii
	LIST OF APPENDICES	xiii
1.	INTRODUCTION	1-3
2.	REVIEW OF LITERATURE	4-26
	2.1 Influence of silicon on growth of horticultural crops	5
	2.2 Influence of silicon on yield and quality parameters in horticultural crops	10
	2.3 Silicon uptake and its influence on other nutrients uptake in other horticultural crops	18
	2.4 Influence of silicon on pest and diseases	21
	2.5 Influence of silicon on physiological disorders of fruit crops	25
3.	MATERIAL AND METHODS	27-43
	3.1 Geographical location of experimental site	27
	3.2 Soil type	27
	3.3 Experimental details	27
	3.4 Observations recorded	32
	3.5 Statistical analysis	43
4	EXPERIMENTAL RESULTS	44-92
	4.1 Vegetative growth parameters	44
	4.2 Nutrient status of leaf at six MAP (3 rd leaf)	58
	4.3 Crop duration	61
	4.4 Bunch characteristics	64
	4.5 Finger characteristics	68
	4.6 Quality parameters	73
	4.7 Yield characteristics	76

Contd...

Chapter No.	Chapter particulars	Page No.
	4.8 Organoleptic evaluation	79
	4.9 Whitefly incidence	81
	4.10 Sigatoka leaf spot index	84
	4.11 Nutrient status of soil after harvesting of banana crop	84
	4.12 Economics	91
5.	DISCUSSION	93-106
	5.1 Effect of diatomaceous earth on growth parameters in banana	93
	5.2 Effect of diatomaceous earth on nutrient status in banana leaf	96
	5.3 Effect of diatomaceous earth on crop duration in banana	98
	5.4 Effect of diatomaceous earth on bunch and finger characteristics in banana	98
	5.5 Effect of diatomaceous earth on quality parameters in banana	101
	5.6 Effect of diatomaceous earth on yield parameters in banana	103
	5.7 Effect of diatomaceous earth on organoleptic evaluation of banana	103
	5.8 Effect of diatomaceous earth on whitefly infestation in banana	104
	5.9 Effect of diatomaceous earth on Sigatoka leaf spot intensity in banana	105
	5.10 Effect of diatomaceous earth on macro and micro nutrient status after harvesting of banana	106
	5.11 Effect of Diatomaceous Earth on Benefit: Cost ratio in banana	106
	5.12 Future line of work	107
6.	SUMMARY AND CONCLUSIONS	108-110
	REFERENCES	111-131
	APPENDICES	132-134

LIST OF ABBREVIATIONS

Sl. No.	Abbreviations	
1.	cv.	Cultivar
2.	cm	Centimetre
3.	m	Meter
4.	%	Per cent
5.	g	Gram
6.	kg	Kilo gram
7.	mt	Metric tone
8.	°B	°Brix
9.	mg/l	milligram per litre
10.	g/l	gram per litre
11.	mm	Milli meter
12.	ml	Milli litre
13.	v/v	Volume by volume
14.	ppm	Parts per million
15.	Si	Silicon
16.	DE	Diatomaceous Earth

LIST OF TABLES

Table No.	Title	Page No.
1.	Influence of Diatomaceous Earth on pseudostem height of banana	45
2.	Influence of Diatomaceous Earth on pseudostem girth of banana	48
3.	Influence of Diatomaceous Earth on number of functional leaves of banana	51
4.	Influence of Diatomaceous Earth on leaf area of banana	53
5.	Influence of Diatomaceous Earth on chlorophyll content of banana	55
6.	Influence of Diatomaceous Earth on number suckers in banana	57
7.	Influence of Diatomaceous Earth on leaf nutrient status of banana	59
8.	Influence of Diatomaceous Earth on crop duration of banana	62
9.	Influence of Diatomaceous Earth on bunch characters of banana	65
10.	Influence of Diatomaceous Earth on finger characteristics of banana	70
11.	Influence of Diatomaceous Earth on fruit quality parameters of banana	74
12.	Influence of Diatomaceous Earth on yield parameters of banana	77
13.	Influence of Diatomaceous Earth on organoleptic scores of banana	80
14.	Influence of Diatomaceous Earth on white fly incidence at five month growth stage of banana	82
15.	Influence of Diatomaceous Earth on Sigatoka leaf spot disease intensity (%) at 5 MAP and harvesting stage of banana	85
16.	Influence of Diatomaceous Earth on soil macro nutrient status after harvesting of banana	88
17.	Influence of Diatomaceous Earth on soil micro nutrient status after harvesting of banana	90
18.	Influence of Diatomaceous Earth on benefit cost ratio of banana	92

LIST OF FIGURES

Figure No.	Title	Page No.
1.	Influence of Diatomaceous Earth on pseudostem height of banana	46
2.	Influence of Diatomaceous Earth on crop duration of banana	63
3.	Influence of Diatomaceous Earth on finger characteristics of banana	71
4.	Influence of Diatomaceous Earth on yield parameters of banana	78
5.	Influence of Diatomaceous Earth on white fly infestation at five month growth stages of banana	83
6.	Influence of Diatomaceous Earth on Sigatoka leaf spot disease intensity (%) at 5 MAP and harvesting stage	86

LIST OF PLATES

Plate No.	Title	Page No.
1.	General view of the experimental plot	28
2.	Land preparation and imposition of treatments in an experimental plot	31
3.	Bunches of banana crop with different Diatomaceous Earth treatments	66
4.	Hands with different Diatomaceous Earth treatments	69

LIST OF APPENDICES

Appendix No.	Title	Page No.
I.	Meteorological data recorded for the experimental period (2013-14)	132
II.	Initial soil analysis data of experimental site	133
III.	Economics of banana cultivation	134

1. INTRODUCTION

Banana (*Musa* spp.) is one of the most important fruit crop, belongs to the family Musaceae and cultivated by man since prehistoric times. Banana provides nutrition and well-balanced diet to millions of people around the globe and also contributes to livelihood through crop production, processing and marketing (Singh, 2002).

It is a monocotyledonous herbaceous perennial with underground, horizontal rhizome from which roots develops in to pseudostem. Each leaf is about 2 to 2.5 m long, it is monocarpic with male, female and hermaphrodite flowers in inflorescence.

Banana is also fourth important food crop in terms of gross value after paddy, wheat and milk products in the world and forms an important crop for subsistence to farmers (Singh and Chundawat, 2002). South-East Asian countries, especially eastern Malaysia is believed to be the center of origin of banana (Saucer, 1952). It grows well in humid tropical low lands and is predominantly distributed between 30⁰ N and 30⁰ S of equator.

Banana is a staple fruit to millions of people in the world. It is easy to digest, nearly fat free with high nutritive value and relatively cheaper than other fruits. The total energy provided by 100 g of edible ripe pulp is 116 K calories, 1.2 g protein, 0.3 g fat, 27.2 g carbohydrates, 0.4 g fibre, 7 mg vitamin C and 0.8 g of minerals (Gopalan *et al.*, 1989).

Besides edible fresh fruits, it has other uses for making products like dried chips, wine, beer, flour and juice. The pseudostems are used for thatching, fabric and mulch. Owing to its multifaceted uses from underground stem up to the male flower, it is referred as '*Kalpatharu*' (a plant of virtues). It is grown in home gardens for consumption as well as in large plantations for domestic and export markets.

Major banana cultivars grown in India are Dwarf Cavendish, Robusta, Grand Naine, Rasthali, Poovan, Hill Banana, Nendran, Red Banana, Monthan and Neypoovan. Among them, Grand Naine is cultivated all over India. Major banana growing states are Tamil Nadu, Maharashtra, Karnataka, Gujarat, Andra Pradesh, Bihar, Assam and Madhya Pradesh. Bananas are cultivated in India in an area of

8,02,600 ha producing 29.72 million tonnes and in 1, 02,710 ha producing 2, 67,563 lakh tonnes in Karnataka. The average national and state productivity of banana was 37 t/ha and 26.1 t/ha respectively (Anon, 2014).

There are 16 described essential plant elements: the macronutrients C, H, O, N, P, K, Ca, Mg, S and the micronutrients, Cl, B, Cu, Fe, Mn, Mo, Ni and Zn (Pilon-Smits *et al.*, 2009). Additionally, there are also beneficial elements, which do not fit in the definition of essentiality in plants, but are nonetheless capable of promoting growth or enhancing tolerance to other biotic factors in plants. Five elements currently considered to impart additional beneficial effects are Al, Co, Na, Se and Si (Pilon-Smits *et al.*, 2009).

Silicon belongs to a separate classification between essential and beneficial known as 'quasi-essential'. Elemental silicon is a metalloid, a division in the periodic Table that includes boron, germanium, arsenic, antimony and tellurium. Metalloids have properties that are a mixture of metals and nonmetals and range from essential in the case of boron, to highly toxic with arsenic (Bienert *et al.*, 2007).

The beneficial effects of Si are mainly associated with its high deposition in the walls of epidermal cells, enhancing their strength and rigidity. The increased mechanical strength reduces lodging and pest attack and increases the light-receiving posture of the plant, thus increasing photosynthesis and hence growth (Epstein, 1999). Deposition of silicon within the epidermis prevents unnecessary transpiration, thereby decreasing water loss (Mitani *et al.*, 2005).

Silicon also plays an active role in the biochemical processes of a plant and in the intracellular synthesis of organic compounds (Ma *et al.*, 2006).

The presence of Si in nutrient solutions has also been reported to affect the absorption and translocation of several macro- and micro-nutrients (Epstein, 1999). More recently, Si amendments were shown to reduce the leaching of phosphate, nitrate and potassium (NPK) (Matichenkov and Bocharnikova., 2010).

All plants are divided into three categories based on their capacity for silicon uptake: accumulators, passive accumulators and rejecters (Ma and Takahashi, 2002). When grown in nutrient solutions containing silicon, plants are defined as accumulators which will deplete silicon in the nutrient solution, passive accumulators

will maintain constant silicon concentration, and rejecters will cause an increase in silicon concentration of the solution as water is absorbed and silicon remains behind (Carnerio *et al.*, 2010).

The banana plant is a silicon accumulator (Henriet *et al.*, 2006). The plants are known to produce phytoliths (discrete silicon deposits) in the leaves and pseudostem, which persist in the soil long after plant death, leading to their use in archaeological studies to track the cultivation and consumption of banana (Lentfer, 2009). When silicon is present in the soil solution at high concentrations, banana plants absorb it passively but switch to active uptake via theoretical transporters when concentrations are low (Henriet *et al.*, 2006).

With this background information and based on the possible benefits of silicon, the present study was carried out to know the effect of Diatomaceous Earth (as source of silicon) on growth, yield and quality of banana cv. Grand Naine with the following objectives:

1. To study the effect of Diatomaceous Earth on growth and yield of banana.
2. To study the effect of Diatomaceous Earth on quality of banana.
3. To study the effect of Diatomaceous Earth on pest and disease incidence in banana.

2. REVIEW OF LITERATURE

Banana is an important commercial fruit crop in the tropical and sub tropical regions of the world. In India, it is grown in different states under different climatic conditions. It is a heavy consumer of nutrients and requires large quantities of nutrients for its growth, development and yield. Supplementation of nutrients at critical stages of growth is essential for enhancement of growth and yield.

Silicon is the second richest element found on the surface of the earth's crust as well as in the soils (Liang *et al.*, 2007). Although silicon is not considered as an essential nutrient for most of the plants, numerous studies have shown that Si treatment improves the growth and yield of various plants, particularly when they are subjected to both abiotic and biotic stresses.

The beneficial effects of Si have been observed in a wide variety of plant species. The beneficial effects of Si are usually expressed more clearly in Si-accumulating plants under various abiotic and biotic stress conditions. Silicon is effective in controlling various pests and diseases caused by both fungi and bacteria in different plant species. Silicon also exerts alleviative effects on various abiotic stresses including salt stress, metal toxicity, drought stress, radiation damage, nutrient imbalance, high temperature, freezing and so on. These beneficial effects are mainly attributed to the high accumulation of silica on the tissue surface although other mechanisms have also been proposed (Ma., 2004).

Most of the research conducted on the benefits of silicon has been conducted on field crops, but the role of silicon in the nutrition of plant species especially in horticultural crops has not been well investigated in comparison to agricultural crops like rice (Iler, 1979).

The research on use of silicon on banana production is very much limited. The work done on horticulture crops and also similar aspects of other horticultural crops has been reviewed in this chapter.

- 2.1 Influence of silicon on growth of horticultural crops.
- 2.2 Influence of silicon on yield and quality of horticultural crops.
- 2.3 Influence of silicon on incidence of pest and disease of horticultural crops.
- 2.4 Influence of silicon on physiological disorders of fruit crops.

2.1 Influence of silicon on growth of horticultural crops

Silicon is considered as an agronomically essential nutrient for the sustainable crop production and with the increase of silicon levels, the dry weight of the plant will increase together with its height. It increases leaf area which enhances of photosynthetic rate and prevents the destruction of chlorophyll and increases the relative water content (RWC) and proline accumulation. Silicon nutrition improves the light-receiving posture of the plants, thereby stimulating photosynthates production in plants; it also plays an important role in phosphorus nutrition having an interrelationship with phosphorus.

2.1.1 Fruit crops

Plants continuously subjected to 50ppm SiO_2 treatment under hydroponic culture showed increased root dry weight and top dry weight of the strawberry plant (Miyake and Eiichi, 1986).

Cai and Rian (1995a) reported that silicon fertilizer application to peacanut could increase the concentration of chlorophyll in the leaves, strong shoot development, double the nut formation and dry weight of the nut.

A study conducted by Cai and Rian (1995b) in apple observed that silicon fertilizer applied at the rate of 15 kg per tree to soil with concentration of available range from 314 to 404 $\text{mg SiO}_2 \text{ kg}^{-1}$ enhanced healthy growth and had stronger shoot, thicker and darker green leaves.

Wang and Galletta (1998) studied the effect of foliar silicon as K_2SiO_3 on metabolic changes in strawberry plants cv. Earliglow. Si application at the rate of 12.75 mM increased chlorophyll content and growth.

The direct effect of silicon containing compounds on citrus grown on sandy soil, soluble silica compound in solution was more effective than soil applied silica material, the maximum shoot weight increase was observed in 10 ppm of soluble silica and root weight increase in 20ppm of soluble silica (David and Vladimir, 1999). Optimization of Si nutrition was responsible for a significant increase in mass of roots and green mass of germinated marsh grapefruit seedlings (Vladimir *et al.*, 2001).

Silicon induced metabolic changes such as increased citric acid and mallic acid levels and decreased fructose, glucose, sucrose and myo-inositol contents. A relationship was determined between the soil Si status and the leaf status content and also tree vigour of Valencia orange. In another study passion fruit seedlings responded well to the calcium silicate application. Then, maximum development in plant height, stem diameter, number of leaves and the dry matter of the shoots and roots were recorded and contents of macro and micro nutrients were evaluated with application of calcium silicate (Prado *et al.*, 2005).

Three contrasted genotypes of *Musa sp.* like *M. acuminata* cv. Grand Naine, *M. acuminata* sp. Bankshi and *M. balbisiana* sp. Tani were grown for six weeks under optimal conditions in hydroponics and were subjected to a wide range of Si supply (0-1.66 mm Si) to quantify the Si uptake and distribution in banana, as well as the effect of Si on banana growth. The rate of Si uptake and the concentration in plant tissues increased markedly with the Si supply (Henriet *et al.*, 2006).

Bhavya (2010) conducted an experiment to examine the response of Bangalore Blue grape vines to foliar silicic acid (SA) and boron (B) spray. Foliar application of 4 ml and 6 ml L⁻¹ SA at 10 days interval (6 sprays) and 6ml L⁻¹ at 20 days interval (3 sprays) significantly influenced growth parameters over control.

Kidane and Laing (2010) studied the agronomic measurements of banana plants treated with biocontrol agents, silicon and mulch in *Fusarium oxysporum* f.sp. *cubens* infested fields. The maximum shoot height, leaf number and pseudostem girth of banana was observed in the treatment of *Fusarium oxysporum* strain N-16 + Silicon + *Trichoderma harzianum* Eco-T + mulch.

Simone *et al.*, (2011) studied the sources of silicon in the development of micro propagated seedlings of banana in *in-vitro* condition. The study revealed that there was an increase in levels of chlorophyll a, b and total chlorophyll in the presence of calcium silicate. Supplementation of culture medium with sodium silicate promoted increase in length, fresh and dry weight of shoots. The silicon provides adequate seedling development.

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

Roshdy *et al.*, (2014) elucidated the single and combined application of Potassium silicate and seaweed extract each at 0.05 to 0.1% was significantly responsible for stimulating the growth characters namely height and girth of pseudostem, leaf area and number of green leaves at bunch shooting of Grand Naine banana plants relative to the check.

Kumbargire *et al.*, (2015) conducted an experiment to examine the response of banana cv. Grand Naine to Diatomaceous Earth used as a source of silicon. Basal dose application of Diatomaceous Earth at 750 kg/ha along with package of practice significantly influenced the yield attributing characters, quality parameters and minimum per cent of whitefly and Sigatoka incidence over the control.

2.1.2 Flower crops

The use of sodium silicate (NaSiO_3) sprays was beneficial in poinsettia. The severity and occurrence of bract necrosis decreased greatly when NaSiO_3 sprays were used on the cultivar 'Supjibi' post-harvest bract damage also decreased in this cultivar. The silicates were applied at 100 ppm effective as CaCl_2 sprays at 400 ppm for up to five weeks after the cyathia began to open in gerbera and it showed increase in leaf area and peduncle length (Mc Avoy and Bible, 1995).

Rose plant cuttings received 50 mg and 100mg L^{-1} silicon was healthier than control. Leaf and root initiation was more, reduced fungal infection and decreased leaflet loss was noticed in plants treated with 50 mg L^{-1} Si (Jeffery and David, 1999).

Rose plant cuttings with 50 and 100 mg L^{-1} Si were healthier than cuttings of control. Leaf initiation might have resulted from new or more rapid root formation, reduced fungal activity, decreased leaflet loss, or a combination of these factors. Sodium silicate addition resulted to mist systems for the purpose of promoting roots through leaf retention (Gillman *et al.*, 2003).

According to Seung *et al.* (2005) silicon in the form of silicon chelate at 500 mg L⁻¹ showed increased plant height, leaf area and number of shoots per plant in miniature rose.

Mary (2005) conducted an experiment on miniature rose cultivars 'Sonya' and 'Alto.' In the first experiment, spray application of foliar-calcium (chelated Ca) increased the plant growth as indicated by a greater dry weight compared to other treatments.

Basal and apical stem diameters increased in ornamental sunflower treated with rice husk ash substrate incorporation at 100 g/m³ Si, KSiO₃ at 140 g/m³, foliar NaSiO₃ at 50, 100, and 150 mg/L Si, and KSiO₃ drench at 50 and 100 mg/L Si (Kamenidou and Todd., 2008).

Tesfagiorgis *et al.*, (2008) reported that addition of nutrient solution at 50 to 100 mg/L of Si enhanced the plant growth of the zucchini and zinnia plant.

Potassium silicate increased the basal stem diameter of zinnia plants when applied as a drench weekly at 200mg/L. The flower and apical stem diameter was increased in zinnia with ashed rice hull media incorporated at 100 g/m³, NaSiO₃ weekly foliar sprays (50, 100, and 150 mg/L Si), KSiO₃ drench (50 and 100 mg/L) and KSiO₃ media incorporation at 140 g/m³ (Kamenidou *et al.*, 2009).

Saeed *et al.*, (2009) reported that increased peduncle diameter, bud diameter and length, shoot length, leaf area, chlorophyll content, reduced malondialdehyde content and cell wall damage in *Rosa hybrida* cv. 'Hot lady' with the application of 150ppm silicon under salt stressed condition.

Potassium silicate (KSiO₃) substrate incorporation or weekly substrate drench, sodium silicate (NaSiO₃) as foliar application and rice husk ash substrate incorporation were used as Si supplements. Gerbera plants supplemented with several Si source and rate combinations particularly NaSiO₃ foliar sprays produced thicker flower peduncles, increased flower diameters, increased height and flowered earlier than non-supplemented controls (Kamenidou *et al.*, 2010).

Neil and Roland (2010) conducted an experiment to examine whether weekly potassium silicate drench would affect morphological traits of several floriculture

species grown in soil less substrate. Plants drenched weekly with 100 mg/L as potassium silicate for 10 weeks. Si showed increased height, diameter, fresh weight, dry weight and flower diameter and leaf thickness in all the 21 cultivars.

2.1.3 Vegetable crops

Adatia and Besford (1986) reported that more of leaf thickness, more dry matter per unit leaf area, significant increment in the fresh and dry weight of root, leaf and increased plant height with the application of Si in cucumber plant.

Liu (1997) reported that, application of silicon fertilizers decreased the occurrence of diseases, increased plant height, leaf area and chlorophyll content in the leaves of tomato plants.

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

Seome *et al.* (2008) reported that, application of silicon as slag increase in the plant growth, leaf area and increased pollen fertility in melon plants.

Silicon supplied through calcium and magnesium silicate to potato induced higher plant height, reduced stem lodging and higher marketable tuber yield and also resulted in higher phosphorus and silicon soil availability and plant uptake (Crusciol *et al.*, 2008).

Luz *et al.* (2008) stated that application of K_2SiO_3 at 1% increased the chlorophyll a, b and total chlorophyll content, increased plant height and leaf area in all parts of the potato plant canopy.

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

Emrich *et al.* (2011) evaluated that the effect of potassium silicate application on leaf at different doses, on the levels of chlorophyll a, b and total chlorophyll in leaves of tomato cultivated in two substrates as well as the influence of these factors on crop yield under protected environment. The increase of potassium silicate doses (0.4%) stimulated the concentration of chlorophyll a, b and total chlorophyll.

Nesreen *et al.* (2011) stated that, the parameters like shoot height (cm), root length (cm), shoot dry weight (g) and root dry weight (g) in beans were significantly increased by silicon solutions as compared with sulphate solutions.

Lettuce (*Lactuca sativa* L. 'Eish') grown in soilless culture resulted significantly increase in fresh root, shoot length and shoot weight compared to control. Applications of 2 and 4 mM Si increases plant weight and thus benefited for the growth of lettuce (Milne *et al.*, 2012).

Silva *et al.* (2012) studied the effects of silicon on chlorophyll and to measure gas exchange and carbohydrate levels in two *Lycopersicon esculentum* cultivars that were exposed to drought. The study confirmed the hypothesis that silicon has a beneficial effect with regard to chlorophyll. Under water-deficient conditions, both cultivars showed an increase in chlorophyll a when treated with silicon in addition to changes in the total chlorophyll levels. These results were supported by the change in leaf water potential. In addition, a reduction of the effects of water restriction was also observed in the transpiration rate, the stomatal conductance and in the levels of total carbohydrates.

2.2 Influence of silicon on yield and quality parameters in horticultural crops

Silicon nutrition has several beneficial effects on growth, yield and quality largely due to its unique physiological role.

2.2.1 Fruit crops

Cai and Rian (1995a) reported that silicon fertilization to peacanut tree could increase the nut yield.

Cai and Rian (1995b) reported that apple tree received Si fertilizer at 15 kg per tree to soil with a concentration of 314 to 404 mg SiO₂ kg⁻¹, enhanced yield (10%) and fruits become redder 3 to 5 days earlier and ripened about 10 days earlier with bright appearance. Fruit freshness was retained for longer period during storage and transportation.

Strawberry plants continuously received 50ppm SiO₂ recorded increased top weight, fruit weight and fruit yield and also showed increased pollen fertility (Miyake and Eiichi, 1986).

Potassium silicate (K₂SiO₃) was applied to grapes cv. Bacchus. It yielded higher compared to control (without silicon) and grape berries may utilize endogenous silicon to fight against diseases (Reynolds *et al.*, 1996).

Voogt and Sonneveld (1997) showed increased yield up to 10% in courgette, with strawberry, a clear reduction was observed in the incidence of powdery mildew. However, with this improved crop yield and quality was obtained with Si (1mM Si L⁻¹) amendment.

Anderson *et al.* (2005) investigated the possible use of silicon for the control of post-harvest anthracnose of 'Hass' avocado. Soluble silicon injecting into trees prior to harvest significantly decreased the severity and incidence of anthracnose.

According to Ochmian *et al.* (2006), foliar application of 0.2% calcium silicate keeps plum fruit more firmly during fruit picking and they lose their firmness slower compared to other two treatments as foliar spray with calcium chloride solution at 0.5% and lime sulphate solution with 0.5% concentration.

Reaple and Laane (2008) investigated the effects of foliar sprays with Agro force (oligomeric silicic acid + boric acid) with different concentrations on plant development, production and quality of the papaya fruit. With the application of 2.7 litres/ha, 5.4 litres/ha and 2.7 litres/ha with trace elements enhanced growth, production and quality compared to control.

Abraham *et al.* (2008) reported that application of potassium silicate reduces the disease lesion caused by *Penicillium digitatum*, reduce the post harvest loss and fruit decay at 100 mg L⁻¹ in citrus fruit.

Mathaba *et al.* (2009) revealed that, silicon at 0.5ppm had greater potential in mitigating chilling injury with less weight loss and membrane damage in citrus fruits.

Bertling *et al.* (2009) reported that 'hass' avocado fruit placed into 5, 13 and 25x 10³ ppm Si (as potassium silicate,) solutions for 20 min to allow penetration of the solution. Thereafter, fruits were allowed to air-dry on the bench and stored at 5.5°C for 16 days. All Si-treatments (5.000, 13.000 and 25.000ppm Si) showed

similarly elevated Si concentrations in fruit fresh weight declined significantly faster in control than in Si-treated fruit, with the highest Si application maintaining the highest weight.

Bhavya (2010) conducted an experiment to examine the response of Bangalore Blue grape vines to foliar Silicic acid (SA) and Boron (B) spray. Application of 4 ml and 6 ml L⁻¹ foliar SA at 10 days interval (6 sprays) and 6ml L⁻¹ foliar SA at 20 days interval (3 sprays) significantly influenced yield and quality parameters over control.

Chitu *et al.* (2010) studied the foliar applied clay effects on apple fruit quality. Kaolin treatments reduced significantly the losses in sunburned fruits from 24-28 per cent in the controls to 12-15 per cent. Because the tested products were containing only ecological components, their application may be extended to the organic crops protection, even though the results seem to be moderate in strength.

Kaluwa *et al.* (2010) demonstrated that, the different sources of silicon (potassium silicate, non toxic-silica, calcium silicate, sodium meta silicate and bio silicate) which were used as post-harvest dips and pre-harvest soil drenches. They revealed that post-harvest applications of Si in the form of potassium silicate seem to be most beneficial to maintain 'Hass' avocado fruit quality, probably due to a suppression of respiration and a reduction in ethylene evolution.

Zhang *et al.* (2011) studied the effects of post-harvest sodium silicate treatment on quality and volatile flavor components of apricot fruit during storage. The results indicated fruit which were treated with 10 mmol/L retarded flesh firmness decrease and alleviated decay. After 9 days of storage, the treated fruits showed 1.95 times for firmness and 58 per cent for rotting rate of control fruits. The silicon treated fruits showed higher content of soluble solids, vitamin C and delayed the decrease of titratable acidity, but there was no significant difference of content of total sugars between the two groups. Sodium silicate treatment significantly reduced the emission of total amount volatile compounds of apricot fruits during storage and enhanced the amount of aldehydes, terpenoids and beta-onone and lowered amount of esters throughout the investigation period in comparison with that of control. Compared with the control, the sodium silicate treatment can maintain post-harvest quality of apricot fruit better and is a feasible way to keep apricot fruit fresh.

Tesfay *et al.* (2011) studied the effects of post-harvest potassium silicate application on phenolics and other anti-oxidant systems aligned to avocado fruit quality. The expression and activity of catalase, the major enzyme with anti-oxidant activity, were also determined. Postharvest potassium silicate (KSil) applications had no effect on respiration rate; in contrast, fruit firmness, weight loss, mesocarp electrical conductivity (EC), total phenolics concentration, lipid peroxidation as well as polyphenol oxidase and catalase activity responded positively to the KSil treatments. Su *et al.* (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.

Shi *et al.* (2012) studied the effect of chitosan/nano-silica coating on the physicochemical characteristics of longan fruit under ambient temperature. The study revealed that the excellent semi-permeable film of chitosan/nano-silica markedly extended shelf life, reduced browning index, retarded weight loss and inhibited the increase of malondialdehyde amount and polyphenol oxidase activity in fresh longan fruit.

Lalithya *et al.* (2014) conducted the experiment to know the response of soil and foliar application of silicon and micro nutrients on leaf nutrient status of sapota as macro nutrient and silicon content was more in the treatment with foliar application of potassium silicate at 8 ml per litre resulted in more yield and quality of fruits.

Roshdy., (2014) reported that single and combined applications of Potassium silicate and seaweed extract each at 0.05 to 0.1% significantly was accompanied with improving bunch and hand weights, and had no significant effect on number of hands per bunch and number of fingers per hand and also was very effective in improving fruit quality in terms of increasing weight, length and diameter of finger, pulp%, TSS% and total sugars% and reducing both fruit peel% and total acidity% in relative to the check treatment.

2.2.2 Flower crops

Gillman *et al.*, (2003) revealed that, with application of 100 and 150 mg silicon per litre resulted lesser incidence of black spot disease and thus helped in

improving the quality of flower. With the application of potassium silicate proved to have beneficial effects on yield and quality of cut flower miniature rose *Rosa hybrida* 'Finocchio' in the rock wool culture system compared to control (Hwang Seungjae *et al.*, 2005).

Tesfagiorgis *et al.*, (2008) reported that, increased plant yield with the application of 50 to 100 mg L⁻¹ of silicate fertilizer by optimal disease in control and maximum growth in Zucchini and Zinnia.

Kamenidou *et al.*, (2009) studied the effect of different source of silicon (KSiO₃ substrate incorporation or weekly substrate drench, NaSiO₃ foliar application and rice husk ash substrate) on the quality traits in Zinnia and ornamental sunflower. The results showed that, application of KSiO₃ as five weekly drenches increased the stem and flower diameter. Similarly, treatment of ornamental sunflower with 200 mg L⁻¹ Si applied as KSiO₃ substrate drench resulted in plants with larger flower diameter.

Saeed *et al.*, (2009) observed the increased flower diameter, flower number and improved colour intensity or saturation of petals in *Rosa hybrida* Var. 'Hot lady' with the application of 150 ppm silicon under salt stressed condition.

Gerbera plants supplemented with several silicon sources (KSiO₃ substrate incorporation or weekly substrate drench, NaSiO₃ foliar application and rice husk ash substrate) at different combinations. Particularly NaSiO₃ foliar spray recorded thicker flower peduncle, increased flower diameter, height and early flowering than control (Kamenidou *et al.*, 2010).

Application of calcium silicate at 7.3 g Si per plot showed increased flower number, height, flower diameter and stem diameter in gerbera (Mayer *et al.*, 2010).

Neil and Roland (2010) conducted an experiment to examine whether weekly potassium silicate drenches would affect morphological traits of several floriculture species grown in soil less substrate. Plants drenched weekly with 100 mg/L as potassium silicate for 10 weeks. Silicon showed increased height, diameter, fresh weight, dry weight, flower diameter and leaf thickness in all the 21 cultivars.

According to Babak and Majid (2011), the use of ethylene production inhibitors such as nickel (Ni), cobalt (Co) and silicon (Si) might have possessed positive impact on post-harvest life of cut flowers of carnations with climacteric respiration. Nickel sulphate, cobalt chloride and potassium silicate caused higher vase life with lower ethylene production.

2.2.3 Vegetable crops

Adatia and Besford (1986) reported that, increased number of fruits, average fruit weight with the application of silica solution at 3mM concentration in cucumber plants. The yield increased from the Si application differed from 6 to 16 per cent for number of fruits and from 11 to 33 per cent for the total yield.

Liang *et al.* (1993) reported that in a solution culture trail, adding 50 mg silicic acid mL^{-1} to a nutrient solution increase the tomato yield by 42 per cent.

Liu (1997) showed that application of silicate and calcium fertilizers increased fruit size and subsequently increased yield up to 20 per cent and improved the flavour of the tomato fruits by increasing sugar concentration in the fruit.

The combination of silicon amendment plus fungicide application was more effective in reducing powdery mildew severity than either silicon or fungicide alone. Silicon amendment resulted in a 5-fold increase in plant Si concentration. Thus, Si amendment resulted in delaying foliage senescence increased pumpkin yield by 60% without increasing the cost of production (Heckman *et al.*, 2003).

The β -carotene and lycopene contents of fruit were significantly increased by Si and nutrient-induced salinity. Both Si and EC enhanced the fruit firmness and the contents of total solid solutes and vitamin C in the tomato fruit and significantly restricted the occurrence of blossom end rot in tomato fruit when the plants were not exposed to salinity (Stamatakis *et al.*, 2003).

Carlor *et al.* (2008) reported that application of silicon resulted in the reduction of stalk lodging and increased mean tuber weight and consequently tuber yield of potato.

Luz (2008) reported that increased in the yield up to 22.4% with the application of 1% K_2SiO_3 in potato plants.

Cucumber plants were cultivated in 12 litre containers filled with substrates amended with sodium silicate, potassium silicate, calcium silicate and ammonium silicates at rates of 2 or 4 g per litre. The results indicated that slow-release calcium silicate and ammonium silicate contributed to increase yield and elevated Si content in cucumber leaves and fruits. Water-soluble sodium and potassium silicates cause increased Na or K concentration and raised pH of substrates and resulted in increasing yield of cucumber (Gorecki and Danielski, 2009).

The production of peruvian carrot clones was evaluated in response to calcium-magnesium silicate. Commercial yield was increased with application of calcium magnesium silicate (Sediyama *et al.*, 2009).

In another study Trazilbo *et al.* (2009) reported that both CaCl_2 and CaSiO_3 were applied at 45 days after emergence of common bean. Both incidence and severity of white mold were significantly reduced with application of CaCl_2 and CaSiO_3 and also increased yield.

Savvas (2009) reported that application of Si and nutrient induced salinity enhanced the fruit firmness, total soluble solids, β -carotene, lycopene and vitamin C in the tomato fruits. Moreover, the addition of Si significantly restricted the occurrence of blossom end rot in tomato when the plants were not exposed to salinity.

Rodrigues *et al.* (2010) stated that in bean plants, lesser plant defoliation were found at the highest potassium silicate rate with pH 5.5 compared to the control. Yield increased by 30 and 43% respectively, as the potassium silicate rates increased from 0 to 60 g L^{-1} with pH 5.5 and 10.5. In another study the effect of granular silicate application has improved the quality and shelf life of tomato in perlite culture. The soluble solid content increased to 6.9 degrees brix with silicon application which was higher than that in the control (6.3 degrees brix).

Dimitrios *et al.* (2011) reported that silicon increased the ascorbic acid content of zucchini squash fruit from plants exposed to higher salinity and significant effect on fruit quality characteristics like weight loss, total soluble solids content and mineral content during storage.

Joseph and Heckman., (2011) also stated that, when calcium silicate used as amendment in soil resulted in fewer fungicide applications and also reduced the cost of production in pumpkin.

Kavya *et al.* (2011) studied the effects of silicon and high boron on growth and yield of tomato (*Lycopersicon esculentum* cv. '191F1') plants. Supplementing the nutrient solution containing high B with 2 mM Si increased both nutrients in the leaves. These results indicate that supplementary silicon can mitigate the adverse effects of high B on fruit yield and whole plant biomass in tomato plants.

Lebedeva *et al.* (2011) revealed the effect of low rates of LSi application (10 kg/ha, 20 kg/ha and 40 kg/ha) on potato plant tuberization and productivity, improvement of the quality and biochemical composition of tubers. It was shown that LSi, used for treatment of potato tubers before sowing at low application rates of 20-40 kg/ha, has a favourable action on the yield and quality of the tubers. In comparison with the control, the additional yield achieved on the background of LSi (20-40 kg/ha) was 18-20 per cent. The best biochemical composition was for the tubers wetted with water and LSi-treated before the sowing, *i.e.*, the content of dry matter and starch increased by 16 per cent and 18 per cent respectively, but the content of nitrates in the tubers decreased 1.6 times. LSi can be recommended for potato cultivation under conditions of conventional and organic agriculture.

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 was showed maximum reproductive growth as compared to that of control.

Toresano *et al.* (2012) studied the effect of the application of monosilicic acid fertilizer on yield and quality of greenhouse triploid watermelon. The monosilicic acid fertilizer had a positive impact on the parameters of fruit quality (°Brix and pulp firmness).

Fernando *et al.* (2012) studied the effect of the application of silicon hydroxide on yield and quality of cherry tomato. Significant differences were observed, including a higher number of fruits (fruits/plant) and a larger yield (kg/m²) in the plots that were fertilized with silicon.

2.3 Silicon uptake and its influence on other nutrients uptake in other horticultural crops

The silicon content of leaves increased proportionally to the increased silicon concentration in the culture solution and the incidence of powdery mildew decreased in strawberry (Miyake and Eiichi, 1986).

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).

Silicon content of grapefruit seedlings treated with amorphous silica increased from 0.066 to 0.156% in shoot and from 0.160 to 0.434% in root (Vladimir and David, 1999).

Mary (2005) showed application of potassium silicate at 125, 250 and 500 mg L⁻¹ increase the silicon and calcium concentration in the leaf tissue of *Rosa chinensis minima* 'Sonja'.

Trederand Cieslinski (2005) studied on cadmium uptake and distribution in strawberry cv. Elsanta plants. Silicon (Si) as potassium silicate applied by spraying or directly onto soil was used to decrease cadmium uptake and alleviate its toxic effect. Si used as soil amendment prior to planting was effective in preventing excessive cadmium uptake by strawberry plants grown on sandy soil. A foliar application by spraying with potassium silicate did not reduce the concentration of cadmium in the individual parts of strawberry plants.

Henriet *et al.* (2006) reported that, the silicon concentration increased in the sequence roots<pseudostem<petiole and midrib of young leaves<lamina of young leaves<old leaves. Whereas, the differences were highly significant between the petiole or mid rib and lamina of young leaves and between young and old leaves.

Opfergelt *et al.* (2006) opined that, the determination of the plant-induced Si-isotopic fractionation is a promising tool to better quantify their role in the continental Si cycle. Si-isotopic signatures of the different banana plant parts and Si source were measured, providing the isotopic fractionation factor between plant and source. Banana plantlets (*Musa acuminata* Colla, cv. Grande Naine) were grown in hydroponics at variable Si supplies (0.08, 0.42, 0.83 and 1.66 mM Si).

Frantz *et al.* (2010) reported that, silicon concentrations of leaf tissue of fourteen ornamental crop species, ranging from a low of about 200 mg kg⁻¹ in petunia to a high of nearly 1.3% (13,000 mg kg⁻¹) dry weight in zinnia.

Kamenidou and Todd., (2008) reported that, application of hydrous KSiO₃ substrate incorporation and KSiO₃ weekly substrate drench (200 mg L⁻¹ Si) increased leaf K, Mg, Cu, Mn and Mo concentration in the ornamental sunflower (*Helianthus annuus* L. 'Ring of Fire').

Foliar sprays of NaSiO₃ at a rate of 150 mg Si L⁻¹ accumulated higher levels of silicon in leaf, peduncle and flower tissues than non-supplemented controls and leaf concentrations of macronutrients, such as N, K, S and Ca, and micronutrients such as, B, Cu, Fe, and Mg were slightly changed in Gerbera plants. Leaf Si concentrations were 1.2–3.3 fold higher in Si-supplemented plants, while the macronutrients, N, K, S, Mg, and Ca and micronutrients like Al and B concentration was increased in KSiO₃ (280 gm m⁻³) supplemented Zinnia plants (Kamenidou *et al.*, 2009).

Frantz *et al.* (2010) investigated the role of Si in plant responses to Cu stress in *Zinnia elegans*. Based on visible plant symptoms and dry weights in Zinnia, Si was found to alleviate copper stress. Furthermore Zinnia showed a reduction in PAL (Phenyl Alanine Ammonia Lyase, a stress-induced enzyme) activity, suggesting Cu stress decreases in tissue exposed to supplemental Si. Cu concentrations inside the leaf were significantly lower in Cu + Si treatments compared to Cu toxicity treatments alone.

Gerbera plants grown in Si-supplemented media accumulated higher levels of silicon in leaf, peduncle and flower tissues than non supplemented controls. Leaf concentrations of macronutrients such as sulphur and potassium and micro nutrients such as boron, copper, iron and manganese were slightly changed among Si-supplemented plants (Kamenidou *et al.*, 2010).

Matichenkov and Bochamikova (2010) also suggested that, Si amendments helps in reducing the leaching loss of phosphate, nitrate and potassium fertilizer.

According to Regan and Peter (2011), the improved soil retention and plant uptake of key nutrients indicated the potential use of agriculture power Silica to displace a significant portion of NPK fertilizers. Silicon can help in reducing urea and phosphate inputs thereby reducing costs and significantly reducing the environmental impact of these fertilizers.

Magnesium silicate solution gave the highest values of N% and P% in contrast to which potassium silicate gave the highest K% values in plant tissue compared to other treatments (Nesreen *et al.*, 2011).

In another study Milne *et al.* (2012) evaluated Lettuce grown in soilless culture resulted in applications of 2 and 4 mM Si increased Si content in shoot when compared to both the 30 and 60 mM NaCl as controls and thus resulted in reduction of Na content in shoots with applications of Si.

Neil and Ronald (2010) conducted an experiment to examine whether weekly potassium silicate drenches would alter leaf Si concentration of several floriculture species grown in soilless substrate. Twenty one cultivars were transplanted into a peat-based substrate. Control plants received no Si supplementation. Whereas, treated plants were given weekly drenches of 100 mg L⁻¹ Si from potassium silicate for 10 weeks. Si supplementation increased leaf Si concentration of 11 cultivars; leaf Si concentrations for these supplemented plants were 13 to 15% greater than control plants.

Su *et al.* (2011) studied the effects of silicon on Mn content in plants of apple on acid soils. Application of silicon reduced the available Mn in soil and resulted in the decrease of Mn content in different organs in varying degrees.

According to Regan and Peter (2011), the improved soil retention and plant uptake of key nutrients indicated the potential use of agriculture power silica to displace a significant portion of NPK fertilizers. Silicon can help in reducing urea and phosphate inputs thereby reducing costs and significantly reducing the environmental impact of these fertilizers.

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2.4 Influence of silicon on pest and disease incidence

Menzies *et al.* (1991) assessed the number of colonies of *Podosphaera fuliginea* that formed on cucumber leaves in response to increasing amounts of Si that was added to the nutrient solution. They found that increasing Si from 0.5 to 2.3 mM resulted in a 43% reduction in the number of colonies per leaf. Ten days after inoculation if the second fully expanded leaf on the plants were inoculated, an 85% reduction was found. In another experiment in which the fourth fully mature leaf was inoculated, the number of colonies per leaf was reduced by 94% at 14 days after inoculation when the plants were grown in medium containing 4.1 mM Si.

Bowen *et al.* (1992) assessed the number of colonies of powdery mildew (*Uncinula necator*) per grape leaf. They found that 17 mM soluble silicon sprays decreased the number of colonies produced by the fungus. They also showed that hyphae did not develop in areas with thick Si deposits.

Mcavoy and Bible (1995) reported that, use of sodium silicate (NaSiO₃) sprays was beneficial in a study on poinsettias. The severity and occurrence of bract necrosis decreased greatly when NaSi sprays were used on the cultivar 'Supjibi'. Post harvest bract damage also decreased in this cultivar. The silicates were applied at 100 ppm and were as effective as CaCl₂ sprays at 400 ppm for up to five weeks after the flower began to open.

Gillman *et al.* (2003) worked on black spot of rose whose causal agent is the fungus *Diplocarpon rosae*. Potassium silicate was assessed as a media-applied treatment for decreasing the severity and incidence of black spot infection. Roses were treated with 0, 50, 100, or 150 mg l⁻¹ silicon as potassium silicate incorporated

into irrigation water on either a weekly or daily schedule. Plants were inoculated with *Diplocarpon rosae*. Roses began to show visual symptoms of infection four days later. Roses that were applied with 150 mg L⁻¹ silicon on a daily schedule had significantly more silicon present in their leaves than other treatments. In addition, roses that were applied with 100 and 150 mg L⁻¹ silicon on a daily schedule had fewer black spot lesions per leaf and fewer infected leaves than any of the other treatments. The results indicated that using potassium silicate in irrigation water may reduce the disease incidence.

Takeshi *et al.* (2004) tested potassium silicate (SiO₂) at different concentrations *i.e.*, 0, 25, 50 and 100 mgL⁻¹ in hydroponics to control the powdery mildew in strawberry. They found the powdery mildew was spreaded in the control plot, but little mildew developed in the plot with 25 mgL⁻¹ silicate, and none in plots with more than 50 mg L⁻¹ silicate.

Bekker *et al.* (2005) worked to know the *in vitro* inhibition of mycelial growth of *Phytophthora cinnamomi* and *Fusarium oxysporum* by soluble silicon at concentration of 40 and 80 ml/pda, soluble silicon (20.7 SiO₂) had completely suppressed the fungi.

Mary (2005) conducted an experiment with weekly spray application of bio fungicides, Silicon-Matrix (potassium silicate), Fosphite (phosphoric acid), Kaligreen (potassium bicarbonate), and Manniplex traffic (chelated Si) on powdery mildew on miniature roses compared to a standard fungicide Heritage (azoxystrobin). Among them Kaligreen (potassium bicarbonate) gave the best control of powdery mildew for cultivar 'Sonya'.

Kanto *et al.* (2006) reported that, the study was conducted to examine the liquid potassium silicate to suppress the occurrence of strawberry powdery mildew on leaves. Liquid potassium silicate 500 mg/l as SiO₂ was applied at an average rate of 0.95 g SiO₂ with a liquid fertilizer auto feeder during the cultivation period.

Shetty *et al.* (2008) studied on powdery mildew caused by *Sphaerotheca pannosa* var. *rosae*. Silicon (Si) mediated resistance to plant pathogenic a fungus has been demonstrated in several patho systems. The study investigated the possibility of controlling powdery mildew in potted roses using silicon as the inducer. A bioassay

was established with four rose cultivars, namely 99/9496-19, 95/5166-1, 98/8285-1 and “Smart”. Plants were watered with increasing concentrations of Si in a nutrient solution, and were inoculated with a defined density of a virulent powdery mildew isolate. Disease reduction ranged from 20-35% after Si treatment compared to the controls.

Jamar *et al.* (2008) conducted field experiment over two growing seasons, the effectiveness and phytotoxicity of inorganic fungicides such as sulphur, lime sulphur, copper, silicon and Armicarb was compared with water for the control of primary apple scab infections in Belgium on high, medium and low scab-susceptible cultivars (cv ‘Pinova’, ‘Pirouette’ and ‘Reinette des Capucins’, respectively). Silicon reduced apple scab on fruits very slightly, but not on leaves. The amounts of wettable sulphur, lime sulphur, copper, silicon and potassium bicarbonate used in this experiment to control apple scab were not phytotoxic and did not increase fruit russet, did increase the yield of each cultivar and did not affect summer density of the beneficial *Typhlodromus pyri*.

Banana plants were treated with combinations of non-pathogenic *Fusarium oxysporum*, *Trichoderma harzianum* Eco-T®, silicon and mulch had significantly higher number of leaves, stem height and girth size than single applications of the treatments. This study demonstrated that the combined application of bio control organisms, silicon and mulching can provide an effective control option for banana growers dealing with *Fusarium* wilt in their plantations (Kidane and Laing, 2010).

Vermeire *et al.* (2011) studied the effects of Si supply on *Cylindrocladium spathiphylli* infection on banana. Plantlets inoculated by dipping the root system in a conidial suspension of the pathogen were grown on a de silicated ferralsol and amended, or not, with 2 mM of soluble Si under green house conditions in Guadeloupe. The root lesion severity was evaluated using the image analysis program WinRHIZO 7, 14 and 21 days after inoculation. A reduction of about 50% of root necrosis was observed 14 days after inoculation for the Si-supplied plants compared with those not supplied with Si. The Si amendment also alleviated growth reduction caused by the pathogen.

Kablan *et al.* (2012) studied that the effect of silicon (Si) uptake on the susceptibility of *Musa acuminata* to *Mycosphaerella fijiensis* was investigated in three

experiments conducted under controlled conditions in which disease progress curve (AUDPCs) calculated for plants grown with Si were significantly lower than the AUDPCs for plants not supplied with Si, regardless of inoculation method. Thus, Si supply could be a valuable tool in integrated pest management against *M. fijiensis* by reducing the disease pressure on banana.

Rogério *et al.* (2012) studied the effects of silicon leaf application, in the form of stabilized silicic acid, on the disease incidence, yield and quality of potato. The treatments consisted of a control (without Si) and silicon foliar spraying at 2 L/ha of a commercial product containing 0.8 per cent of soluble silicon as concentrated, stabilized silicic acid. Silicon application reduces the severity of late blight and the incidence of black leg, besides increasing tuber yield and tuber dry matter content. Leaf-supplied silicon increases potato tuber yield, regardless of its effect on disease incidence.

Wolff *et al.* (2012) evaluated the foliar applications of silicon fertilizers inhibit powdery mildew development in greenhouse cucumber. The products Carbon Silipower and Carbon Defence were supplied to the mildew susceptible cultivars 'Euphoria' and 'Jessica', one or two times per week in two different concentrations. All treatments resulted in a significantly lower mildew infection development than untreated control plants (water only). In general, more frequent applications improved the fungal inhibitive effect. The most effective treatment was a high concentration of Carbon Silipower solution (with 56 mM Si) applied twice per week, reducing the disease severity by as much as 87 per cent compared to the control.

Leila *et al.* (2012) studied the effect of silicon in combination with *Torulaspora delbrueckii* on apple blue mould disease. In vivo, silicon at 0.2 and 1 per cent (wt./vol.) in combination with antagonistic yeast (1×10^8 cell/ml) was a more effective approach to reduce the lesion diameter of blue mould decay of apples than the application of silicon or *T. delbrueckii* alone at 20 and 4 °C, respectively.

Alessandro *et al.* (2012) studied the effect of silicon in reducing the symptoms of fusarium wilt, caused by *Fusarium oxysporum f. sp. cubense* (Foc), on banana plants. The findings showed that supplying silicon to banana plants, especially to a susceptible cultivar to *Fusarium oxysporum f. sp. cubense*, had a great potential in reducing the intensity of Fusarium wilt and may play a key role in disease

management when banana plants are cultivated in Si-deficient soils infested by this pathogen.

Farahani *et al.* (2012) studied the effect of two strains of antagonistic yeasts in combination with silicon against two isolates of *Penicillium expansum* on apple fruit. The results of this study emphasized the synergistic effects of the yeasts A4 and A6 in combination with silicon and the different behaviours of *P. expansum* isolates against the combined treatments.

Rodrigo *et al.* (2012) studied the effect of calcium and magnesium silicate on *Meloidogyne javanica* reproduction and development of banana Prata-anã seedlings. The result concluded that the doses of 1.28 and 2.56 g of calcium and magnesium silicate/dm³ of soil significantly reduced the number of eggs of *M. javanica* and reproduction factor (RF = final population/initial population) of *M. javanica* compared to control.

Hassan *et al.* (2013) noticed the combination of silicon and hot water to control post-harvest blue mould caused by *Penicillium expansum* in apple. The results of this study showed that concentrations of silicon especially combination with hot water affects apples responses to *P. expansum* and could be an important method for control of apple blue mould.

Wang *et al.* (2013) studied the soil microbial effects of silicon-induced tomato resistance against *R. solanacearum* through pot experiment. The results suggested that silicon amendment is an effective approach to control *R. solanacearum*. Moreover, Si-mediated resistance in tomato against *R. solanacearum* is associated with the changes of soil microorganism amount and soil enzyme activity.

Jayawardana *et al.* (2014) reported that root supplement of Si was effective over foliar spraying against anthracnose disease development caused by *Colletotrichum gloeosporioides* in *Capsicum annuum* L. 'Muria F1'.

2.5 Influence of silicon on physiological disorders of fruit crops

Lieten *et al.* (2002) studied the effect of silicon on albinism of strawberry. The result indicated that insufficient colouring was related to the concentration of silicon applied by the nutrient solution.

Melgarejo *et al.* (2004) studied the effect of kaoline spray against pomegranate sunburn in var. Mollar de Elche. Surround WP (2.5 and 5%), a product comprising processed, refined kaoline (5%) was sprayed over the whole canopy and fruits four times at 2-3week interval from mid-June to early august. The result suggests that significant reduction in leaf and fruit temperature (2.5 0 c) as compared to the control (4.9%). Sunburn damage of fruit was reduced from 21.9 per cent in untreated control to 9.4 per cent in the surround kaoline treated fruits.

Gong *et al.*, (2003) studied the effects of silicon application on apple internal bark necrosis (IBN) induced by high content of manganese. The results showed that the simultaneous application of Mn and silicon both with the dosage of 400 mg/kg could effectively prevent Fuji trees of apple from developing IBN.

Yazici and Kaynak (2009) studied the effects of kaolin and shading treatments on sunburn in fruits of Hicaznar cultivar of pomegranate. Applications of kaolin (3%) was the best method for preventing sunburn in fruits of Hicaznar pomegranate cultivar and increased soluble dry matter content and red color of fruits. Among kaolin applications, KI was the most effective application for reducing sunburn in pomegranate fruit.

Rhman (2010) studied the effect of controlled irrigation, bagging, spraying with zinc sulphate (ZnSO₄) at 1 per cent and kaolin spray at 6 per cent on fruit cracking of Manfaluty. All studied treatments (controlled irrigation, bagging, zinc sulphate and kaolin) were effective in reducing the percentage of fruit cracking. The minimum cracking values were obtained by using controlled irrigation combined with zinc sulphate (ZnSO₄) spray at 1 per cent and controlled irrigation with kaolin spray at 6 per cent in both seasons.

Putra *et al.* (2010) observed the weak neck in *Musa sp.* cv. Rastali. The results of sprays indicated that there is high probability that application of magnesium, boron and silicon may solve weak neck.

3. MATERIAL AND METHODS

The present investigation was carried out in the field of department of fruit science, Kittur Rani Channamma College of Horticulture, Arabhavi, Gokak taluk, Belgaum District, Karnataka, during 2013-14 to study the effect of Diatomaceous Earth on growth, yield and quality of banana cv. Grand Naine. The material used, techniques adopted and observations recorded during the course of investigation are enumerated in this chapter.

3.1 Geographical location of Experimental site

Arabhavi is situated in Northern Dry Zone (Zone-3) of Agro-climatic Zone of Karnataka at 16° 15' North latitude and 74° 45' East longitude and at an altitude of 612.03 m above the mean sea level. This zone receives a fairly well distributed rainfall of about 490 mm from June to November. On an average, the daily maximum and minimum temperatures are 36.4° C and 20.8° C, respectively. The relative humidity on an average varies between 48 and 90 per cent. The materials used and methods followed in conducting the experiments are described in this chapter with appropriate headings (Plate 1).

The meteorological data for the period of experimentation were collected from the meteorological observatory of the Agricultural Research Station, Arabhavi and is presented in the Appendix I.

3.2 Soil type

The experiment was conducted in black soil. The data of the soil analysis is presented in Appendix II.

3.3 Experimental details

3.3.1 Cultivar

Grand Naine is one of the popular cultivar grown in South East Asian and African countries and is a tall mutant of Dwarf Cavendish and is the most accepted due to its many desirable traits such as excellent fruit quality, uniform sized long fingers leads to easy packing, immune to Fusarium wilt *etc.*



Plate 1: General view of the experimental plot

3.3.2 Design of experiment

The experiment was laid out in Randomised Blocks Design (RBD) with ten treatments and replicated thrice.

No. of Treatments	: 10
No. of Replications	: 3
Spacing	: 1.8 m × 1.8 m
Date of main crop planting	: June 2013
Number of plants / treatment	: 48
Total no. of plants	: 480
Net plot size	: 31.81 m ²
Total area covered	: 1552 m ²

3.3.3 Treatment details

- T₁– Absolute control
- T₂– Recommended dose of fertilizers
- T₃ – Half of recommended fertilizers
- T₄ – 500 kg/ha DE alone
- T₅ – Half of RDF + 250 kg/ha DE
- T₆ - Half of RDF + 500 kg/ha DE
- T₇ – Half of RDF + 750 kg/ha DE
- T₈ – RDF + 250 kg/ha DE
- T₉ – RDF + 500 kg/ha DE
- T₁₀ – RDF + 750 kg/ha DE

*DE = Diatomaceous Earth

3.3.4 Treatment imposed

Diatomaceous Earth as a source of silicon was applied as a basal doses in this experiment with respect to their treatments. The dosage of Diatomaceous Earth used in this experiment was 250, 500 and 750 kg/ha (Plate 2).

The inorganic nutrient nitrogen was applied in the form of urea (46%), phosphorus was applied in the form of single super phosphate (16%P) and potassium applied in the form of Murate of potash (60% K). These treatments were imposed according to the package of practices of UHS, Bagalkot (Anon., 2013).

Time of application	Nitrogen (g/plant)	Phosphorus (g/plant)	Potassium (g/plant)
35 DAP	20	20	25
70 DAP	45	20	55
105 DAP	45	20	55
140 DAP	45	20	55
175 DAP	45	20	55
At the time of flowering	-	-	55
Total (RDF)	200	100	300

DAP = days after planting

3.3.5 Selection of plot

3.3.5.1 Planting

Uniform sized one months old banana tissue cultured plants of cv. Grand Naine were planted at spacing of 1.8 m ´ 1.8 m during June, 2013 and 20 t/ha of FYM was applied.

3.3.5.2 Irrigation

Drip irrigation method was adopted and regularly watering was done to maintain optimum soil moisture.



Plate 2: Land preparation and treatment imposition in an experimental plot

3.3.5.3 Weeding

Hand weeding was done at fortnightly interval after desuckering to keep the plot weed free.

3.3.5.4 Earthing up of plants

Earthing up was done five months after planting and at the time of flowering.

3.3.5.5 Desuckering

The suckers emerging from the mother rhizome were manually removed at monthly intervals.

3.3.5.6 Proping

Fifteen days after flowering, propping was done by using plastic thread to avoid the falling of plants due to heavy wind and the weight of bunches in later stage.

3.3.5.7 Denavelling

The male flower from each plant was removed when the last hand in the bunch was unable to develop and drop down after complete filling of bunches.

3.3.5.8 Plant protection measures

Regular spraying of systemic insecticides (dimethoate, chlorophyriphos and trizophos (1.5ml/litre) was undertaken for managing the sucking pest and Propiconazole (1g/L) was sprayed for sigatoka leaf spot and Streptocycline (0.5g/L) + COC (3g/L) combination solution were drenched around the plants to avoid bacterial rhizome rot.

3.4 Observations recorded

Six uniformly growing plants were selected in each replication under each treatment for recording observation.

3.4.1 Vegetative growth parameters

Growth parameters were recorded at monthly interval from one month of planting to nine months after planting.

3.4.1.1 Pseudostem height (cm)

The pseudostem height was measured from the ground level to the marked point up to the height of the pseudostem where the bifurcation of leaves was noticed and the mean was expressed in centimetres.

3.4.1.2 Pseudostem girth (cm)

The girth of plant was measured at 30 cm above the ground level at monthly interval till shooting of the plants and expressed in centimetres.

3.4.1.3 Number of leaves per plant

The leaves were counted from each tagged plant at monthly interval till shooting and averaged was expressed as number of leaves per plant.

3.4.1.4 Leaf area (m²)

The leaf area was calculated per plant using the following formula and expressed in square meter (Murray, 1960).

$$\text{Leaf area} = \text{Leaf length} \times \text{Leaf width} \times 0.8 \times \text{number of leaves}$$

3.4.1.5 Total leaf chlorophyll content

Leaf samples for chlorophyll estimation were taken from healthy, fully opened matured leaves at five months after planting and at the time of harvesting. The samples were brought in polythene bags from field and cut into pieces. A known weight of 150 mg of samples randomly from 5 leaves in each treatment was crushed using 10 ml DMSO (Di Methyl Sulphoxide) and kept for overnight (Hiscox and Israelstam, 1979). The extract was used for measuring optical density at three wave lengths of 645, 652 and 663 nm by using spectro photometer (Arnon, 1949). The leaf chlorophyll content was calculated by the following formula.

$$\text{Chlorophyll 'a'} = \frac{(12.7 A_{663} - 2.69 A_{645}) \times V \times 1}{1000 \times \text{Fresh weight}}$$

$$\text{Chlorophyll 'b'} = \frac{(22.9 A_{645} - 4.68 A_{663}) \times V \times 1}{1000 \times \text{Fresh weight}}$$

$$\text{Total Chlorophyll} = \frac{(A_{652}) \times 1000}{34.5 \times W} \times \frac{V}{1000 \times \text{Fresh weight}}$$

Where,

W is weight of leaf sample taken and V is volume made up

3.4.1.6 Number of suckers /plant

The number of suckers was counted before every desuckering and the mean number of suckers were calculated.

3.4.2 Crop duration

3.4.2.1 Days for shooting after planting

The days taken for shooting from planting were recorded and the mean number of days taken for shooting was calculated.

3.4.2.2 Days taken to harvest after shooting

The actual number of days taken from shooting to maturity was recorded and mean number of days was calculated.

3.4.2.3 Total crop duration

Total crop duration was calculated by adding days taken for shooting after planting and days taken to harvest after shooting and the mean total crop duration was calculated.

3.4.3 Bunch characters

The following bunch characters were recorded at the time of harvest of bunches.

3.4.3.1 Bunch length (cm)

The length of bunch was recorded by using measuring tape after harvest from first hand at the top up to the last hand in the tagged plants and the average was worked out and expressed in centimetres.

3.4.3.2 Bunch width (cm)

The bunch width was measured by using measuring tape at the middle of the bunch and the mean width of the bunch was recorded and expressed in centimetres.

3.4.3.3 Number of hands per bunch

Total number of hands per bunch was calculated and mean was recorded.

3.4.3.4 Number of fingers in third hand

The actual number of fingers in third hand from the proximal end of the bunch was counted and the mean was worked out.

3.4.3.5 Total number of fingers per bunch

The total number of fingers per bunch was counted and the mean number of fingers per bunch was recorded.

3.4.4 Finger characteristics

For recording the finger characters, five ripe fingers from third hand were used.

3.4.4.1 Finger weight (g)

Fingers were weighed by using electronic balance and mean weight of fingers was recorded and expressed in gram.

3.4.4.2 Finger length (cm)

Finger length was measured by using foot scale from the top of a finger to the pedicel and mean length of finger was determined and expressed in centimeter.

3.4.4.3 Finger girth (cm)

Finger girth was measured at the centre of finger by using vernier calipers and mean girth of finger was recorded and expressed in centimeter.

3.4.4.4 Pulp weight (g)

The pulp weight of the ripened fruit was recorded using electronic balance after removing the peel and the mean weight of pulp was worked out and expressed in gram.

3.4.4.5 Peel weight (g)

The peel weight of the ripened fruit was recorded using electronic balance and the mean weight of peel was recorded in gram.

3.4.4.6 Pulp to peel ratio

The pulp to peel ratio was calculated by dividing pulp weight to peel weight and mean was worked out.

3.4.5 Quality parameters

For recording quality parameters, the same five fully ripened fingers selected for finger characters were used.

3.4.5.1 Days taken for ripening

Fully matured fingers from respective bunch were kept for ripening and the number of days taken for ripening was recorded.

3.4.5.2 Shelf life (days)

The shelf life of fingers (days) from the day of ripening till the last edible stage was assessed and the mean was worked out.

3.4.5.3 Total soluble solids (⁰B)

The total soluble solid of pulp was recorded using hand refractometer and expressed in ⁰Brix (⁰B).

3.4.5.4 Titrable acidity (%)

The titrable acidity of pulp of selected fingers was determined by titrating the juice against standard NaOH with phenolphthalein as indicator. The acidity was expressed in percentage.

3.4.5.5 TSS: Acid ratio

TSS: Acid ratio was calculated by dividing total soluble solids by titrable acidity.

3.4.5.6 Reducing sugar (%)

Reducing sugar of juice obtained from pulp of selected fingers was estimated by dinitrosalicylic acid method (Miller, 1972). The mean values were expressed in percentage.

3.4.5.7 Total sugar (%)

The total sugar of juice was estimated by following the procedure used for reducing sugar after inversion of the non-reducing sugar using dilute hydrochloric acid. The mean value was expressed in percentage.

3.4.5.8 Non-reducing sugar (%)

Non-reducing sugar was calculated using formula given below and expressed in percentage.

$$\text{Non-reducing sugar} = \text{Total sugar (\%)} - \text{Reducing sugar (\%)} \times 0.95.$$

3.4.6 Yield characters

3.4.6.1 Yield per plant (kg/plant)

Bunch was weighed by using Avery balance and the mean weight of bunch was recorded and expressed in kilogram per plant.

3.4.6.2 Yield per plot (kg/plot)

Yield per plot was calculated by adding the total bunch weight of plants in a plot and it is expressed in kilogram per plot.

3.4.6.3 Yield per hectare (t/ha)

Yield per hectare was calculated by multiplying respective yield per plot with one hectare area and is expressed in tonnes per hectare.

3.4.7 Organoleptic evaluation

Organoleptic evaluation of fresh banana fruits was carried out by 20 judges (comprising of faculty and post graduate students) of Kittur Rani College of Horticulture, Arabhavi. The fruit characters like colour, texture, taste and overall acceptability of banana fruits was evaluated on a five point hedonic scale using following score card. The mean score was given by 20 judges were used for statistical analysis.

Hedonic scale	Score
Excellent	7.0-9.0
Very good	5.0-7.0
Good	3.0-5.0
Fair	3.0-1.0
Poor	1

3.4.8 Leaf analysis

Leaf samples were collected from third fully opened leaf from designated plants in each treatment from each replication after six months of planting. Leaf strips from middle portion of both the sides are collected and cleaned with distilled water and then leaf samples were oven dried at 50⁰c until they attain constant weight and used for nutrient analysis. Estimation of total nitrogen, phosphorus, potash and micronutrients were done by following the standard procedures.

3.4.8.1 Nitrogen (%)

Nitrogen was estimated by Microkjeldhal method (Humphries, 1956) and expressed in percentage.

3.4.8.2 Phosphorous (%)

Phosphorus content was estimated in triple acid extract by adopting Vanado molybdate phosphoric yellow colour method (Jackson, 1967).

3.4.8.3 Potassium (%)

Potassium content was estimated by reading flame photometer values of triple acid extract (Jackson, 1967).

3.4.8.4 Calcium (%)

Calcium was estimated by titration with EDTA (disodiumdihydrogen-ethylenediaminetetraacetate) by following method suggested by (Lindsay and Norvell, 1978).

3.4.8.5 Magnesium (%)

Magnesium was estimated by subtracting the magnesium from the combination of calcium and magnesium which was estimated by EDTA titration to EBT (Erochrome Black T) endpoint, as reported by (Lindsay and Norvell, 1978).

3.4.8.6 Copper (%)

Copper content was estimated by Diethylenetriaminepentaacetic acid (DTPA) method which was reported by (Lindsay and Norvell, 1978).

3.4.8.7 Zinc (%)

Zinc content was estimated by Diethylenetriaminepentaacetic acid (DTPA) method which was reported by (Lindsay and Norvell, 1978).

3.4.8.8 Silicon (%)

Silicon content was estimated by ANSA (1-amino-2-naphthol-4-sulphonic acid) method (Kadalli *et al.*, 2013).

3.4.9 Soil analysis

Soil samples were collected from different spots in the experimental site before planting of banana and after harvesting (from each treatment in all replications). Samples were air-dried and analyzed for nutrient status in the soil.

3.4.9.1 Soil pH

Soil pH was determined by potentiometric method in 1: 2.5 soil water suspension using pH meter (Jackson, 1967).

3.4.9.2 Electrical conductivity

An electrical conductivity of soil samples was measured in soil-water extract of 1:2.5 ratio using conductivity bridge (Jackson, 1967) and expressed in dS/m.

3.4.9.3 Organic carbon

The soil organic carbon was determined by Walkey and Black's wet oxidation method by using potassium dichromate.

$$\text{O.C (\%)} = \frac{\text{Blank titre value} - \text{Sample titre value} \times \text{N of FAS} \times 0.003}{\text{Weight of soil}} \times 100$$

FAS - Ferrous ammonium sulphate

N - Normality

3.4.9.4 Available Nitrogen

Available nitrogen was determined by modified alkaline potassium permanganate method as described by Subbaiah and Asija (1956). Available Nitrogen was calculated by using formula

$$\text{Available N (kg/ha)} = \frac{\text{Sample TV} - \text{Blank TV} \times \text{N of H}_2\text{SO}_4 \times 0.014}{\text{Weight of soil}} \times 2 \times 10^6 \times 1.12$$

TV - Titre Value

N - Normality

3.4.9.5 Available Phosphorous

The available phosphorous in soil was extracted by using Bray's extractant reagent. The ammonium molybdate solution and stannous chloride solution was added to this filtrate solution to develop blue colour and measured intensity of colour by using spectrophotometer. Standard solutions of P with concentration of 0, 0.1, 0.2, 0.4, 0.6, 0.8 and 1.0 ppm were prepared by following the same procedure but without using soil sample (Jackson, 1973).

$$\text{Available P (kg/ha)} = \frac{\text{Graph ppm}}{10^6 \text{ Wt. of soil}} \times \frac{\text{Vol. of extractant}}{\text{Aliquot taken}} \times \frac{\text{Vol. made}}{2.29} \times 2 \times 10^6$$

3.4.9.6 Available Potassium

The available potassium was extracted from soil by using neutral normal ammonium acetate solution and the aliquot was fed to calibrated flame photometer for K estimation. 0, 10, 20, 30 and 40 ppm of K standard solution was pipette out to volumetric flask from 100 ppm of potassium standard solution (Black, 1965). These samples were fed to flame photometer to obtain flame photometer reading.

$$\text{Available K (kg/ha)} = \frac{\text{Graph ppm}}{10^6} \times \frac{\text{Vol. of extractant}}{\text{Weight of soil}} \times 2 \times 10^6 \times 1.2$$

3.4.9.7 Estimation of silicon

Silicon was estimated by acetic acid method. Soil was weighed and transferred to the centrifuge tube and 12.5 ml of 0.5 N acetic acid was added and then mechanically shaken for an hour. The content was centrifused for 3 min with 3000 rpm to get a clear solution. Then the content was filtered to get clear, colourless solution. 0.5 ml of aliquot was taken and to this 10.5 ml of distilled water was added. Again to this 0.25 ml of HCl (Hydrochloric acid), 0.5 ml of 10 per cent ammonium molybdate, 0.5 ml of 20 per cent tartaric acid and 0.5 ml of reducing agent ANSA (Amino Naphthol Sulphonic Acid) was added. The absorbance was measured at 630 nm with an ultraviolet visible spectrophotometer. Standard solutions with concentration of 0.2, 0.4, 0.8, 1.2 and 1.6 ppm were prepared by the following formula.

$$\text{Si (kg/ha)} = \text{Absorbance value} \times \text{slope} \times \text{Dilution Factor} \times 2.24$$

3.4.10 Pest and Disease occurrence

3.4.10.1 White fly infestation

3.4.10.1.1 Number of whiteflies colony per leaf

The total number of whitefly colony in each infested leaf was counted in sample plants in each treatment and the mean was calculated.

3.4.10.1.2 Number of whiteflies per colony

The total number of adult whiteflies per colony in each leaf was counted in labelled plants in each treatment and the mean was calculated.

3.4.10.1.3 Per cent leaf infestation

The per cent leaf infestation from each treatment and from four banana plants was selected and the total number of infested and healthy leaves was counted and the mean was calculated.

3.4.10.2 Sigatoka leaf spot intensity

The disease intensity was recorded at fifth months after planting. Sigatoka leaf spot index was assessed at 150, 180 and 210 days after planting by scoring each leaf based on severity of intensity (Stover, 1971). It was recorded as per the International Musa Testing Programme guidelines, modified by Gaul *et al.* (1993).

The scoring was given as follows

0 = No infection

1 = Less than 1% lamina with infection

2 = 1 to 5% lamina with infection

3 = 6 to 15% lamina with infection

4 = 16 to 33% lamina with infection

5 = 34 to 50% lamina with infection

6 = 51 to 100% lamina with infection

The infection index was calculated as per formula given here.

$$\text{Infection index} = \frac{\sum nb}{(N-1) T} \times 100$$

Where,

n= Number of leaves in each grade

b = Grade

N = Number of grades in the scale (7)

T = Total number of leaves scored

3.4.11 Economics

The prices of the inputs in rupees prevailing at the time of experimentation were considered for working out of cost of cultivation.

Net return per hectare was calculated by deducing cost of cultivation from gross returns per hectare. Benefit cost ratio was worked out as follows.

$$\text{Benefit cost ratio} = \frac{\text{Net returns (Rs./ha)}}{\text{Cost of cultivation (Rs./ha)}}$$

3.5 Statistical analysis

Statistical analysis of the data was done by following the Fisher's analysis of variance (ANOVA) technique as given by Panse and Sukhatme (1967). The level of significance used in 'F' and 't' tests was P=0.05.

4. EXPERIMENTAL RESULTS

The results of the present investigation entitled “Study of Diatomaceous Earth (as a source of silicon) on growth, yield and quality of Banana cv. Grand Naine (*Musa* AAA)” was carried out to know the effect of silicon and the field experiment was carried out at Kittur Rani Channamma College of Horticulture, Arabhavi, Gokak taluk, Belgaum District, Karnataka, during 2013-14. Results of the experiment are presented in this chapter.

4.1 Vegetative growth parameters

All the vegetative growth parameters were recorded at different stages from one month after planting (MAP) to nine months after planting.

4.1.1 Pseudostem height (cm)

The data on pseudostem height is presented in Table 1 was shows significantly increased by the soil application of DE (as a source of silicon) compared to control. Further, as the crop growth period increased, there was a marked increase in pseudostem height due to application of silicon. Significant differences were observed in all the treatments during the stages from one MAP to nine MAP.

At one MAP, the significantly highest pseudostem height (21.31cm) was observed in T₁₀ (RDF + 750 kg/ha of DE) followed by T₂ (18.97 cm) which was statistically on par with T₉ (18.75cm), T₃ (18.50cm), T₅ (18.28 cm), T₈ (18.22), T₇ (18.06), T₆ (17.86) and T₄ (17.75) whereas, least pseudostem height (17.53cm) was observed in T₁ (Absolute control).

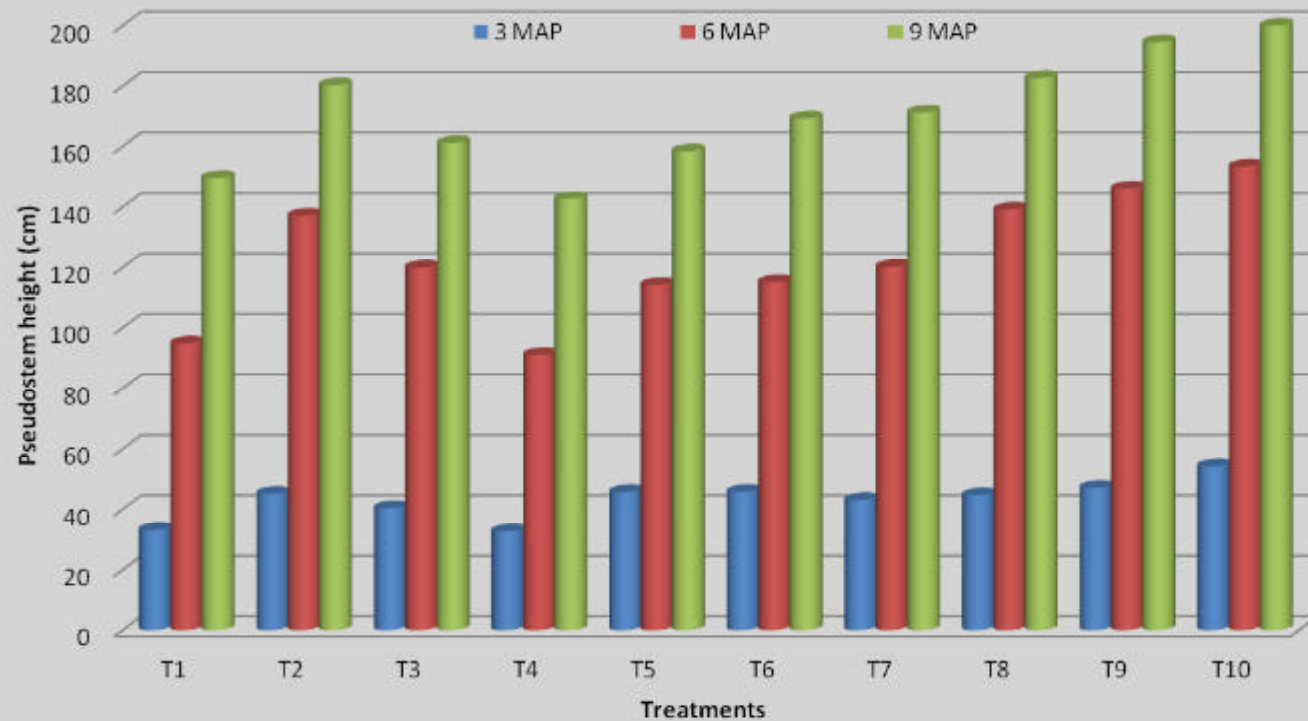
At second MAP, maximum pseudostem height (38.33 cm) was recorded in T₁₀ (RDF + 750 kg/ha of DE) which was statistically on par with T₉ (36.00 cm), T₂ (35.86 cm), T₅ (34.72) and T₆ (34.67) followed by the treatment T₈ (34.56 cm), T₇ (32.89 cm) and T₃ (31.28 cm) whereas, minimum pseudostem height (25.39 cm) was recorded in the treatment T₄ (DE alone).

At third MAP, maximum pseudostem height (54.11 cm) was recorded in T₁₀ (RDF + 750 kg/ha of DE) followed by T₉ (47.06 cm) which was statistically on par with T₆ (45.71 cm), T₅ (45.67 cm) and T₂ (45.11 cm) whereas, minimum pseudostem height (32.67 cm) was recorded in T₄ (DE alone).

Table 1: Influence of Diatomaceous Earth on pseudostem height (cm) of banana

Treatment	Pseudostem height (cm)								
	Months after planting								
	1	2	3	4	5	6	7	8	9
T ₁ - Absolute control	17.53	26.44	33.11	46.83	65.28	94.78	109.33	123.72	149.61
T ₂ - Recommended dose of fertilizers	18.97	35.86	45.11	66.83	96.83	137.06	156.17	172.89	180.28
T ₃ -Half of Recommended dose of fertilizers	18.50	31.28	40.33	63.72	83.94	119.94	135.17	143.94	161.06
T ₄ - DE alone	17.75	25.39	32.67	45.83	64.67	91.00	104.56	119.00	142.61
T ₅ - Half of RDF+DE @ 250 kg/ha	18.28	34.72	45.67	63.06	84.67	114.17	125.83	147.22	158.39
T ₆ - Half of RDF+ DE @ 500 kg/ha	17.86	34.67	45.71	62.67	88.28	115.11	135.22	148.89	169.39
T ₇ - Half of RDF+ DE @ 750 kg/ha	18.06	32.89	43.06	61.56	91.78	120.17	137.61	157.11	171.28
T ₈ - RDF+ DE @ 250 kg/ha	18.22	34.56	44.61	66.78	95.06	139.06	158.50	174.50	182.61
T ₉ - RDF+ DE @ 500 kg/ha	18.75	36.00	47.06	73.17	102.33	146.11	164.33	183.28	194.50
T ₁₀ - RDF+ DE @ 750 kg/ha	21.31	38.33	54.11	80.22	110.39	153.28	171.89	192.33	208.29
SEm±	0.65	1.24	1.45	3.18	5.23	4.47	5.96	6.02	5.97
C.D (0.05)	1.93	3.68	4.31	9.45	15.55	13.28	17.70	17.90	17.74

RDF- Recommended dose of fertilizers



- T₁ – Absolute control
- T₂ – Recommended dose of fertilizers
- T₃ – Half of Recommended dose of fertilizers
- T₄ – DE alone
- T₅ – Half of RDF+DE @ 250 kg/ha
- T₆ – Half of RDF+ DE @ 500 kg/ha
- T₇ – Half of RDF+ DE @ 750 kg/ha
- T₈ – RDF+ DE @ 250 kg/ha
- T₉ – RDF+ DE @ 500 kg/ha
- T₁₀ – RDF+ DE @ 750 kg/ha

Fig. 1: Influence of Diatomaceous Earth on pseudostem height (cm) of banana

After fourth MAP, maximum pseudostem height (80.22 cm) was noticed in T₁₀ (RDF + 750 kg/ha of DE) which was statistically on par with T₉ (73.17 cm) followed by T₂ (66.83 cm), T₈ (66.78 cm) and T₃ (63.72 cm) whereas, minimum pseudostem height (45.83 cm) was recorded in T₄ (DE alone).

At fifth MAP, maximum pseudostem height (110.39 cm) was recorded in T₁₀ (RDF + 750 kg/ha of DE) which was statistically on par with T₉ (102.33 cm), T₂ (96.83 cm) and T₈ (95.06 cm) followed by T₇ (91.78 cm), T₆ (88.28 cm) and T₅ (84.67 cm) whereas, minimum pseudostem height (64.67 cm) was recorded in T₄ (DE alone).

During sixth MAP, maximum pseudostem height (153.28 cm) was recorded in T₁₀ (RDF + 750 kg/ha of DE) which was statistically on par with T₉ (146.11 cm) followed by T₈ (139.06 cm), T₂ (137.06 cm), T₇ (120.17 cm) and T₃ (119.94 cm) whereas, minimum pseudostem height (91.00 cm) was recorded in T₄ (DE alone).

At seventh MAP, maximum pseudostem height (171.89 cm) was recorded in T₁₀ (RDF + 750 kg/ha of DE) which was statistically on par with T₉ (164.33 cm), T₈ (158.50 cm) and T₂ (156.17 cm) followed by T₇ (137.61 cm), T₆ (135.22 cm) and T₃ (135.17 cm) whereas, minimum pseudostem height (104.56 cm) was recorded in T₄ (DE alone). Similar trend were observed during the growth stage of eighth and ninth MAP.

The values for pseudostem height were significantly higher when the plants were applied with T₁₀ (RDF + 750 kg/ha of DE) which was on par with T₉ (RDF + 500 kg of DE) and followed by T₈ (RDF + 250 kg of DE) and T₂ (RDF only) except one and three MAP

4.1.2 Pseudostem girth

The data is presented in Table 2 indicated that, effect of diatomaceous earth (as a source of silicon) on pseudostem girth was significant at all the stages of crop growth compared to control.

With respect to pseudostem girth at one MAP, maximum pseudostem girth (2.70 cm) was observed in T₁₀ (RDF + 750 kg/ha of DE) which was statistically on par with T₉ (2.63 cm), T₂ (2.53 cm), T₈ (2.52 cm), followed by T₆ (2.36cm) while the minimum pseudostem girth (2.28 cm) was observed in T₄ (DE alone).

Table 2: Effect of Diatomaceous Earth on pseudostem girth (cm) of banana

Treatment	Pseudostem girth (cm)								
	Months after planting								
	1	2	3	4	5	6	7	8	9
T ₁ - Absolute control	2.30	2.39	3.59	5.74	7.82	9.25	11.25	12.14	13.90
T ₂ - Recommended dose of fertilizers	2.53	2.75	4.60	7.31	11.15	14.52	15.79	16.94	18.76
T ₃ -Half of Recommended dose of fertilizers	2.36	2.48	4.20	6.72	10.18	12.34	13.73	14.24	15.83
T ₄ - DE alone	2.28	2.37	3.43	5.69	7.58	9.15	11.18	11.93	13.67
T ₅ - Half of RDF+DE @ 250 kg/ha	2.36	2.54	4.50	6.73	10.05	12.25	14.14	14.60	15.82
T ₆ - Half of RDF+ DE @ 500 kg/ha	2.36	2.57	4.56	6.87	10.27	12.32	14.86	15.81	16.11
T ₇ - Half of RDF+ DE @ 750 kg/ha	2.35	2.63	4.69	6.92	10.43	13.03	15.38	16.13	17.02
T ₈ - RDF+ DE @ 250 kg/ha	2.52	2.82	4.76	7.96	11.28	14.83	16.22	18.12	19.26
T ₉ - RDF+ DE @ 500 kg/ha	2.63	3.03	4.88	8.11	11.90	15.17	16.90	18.81	20.25
T ₁₀ - RDF+ DE @ 750 kg/ha	2.70	3.72	5.42	8.49	12.97	15.67	17.15	19.14	21.23
SEm±	0.08	0.18	0.29	0.43	0.43	0.52	0.87	0.79	0.94
C.D (0.05)	0.23	0.53	0.85	1.27	1.27	1.56	2.59	2.36	2.79

RDF- Recommended dose of fertilizers

During two MAP, the highest pseudostem girth (3.72 cm) was recorded in T₁₀ (RDF + 750 kg/ha of DE), followed by T₉ (3.03 cm), T₈ (2.82 cm), T₂ (2.75 cm) and T₇ (2.63 cm) whereas, least pseudostem girth (2.37 cm) was recorded in T₄ (DE alone).

At third MAP, maximum pseudostem girth (5.42 cm) was recorded in T₁₀ (RDF + 750 kg/ha of DE) which was statistically on par with T₉ (4.88 cm), T₈ (4.76 cm), T₇ (4.69 cm) and T₂ (4.60 cm), followed by T₆ (4.56 cm) and T₅ (4.50 cm) whereas, minimum pseudostem girth (3.43 cm) was recorded in T₄ (DE alone).

During four MAP, maximum pseudostem girth (8.49 cm) was recorded in T₁₀ (RDF + 750 kg/ha of DE) which was statistically on par with T₉ (8.11 cm), T₈ (7.96 cm) and T₂ (7.31 cm), followed by T₇ (6.92 cm), T₆ (6.87 cm) and T₅ (6.73 cm) whereas, minimum pseudostem girth (5.69 cm) was observed in T₄ (DE alone).

At five MAP, maximum pseudostem girth (12.97 cm) was noticed in T₁₀ (RDF + 750 kg/ha of DE) which was statistically on par with T₉ (11.90 cm), followed by T₈ (11.28 cm), T₂ (11.15 cm), T₇ (10.43 cm) and T₆ (10.27 cm) whereas, minimum pseudostem girth (7.58 cm) was recorded in T₄ (DE alone).

However after six MAP, maximum pseudostem girth (15.67 cm) was observed in T₁₀ (RDF + 750 kg/ha of DE) which was statistically on par with T₉ (15.17 cm), T₈ (14.83 cm) and T₂ (14.52 cm), followed by T₇ (13.03 cm), T₃ (12.34 cm), and T₆ (12.32 cm), while, minimum pseudostem girth (9.15 cm) was recorded in T₄ (DE alone).

During seven MAP, maximum pseudostem girth (17.15 cm) was observed in T₁₀ (RDF + 750 kg/ha of DE) which was on par with T₉ (16.90 cm) T₈ (16.22 cm), T₂ (15.79 cm), T₇ (15.38) and T₆ (14.86 cm), followed by T₅ (14.14 cm) whereas, minimum pseudostem girth (11.18 cm) was recorded in T₄ (DE alone).

The values for pseudostem girth at both eight and nine MAP were showed similar pattern. In T₁₀ (RDF + 750 kg/ha of DE) the highest pseudostem girth was found at both eight and nine MAP with 19.14 cm and 21.23 cm respectively, which was statistically on par with T₉ (18.81 cm and 20.25 cm at eight and nine MAP respectively), T₈ (18.12 cm and 19.26 cm at eight and nine MAP respectively) and T₂ (16.94 cm and 18.76 cm at eight and nine MAP respectively), followed by T₇

(16.13 cm and 17.02 cm at eight and nine MAP, respectively) whereas, least pseudostem girth (11.93cm and 13.67 cm at eight and nine MAP, respectively) was recorded in T₄ (DE alone).

4.1.3 Number of functional leaves per plant

The data on number of functional leaves per plant as influenced by diatomaceous earth are presented in Table 3.

The results indicate that the influence of Diatomaceous Earth on number of functional leaves per plant was differed significantly among the treatments compared to control at all the stages of crop growth. As the dose of silicon increased and crop growth period increases, the number of functional leaves per plant also increased.

At one MAP, the maximum number of functional leaves (6.32) was found in T₁₀ (RDF + 750 kg/ha of DE) which was on par with T₉ (6.03), T₈ (5.71) and T₂ (5.65) followed by T₇ (5.62) and T₆ (5.52) whereas, minimum number of functional leaves (5.06) was recorded in T₄ (DE alone).

During second MAP, the maximum number of functional leaves (9.49) was recorded in T₁₀ (RDF + 750 kg/ha of DE) which was statistically on par with T₉ (9.27), T₈ (9.17), T₂ (9.12), T₇ (8.78), T₆ (8.67) and T₅ (8.56) followed by T₃ (8.50) whereas, minimum number of functional leaves (7.65) was recorded in T₄ (DE alone).

The results showed that the values for number of functional leaves per plant at both three and four MAP were showed similar pattern. In T₁₀ (RDF + 750 kg/ha of DE) the maximum number of functional leaves was found at both three and four MAP with 12.28 and 14.37 respectively, which was statistically on par with T₉ (11.86 and 14.03 at three and four MAP, respectively), T₈ (11.67 and 13.80 at three and four MAP, respectively), T₂ (11.50 and 13.51 at three and four MAP, respectively) and T₇ (11.04 and 12.67 at three and four MAP, respectively) followed by the treatment T₆ (10.87 and 12.50 at three and four MAP, respectively) and T₅ (10.78 and 12.44 at three and four MAP, respectively) whereas, minimum number of functional leaves (9.11 and 10.63 at three and four MAP, respectively) was recorded in T₄ (DE alone).

Similar results were recorded from five months after planting to nine months after planting. Significantly highest numbers of functional leaves were consent when

Table 3: Influence of Diatomaceous Earth on number of functional leaves on banana

Treatment	Number of functional leaves								
	Months after planting								
	1	2	3	4	5	6	7	8	9
T ₁ - Absolute control	5.20	7.84	9.29	10.73	11.80	13.06	14.68	15.31	15.90
T ₂ - Recommended dose of fertilizers	5.65	9.12	11.50	13.51	15.61	17.34	19.00	20.39	21.01
T ₃ -Half of Recommended dose of fertilizers	5.39	8.50	10.39	12.17	13.17	15.39	16.83	17.67	18.28
T ₄ - DE alone	5.06	7.65	9.11	10.63	11.72	13.01	14.44	15.28	15.66
T ₅ - Half of RDF+DE @ 250 kg/ha	5.33	8.56	10.78	12.44	13.67	16.06	17.07	17.94	18.78
T ₆ - Half of RDF+ DE @ 500 kg/ha	5.52	8.67	10.87	12.50	13.96	16.67	17.33	18.44	19.33
T ₇ - Half of RDF+ DE @ 750 kg/ha	5.62	8.78	11.04	12.67	14.34	16.83	18.10	18.89	19.44
T ₈ - RDF+ DE @ 250 kg/ha	5.71	9.17	11.67	13.80	16.06	18.00	19.28	20.79	21.33
T ₉ - RDF+ DE @ 500 kg/ha	6.03	9.27	11.86	14.03	16.11	18.17	19.83	21.11	21.61
T ₁₀ - RDF+ DE @ 750 kg/ha	6.32	9.49	12.28	14.37	16.72	18.56	20.11	21.23	22.17
SEm±	0.23	0.33	0.45	0.62	0.68	0.81	0.88	0.98	0.99
C.D (0.05)	0.68	0.98	1.33	1.83	2.01	2.40	2.63	2.90	2.96

RDF- Recommended dose of fertilizers

the plants were applied with T₁₀ (RDF + 750 kg/ha of DE) and the least numbers of functional leaves were recorded in T₄ (DE alone).

4.1.4 Leaf area (m²)

The data on leaf area as influenced by the different concentrations of diatomaceous earth are presented in Table 4.

The results indicate that the influence of diatomaceous earth on leaf area was significant at all the stages of crop growth except one MAP.

During one MAP, the maximum leaf area (0.05 m²) was recorded in T₁₀, T₈, T₇, T₅, T₃ and T₂ whereas; minimum leaf area (0.04 m²) was recorded in T₁, T₄, T₆ and T₉. However, the data was statistically non-significant.

At two MAP, maximum leaf area (0.34 m²) was noticed in T₁₀ (RDF + 750 kg/ha of DE) which was statistically on par with T₉ (0.32 m²), T₈ (0.30 m²) and T₂ (0.28 m²) followed by T₇ (0.26 m²), T₆ (0.25 m²) and T₅ (0.24 m²), while the minimum leaf area (0.19 m²) was recorded in T₄ (DE alone).

The results showed that the values for leaf area at both three and four MAP were showed similar pattern. The maximum leaf area (1.73 m² and 3.47 m²) was observed in T₁₀ (RDF + 750 kg/ha of DE) at three and four MAP, respectively, which was followed by T₉ (1.39 m² and 3.10 m² at three and four MAP, respectively), T₈ (1.23 m² and 2.90 m² at three and four MAP, respectively) and T₂ (1.19 m² and 2.65 m² at three and four MAP, respectively) while minimum leaf area (0.45 m² and 1.49 m² at three and four MAP, respectively) was noticed in T₄ (DE alone).

During five MAP, maximum leaf area (5.05 m²) was noticed in the treatment T₁₀ (RDF + 750 kg/ha of DE) which was statistically on par with T₉ (4.74 m²), T₈ (4.67 m²) and T₂ (4.52 m²) followed by T₇ (4.15 m²), T₆ (4.02 m²) and T₅ (3.84 m²), while the minimum leaf area (3.14 m²) was recorded in T₄ (DE alone).

At six MAP, maximum leaf area (7.21 m²) was noticed in T₁₀ (RDF + 750 kg/ha of DE) which was statistically on par with T₉ (7.05 m²), T₈ (6.98 m²), T₂ (6.76 m²) and T₇ (6.15 m²) followed by T₆ (5.81 m²) and T₅ (5.47 m²), while the minimum leaf area (4.02 m²) was recorded in T₄ (DE alone).

Table 4: Influence of Diatomaceous Earth on leaf area (m²) of banana

Treatment	Leaf area (m ²)								
	Months after planting								
	1	2	3	4	5	6	7	8	9
T ₁ - Absolute control	0.04	0.17	0.49	1.51	3.15	4.11	4.89	6.34	8.89
T ₂ - Recommended dose of fertilizers	0.05	0.28	1.19	2.65	4.52	6.76	8.47	12.24	14.74
T ₃ -Half of Recommended dose of fertilizers	0.05	0.22	0.87	2.19	3.61	5.38	6.85	10.14	12.41
T ₄ - DE alone	0.04	0.19	0.45	1.49	3.14	4.02	4.54	6.24	8.52
T ₅ - Half of RDF+DE @ 250 kg/ha	0.05	0.24	0.94	2.37	3.84	5.47	7.04	10.42	13.20
T ₆ - Half of RDF+ DE @ 500 kg/ha	0.04	0.25	0.97	2.45	4.02	5.81	7.31	10.93	13.88
T ₇ - Half of RDF+ DE @ 750 kg/ha	0.05	0.26	0.99	2.52	4.15	6.15	7.44	11.20	14.29
T ₈ - RDF+ DE @ 250 kg/ha	0.05	0.30	1.23	2.90	4.67	6.98	9.22	12.52	15.08
T ₉ - RDF+ DE @ 500 kg/ha	0.04	0.32	1.39	3.10	4.74	7.05	9.93	13.17	15.54
T ₁₀ - RDF+ DE @ 750 kg/ha	0.05	0.34	1.73	3.47	5.05	7.21	10.25	13.42	16.49
SEm±	0.01	0.02	0.08	0.15	0.24	0.41	0.44	0.62	0.82
C.D (0.05)	NS	0.06	0.25	0.45	0.73	1.22	1.30	1.85	2.45

RDF-Recommended dose of fertilizers

After seven MAP, maximum leaf area (10.25 m²) was noticed in T₁₀ (RDF + 750 kg/ha of DE) which was statistically on par with T₉ (9.93 m²), T₈ (9.22 m²) followed by T₂ (8.47 m²), T₇ (7.44 m²), T₆ (7.31 m²) and T₅ (7.04 m²), while the minimum leaf area (4.54 m²) was recorded in T₄ (DE alone).

Values recorded at eight MAP, showed a significant variation for leaf area. The maximum leaf area (13.42 m²) was observed in T₁₀ (RDF + 750 kg/ha of DE) which was statistically on par with T₉ (13.17 m²), T₈ (12.52 m²) and T₂ (12.24 m²) followed by T₇ (11.20 m²), T₆ (10.93 m²) and T₅ (10.42 m²) while minimum leaf area (6.24 m²) was noticed in T₄ (DE alone).

The observations recorded for leaf area during nine MAP have differed significantly. The maximum leaf area (16.49 m²) was observed in T₁₀ (RDF + 750 kg/ha of DE) which was statistically on par with T₉ (15.54 m²), T₈ (15.08 m²), T₂ (14.74 m²) and T₇ (14.29 m²) followed by T₆ (13.88 m²) and T₅ (13.20 m²) while minimum leaf area (8.52 m²) was noticed in T₄ (DE alone).

4.1.5 Chlorophyll content

The data on the Chlorophyll content was influenced by diatomaceous earth on banana are presented in Table 5.

The perusal of the data indicates that, the influence of diatomaceous earth on chlorophyll content was significant at five MAP and at the time of harvesting. There was significant variation for chlorophyll content of the leaves among the treatments at five MAP and at the time of harvesting.

4.1.5.1 Chlorophyll 'a' (mg/ g of tissue)

At five MAP, the highest values for chlorophyll 'a' content (1.75 mg/g) was recorded in T₁₀ (RDF + 750 kg/ha of DE) which was followed by T₉ (1.65 mg/g), T₈ (1.54 mg/g) and T₇ (1.52 mg/g), while least values T₁ (0.65 mg/g) were recorded in T₁ (absolute control). However, chlorophyll 'a' content was significantly increased at the time of harvesting. Significantly highest chlorophyll 'a' content (1.74 mg/g) was recorded in T₁₀ (RDF + 750 kg/ha of DE) which was on par with T₉ (1.74 mg/g), followed by the treatment T₈ (1.66 mg/g), T₇ (1.54 mg/g) and T₂ (1.40 mg/g), while least values (0.79 mg/g) were recorded in T₁.

Table 5: Influence of Diatomaceous Earth on chlorophyll content of banana crop

Treatments	Chlorophyll content of leaf (mg/g)					
	5 Months after planting			At the time of harvesting		
	Chlorophyll a	Chlorophyll b	Total chlorophyll	Chlorophyll a	Chlorophyll b	Total chlorophyll
T ₁ - Absolute control	0.65	0.24	0.89	0.79	0.24	0.93
T ₂ - RDF*	1.30	0.43	1.73	1.40	0.43	1.83
T ₃ -Half of RDF	1.12	0.29	1.41	1.19	0.29	1.48
T ₄ - D.E alone	0.69	0.25	0.94	0.82	0.25	1.07
T ₅ - Half of RDF+DE @ 250 kg/ha	1.25	0.32	1.57	1.26	0.32	1.68
T ₆ - Half of RDF+ DE @ 500 kg/ha	1.28	0.38	1.66	1.32	0.38	1.70
T ₇ - Half of RDF+ DE @ 750 kg/ha	1.52	0.48	2.00	1.54	0.48	2.02
T ₈ - RDF+ DE @ 250 kg/ha	1.54	0.63	2.17	1.66	0.63	2.29
T ₉ - RDF+ DE @ 500 kg/ha	1.65	0.68	2.33	1.74	0.82	2.56
T ₁₀ - RDF+ DE @ 750 kg/ha	1.75	0.64	2.39	1.74	0.78	2.52
S. Em±	0.03	0.03	0.03	0.01	0.05	0.06
C.D (0.05)	0.08	0.06	0.16	0.03	0.14	0.17

RDF-Recommended dose of fertilizers

4.1.5.2 Chlorophyll 'b' (mg/g of tissue)

The chlorophyll 'b' content increased at 5 MAP. The significantly highest chlorophyll 'b' content (0.68 mg/g) was recorded in T₉ (RDF + 500 kg/ha DE) which was on par with T₁₀ (0.64 mg/g), followed by T₈ (0.48 mg/g), T₂ (0.43 mg/g) and T₆ (0.38 mg/g), whereas the least chlorophyll 'b' content (0.24 mg/g) was found in T₁.

At the time of harvesting, the chlorophyll 'b' content has increased significantly in all the treatments. The significantly highest chlorophyll 'b' content was found in T₉ (0.82 mg/g) which was on par with T₁₀ (0.78mg/g) followed by T₈ (0.63 mg/g), T₇ (0.48mg/g) and T₂ (0.43 mg/g), while least chlorophyll 'b' content (0.24 mg/g) was recorded in T₁.

4.1.5.3 Total chlorophyll (mg/g of tissue)

The data on the effect of diatomaceous earth on total chlorophyll was recorded during five MAP and at the time of harvesting and is presented in Table 5.

A significant difference in the total chlorophyll content was observed. During five MAP, the highest total chlorophyll content was recorded in T₁₀ (2.39 mg/g) which was on par with T₉ (2.33 mg/g) followed by T₈ (2.17 mg/g), T₇ (2.00 mg/g) and T₂ (2.40 mg/g) while the lowest value (0.89 mg/g) was recorded in T₁ (Absolute control).

Significantly highest total chlorophyll content was found in T₉ (2.56 mg/g) which was on par with T₁₀ (2.52 mg/g) followed by T₈ (2.29 mg/g), T₇ (2.02 mg/g) and T₂ (1.83 mg/g) whereas the lowest total chlorophyll content (0.93 mg/g) was recorded in T₁.

The plants which were applied with diatomaceous earth have showed significantly superior results for chlorophyll 'a', chlorophyll 'b' and total chlorophyll.

4.1.6 Number of suckers

The data on the effect of diatomaceous earth on number of suckers produced were significant among treatments from four MAP to nine MAP and is presented in Table 6.

Table 6: Influence of Diatomaceous Earth on number of suckers in banana

Treatment	Number of suckers					
	Months after planting					
	4	5	6	7	8	9
T ₁ - Absolute control	1.31	1.74	2.28	2.50	2.88	3.39
T ₂ - Recommended dose of fertilizers	2.06	2.54	3.30	3.51	4.14	4.97
T ₃ - Half of Recommended dose of fertilizers	1.72	2.17	2.83	3.10	3.49	3.90
T ₄ - DE alone	1.34	1.62	2.24	2.42	2.93	3.44
T ₅ - Half of RDF+DE @ 250 kg/ha	1.94	2.28	2.83	3.17	3.72	4.01
T ₆ - Half of RDF+ DE @ 500 kg/ha	2.11	2.37	3.00	3.27	3.96	4.22
T ₇ - Half of RDF+ DE @ 750 kg/ha	2.26	2.61	3.13	3.22	4.03	4.42
T ₈ - RDF+ DE @ 250 kg/ha	2.11	2.57	2.94	3.55	4.29	4.93
T ₉ - RDF+ DE @ 500 kg/ha	2.22	2.56	3.22	3.72	4.28	5.14
T ₁₀ - RDF+ DE @ 750 kg/ha	2.43	2.79	3.44	4.02	4.44	5.39
SEm±	0.20	0.16	0.24	0.17	0.25	0.27
C.D (0.05)	0.59	0.48	0.72	0.51	0.74	0.79

RDF-Recommended dose of fertilizers

During four MAP, highest number of suckers produced (2.43) was noticed in T₁₀ (RDF + 750 kg/ha DE) which was on par with T₇ (2.26), T₉ (2.22), T₈ (2.11), T₆ (2.11), T₂ (2.06) and T₅ (1.94) while the least number of suckers (1.31) was produced in T₁ (Absolute control).

At five MAP, maximum number of suckers (2.79) was noticed in T₁₀ (RDF + 750 kg/ha DE) which was on par with T₇ (2.61), T₈ (2.57), T₉ (2.56), T₂ (2.54) and T₆ (2.37) while the least number of suckers (1.62) was produced in T₄ (DE alone).

After six MAP, maximum number of suckers (3.44) was noticed in T₁₀ (RDF + 750 kg/ha DE) which was on par with T₂ (3.30), T₉ (3.22), T₇ (3.13), T₆ (3.00), T₈ (2.94), T₅ (2.83) and T₃ (2.83) while the minimum number of suckers (2.24) was produced in T₄. During seven MAP, maximum number of suckers (4.02) was noticed in T₁₀ (RDF + 750 kg/ha DE) which was on par with T₉ (3.72), T₈ (3.55) and T₂ (3.51) followed by T₆ (3.27), T₇ (3.22) and T₅ (3.17) while the minimum number of suckers (2.42) was produced in T₄.

During eight MAP, highest number of suckers (4.44) was noticed in T₁₀ (RDF + 750 kg/ha DE) which was on par with T₈ (4.29), T₉ (4.28), T₂ (4.14), T₇ (4.03), T₆ (3.96) and T₅ (3.72), while the least number of suckers (2.88) was produced in T₁ (Absolute control). However during nine MAP, highest numbers of suckers (5.39) was noticed in T₁₀ (RDF + 750 kg/ha DE) which were on par with T₉ (5.14), T₂ (4.97) and T₈ (4.93) while the least number of suckers (3.39) was produced in T₁ (Absolute control).

4.2 Nutrient status of leaf at six MAP (3rd leaf)

Effect of different treatments on nutrient status of third leaf at six MAP *viz.*, nitrogen, phosphorus, potassium, magnesium, calcium, zinc, iron, copper, and silica is presented in Table 7.

The data showed significant results among treatments for P, K, Mg, Ca, Zn and Si, whereas in case of N and Cu data found non-significant.

4.2.1 Nitrogen (%)

There was a non significant difference obtained among the different treatments with reference to nitrogen content in banana leaf. However highest nitrogen content

Table 7: Influence of Diatomaceous Earth on leaf nutrient status of banana

Treatments	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Zn (ppm)	Cu (ppm)	Fe (ppm)	Si (%)
T ₁ - Absolute control	3.86	0.40	1.09	1.05	0.55	9.50	8.85	136.13	0.80
T ₂ - RDF*	3.40	0.42	1.02	0.71	0.34	10.50	9.00	60.60	0.70
T ₃ - Half of Recommended dose of fertilizer	3.37	0.40	1.13	1.10	0.51	8.95	12.45	151.30	0.56
T ₄ - D.E alone	2.94	0.42	1.12	0.90	0.44	9.45	8.30	70.65	1.17
T ₅ - Half of RDF+DE @ 250 kg/ha	3.34	0.45	0.96	1.02	0.45	8.75	8.90	57.45	0.66
T ₆ - Half of RDF+ DE @ 500 kg/ha	3.31	0.42	0.95	0.76	0.38	9.00	9.30	76.75	0.75
T ₇ - Half of RDF+ DE @ 750 kg/ha	3.28	0.40	1.03	0.73	0.30	8.20	8.45	55.55	0.76
T ₈ - RDF+ DE @ 250 kg/ha	3.15	0.37	1.03	0.73	0.31	7.35	8.40	96.90	0.86
T ₉ - RDF+ DE @ 500 kg/ha	3.11	0.47	1.52	1.04	0.53	9.90	10.25	64.80	0.70
T ₁₀ - RDF+ DE @ 750 kg/ha	3.21	0.47	1.74	0.86	0.36	8.80	10.25	60.95	1.26
C.D (0.05)	NS	0.03	0.31	0.21	0.12	1.61	NS	59.69	0.07

RDF-Recommended dose of fertilizers NS-Non significant

(3.86%) was observed in T₁ whereas lowest nitrogen content (2.94%) was found with T₄ (DE alone).

4.2.2 Phosphorous (%)

The leaf content of phosphorus varied significantly among the different treatments. Highest phosphorus content (0.47%) in the 3rd leaf was observed in both T₁₀ (RDF + 750 kg/ha of DE) and T₉ (RDF + 750 kg/ha of DE) which were on par with T₅ (0.45%) followed by T₆ (0.42%), T₄ (0.42%) and T₂ (0.42%), while minimum phosphorous content (0.37%) was observed in T₈ (RDF + 250 kg/ha of DE).

4.2.3 Potassium (%)

There was a significant difference among the different treatments with respect to potassium content of the leaf. The maximum potassium content (1.74%) was observed in leaves which received full dose of RDF + 750 kg/ha of DE *i.e.* T₁₀ which was on par with T₉ (1.52) followed by T₃ (1.13%), T₄ (1.12%) and T₁ (1.09) while minimum potassium content (0.95%) was observed in T₆.

4.2.4 Calcium (%)

There was a significant difference among the different treatments with respect to calcium content of the leaf. The maximum calcium content (1.10%) was observed in T₃ (half dose RDF) which was on par with T₁ (1.05%), T₉ (1.04%), T₅ (1.02%) and T₄ (0.90%) followed by T₁₀ (0.86%) and T₆ (0.76%) while minimum calcium content (0.71%) was observed in T₂.

4.2.5 Magnesium (%)

It was observed that there was a significant difference between the treatments. Among the treatments, T₁ (Absolute control) recorded highest (0.55%) leaf magnesium content which was on par with T₉ (0.53%), T₃ (0.51%), T₅ (0.45%) and T₄ (0.44%) followed by T₆ (0.38%), T₁₀ (0.36%) and T₂ (0.34%) while minimum magnesium content (0.30%) was observed in T₇.

4.2.6 Zinc (ppm)

There was a significant difference among the different treatments with respect to zinc content of leaf. The maximum zinc content (10.50%) was observed in leaves

which received full dose RDF *i.e.* T₂ which was on par with T₉ (9.90%), T₁ (9.50%), T₄ (9.45%), T₆ (9.00%) and T₃ (8.95%) followed by T₁₀ (8.80%) and T₅ (8.75%) while minimum zinc content (7.35%) was observed in T₈.

4.2.7 Copper (ppm)

There was a non significant difference obtained among the different treatments with reference to copper content in banana leaf.

4.2.8 Iron (ppm)

The data renders significant difference on iron content in the leaf. Among the treatments the maximum iron composition in leaf (151.30ppm) was noticed in T₃ (half RDF) which was on par with T₁ (136.13 ppm) and T₈ (96.90ppm) whereas the minimum iron composition in leaf (55.55ppm) was found in T₇ (Half of RDF + 750 kg/ha DE).

4.2.9 Silicon (%)

There was a significant difference among the different treatments with respect to silicon content of leaf. The maximum silicon content (1.26%) was observed in leaves which received RDF + 750 kg/ha of DE *i.e.* T₁₀ which was followed by T₄ (1.17%), T₈ (0.86%), T₁ (0.80%), T₇ (0.76%) and T₆ (0.75%) while minimum silicon content (0.56%) was observed in T₃.

4.3 Crop duration

The Table 8 depicts the effect of diatomaceous earth on crop duration (Days taken for flowering after planting, days taken for flowering to harvest and total crop duration).

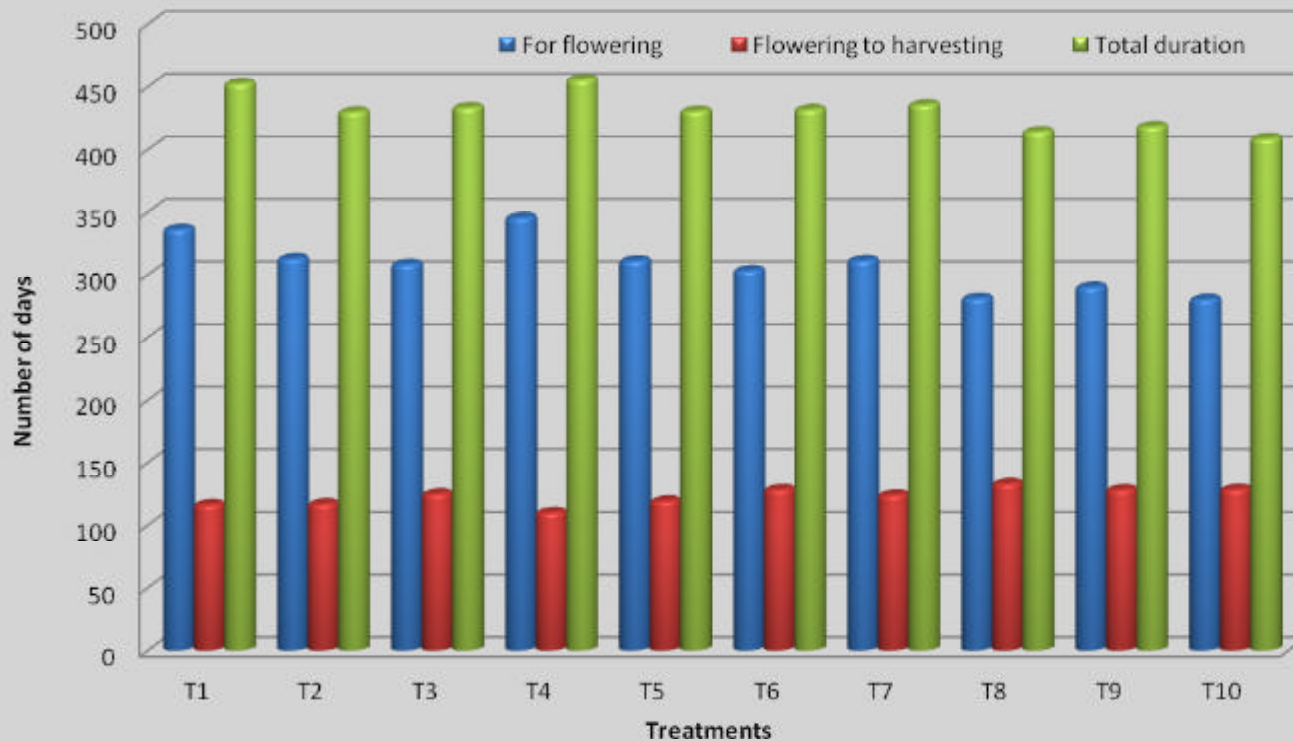
4.3.1 Days taken for flowering after planting

The data pertaining to days taken for flowering after planting were found to differ significantly among the treatments. An early flowering (280.33 days) was recorded in T₁₀ (RDF + 750 kg/ha of DE) and maximum days taken for flowering (345.61 days) was noticed in T₄ (DE alone).

Table 8: Influence of Diatomaceous Earth on crop duration of banana

Treatments	Number of days taken		
	For flowering	Flowering to harvesting	Total duration
T ₁ - Absolute control	336.25	116.41	452.66
T ₂ - RDF	312.94	117.08	430.02
T ₃ - Half of Recommended dose of fertilizer	308.5	124.97	433.47
T ₄ - D.E alone	345.61	110.16	455.77
T ₅ - Half of RDF+DE @ 250 kg/ha	311.33	119.33	430.66
T ₆ - Half of RDF+ DE @ 500 kg/ha	303.5	128.41	431.91
T ₇ - Half of RDF+ DE @ 750 kg/ha	311.58	124.11	435.69
T ₈ - RDF+ DE @ 250 kg/ha	281.11	133.14	414.25
T ₉ - RDF+ DE @ 500 kg/ha	290.07	128.25	418.32
T ₁₀ - RDF+ DE @ 750 kg/ha	280.33	128.61	408.94
S.Em±	12.04	N.S	7.43
C.D (0.05)	35.79		22.07

RDF-Recommended dose of fertilizers



- T₁ – Absolute control
- T₂ – Recommended dose of fertilizers
- T₃ – Half of Recommended dose of fertilizers
- T₄ – DE alone
- T₅ – Half of RDF+DE @ 250 kg/ha
- T₆ – Half of RDF+ DE @ 500 kg/ha
- T₇ – Half of RDF+ DE @ 750 kg/ha
- T₈ – RDF+ DE @ 250 kg/ha
- T₉ – RDF+ DE @ 500 kg/ha
- T₁₀ – RDF+ DE @ 750 kg/ha

Fig. 2: Influence of Diatomaceous Earth on crop duration of banana

4.3.2 Days taken to harvest from flowering

There was a non significant difference obtained among the different treatments with reference to days taken to harvest from flowering. However minimum days taken for harvest from flowering (110.16 days) was observed in T₄, whereas maximum days taken for harvest from flowering (133.14 days) was noticed in T₈ (RDF + 250 kg/ha of DE)

4.3.3 Total crop duration

The total crop duration differed significantly among the different treatments. The treatment T₁₀ (RDF + 750 kg/ha of DE) recorded the early crop duration (408.94 days) which was on par with T₈ (414.25 days), T₉ (418.32 days), T₂ (430.02 days) and T₅ (430.66 days) followed by T₆ (431.91 days) and T₃ (433.47 days), while delayed crop duration (455.77 days) was noticed in T₄ (DE alone).

4.4 Bunch characteristics

The data pertaining to bunch characters *viz.*, bunch length, bunch width, number of hands per bunch, number of fingers per hand and total number of fingers per bunch as influenced by different dose of Diatomaceous Earth presented in Table 9 and Plate 3.

4.4.1 Bunch length (cm)

The influence of different treatments of diatomaceous earth on length of bunch was significant in banana. The maximum bunch length (90.65 cm) was observed in T₁₀ (RDF + 750 kg/ha DE) which was statistically on par with T₉ (85.01 cm) followed by T₈ (81.64 cm), T₆ (77.36 cm), T₂ (77.35 cm) and T₇ (76.37 cm). On the contrary, minimum bunch length (65.25 cm) was observed in T₃ (half RDF).

4.4.2 Bunch width (cm)

The influence of different treatments of diatomaceous earth on width of bunch was significant in banana. The maximum bunch width (44.87 cm) was observed in T₁₀ (RDF + 750 kg/ha DE) which was statistically on par with T₉ (44.62 cm), T₈ (42.83), T₆ (42.68), T₂ (42.66) and T₅ (42.04 cm) followed by T₃ (37.90 cm), while the minimum bunch width (35.17 cm) was observed in T₁ (Absolute control).

Table 9: Influence of Diatomaceous Earth on bunch characters of banana

Treatments	Bunch length (cm)	Bunch width (cm)	Number of hands per bunch	Number of fingers in 3 rd hand	Total number of fingers per bunch
T ₁ - Absolute control	66.31	35.17	8.16	14.87	110.50
T ₂ - RDF	77.35	42.66	9.40	17.56	158.53
T ₃ - Half of Recommended dose of fertilizer	65.25	37.90	8.64	16.22	142.43
T ₄ - D.E alone	68.14	35.91	8.18	17.40	159.55
T ₅ - Half of RDF+DE @ 250 kg/ha	70.53	42.04	9.59	17.79	154.97
T ₆ - Half of RDF+ DE @ 500 kg/ha	77.36	42.68	8.93	18.23	158.39
T ₇ - Half of RDF+ DE @ 750 kg/ha	76.37	41.44	9.45	17.98	166.17
T ₈ - RDF+ DE @ 250 kg/ha	81.64	42.83	13.43	18.90	177.80
T ₉ - RDF+ DE @ 500 kg/ha	85.01	44.62	10.56	20.67	189.22
T ₁₀ - RDF+ DE @ 750 kg/ha	90.65	44.87	11.58	20.97	201.86
S.Em±	2.92	1.51	1.04	0.58	6.86
CD (0.05)	8.66	4.47	3.08	1.70	20.38

RDF-Recommended dose of fertilizers

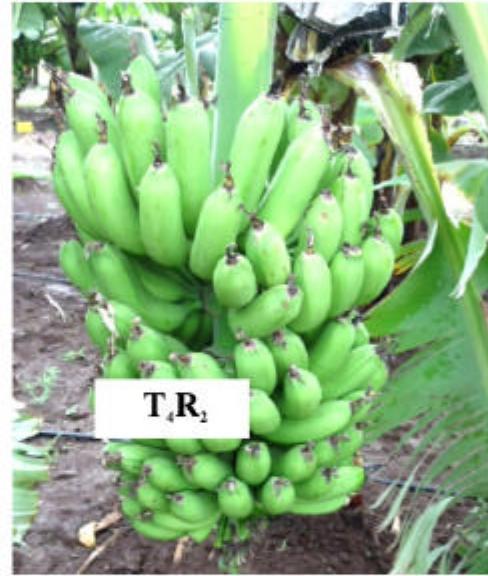
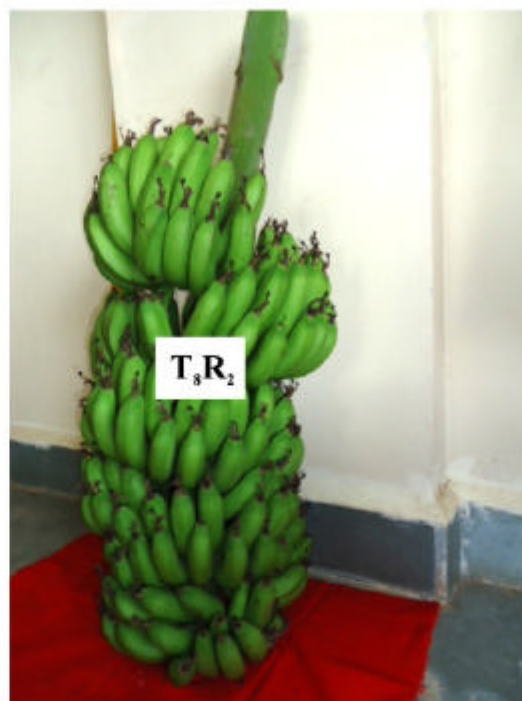


Plate 3: Bunches of banana crop with different Diatomaceous Earth treatments

Plate 3 contd...



4.4.3 Number of hands per bunch

Influence of diatomaceous earth was significantly differed among the different treatments with respect to number of hands per bunch. Significantly higher number of hands per bunch (13.43) was recorded in T₈ (RDF + 250 kg/ha DE) which was statistically on par with T₁₀ (11.58) and T₉ (10.56) followed by T₅ (9.59), T₇ (9.45) and T₂ (9.40). On the contrary, minimum number of hands per bunch (8.16) was observed in T₁ (Absolute control) (Plate 4).

4.4.4 Number of fingers per hand (3rd)

Influence of diatomaceous earth was significantly differed among the different treatments with respect to number of fingers per third hand. The maximum number of fingers in third hand (20.97) was recorded in T₁₀ (RDF + 750 kg/ha DE) which was on par with T₉ (20.67) followed by T₈ (18.90), T₆ (18.23) and T₇ (17.98), while the minimum number of fingers per hand (14.87) was noticed in T₁ (Absolute control).

4.4.5 Number of fingers per bunch

There was a significant difference among the different treatments as far as total number of fingers per bunch is concerned. The treatment T₁₀ (RDF + 750 kg/ha DE) has showed maximum number of finger per bunch (201.86) which was on par with T₉ (189.22) followed by T₈ (177.80), T₇ (166.17) and T₄ (159.55), while the lower number of fingers per bunch (110.50) was observed when plants were applied with no fertilizer.

4.5 Finger characteristics

The effect of Diatomaceous Earth applied to soil on finger characteristics such as finger weight, finger girth, finger volume, finger length, pulp weight, peel weight and pulp to peel ratio is presented in Table 10.

4.5.1 Finger weight (g)

There was a significant difference among the different treatments as far as finger weight is concerned. The plants receiving full dose of RDF + 750 kg/ha DE *i.e.* treatment T₁₀ has showed the maximum finger weight (145.19 g) which was on par

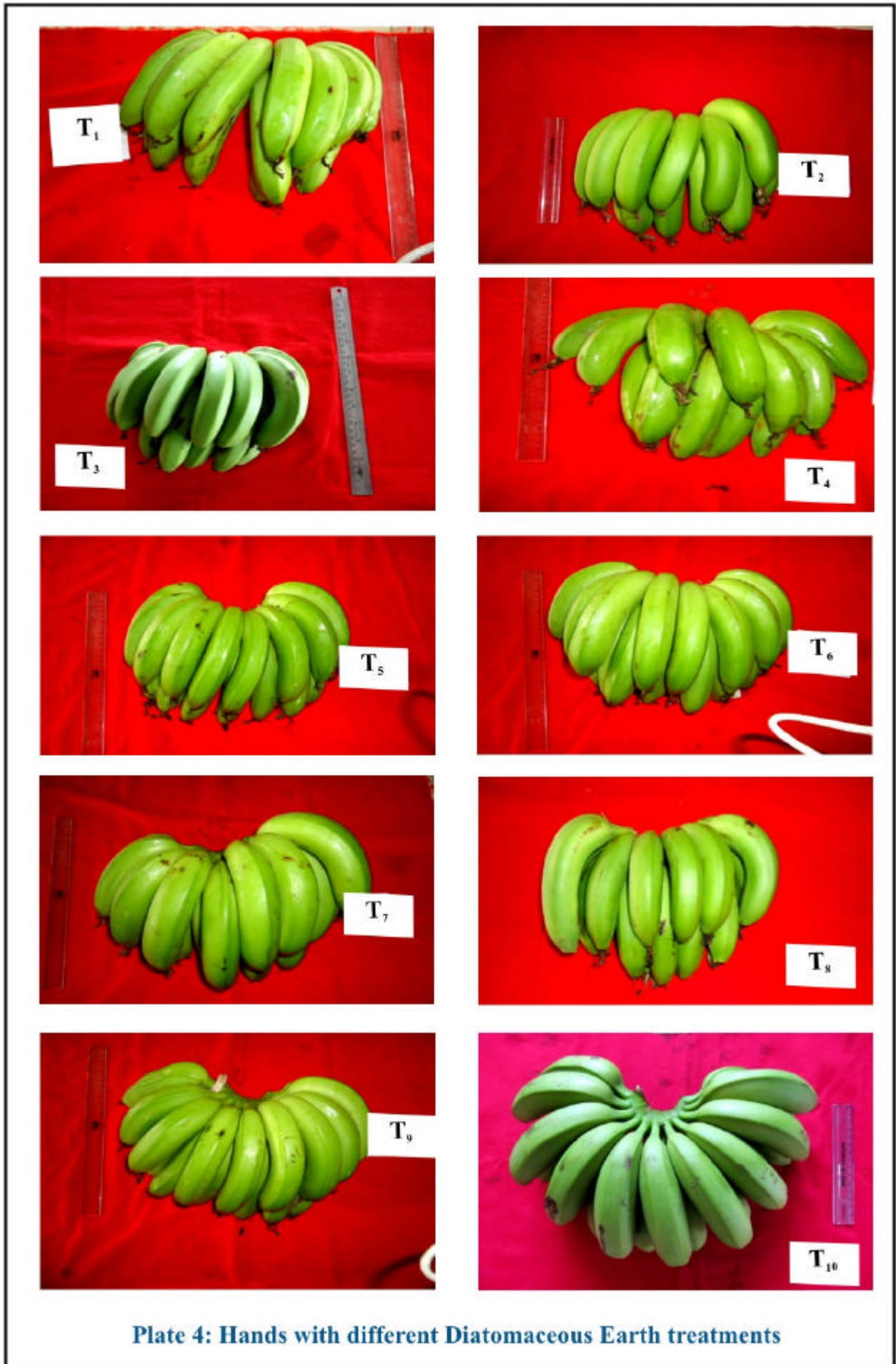
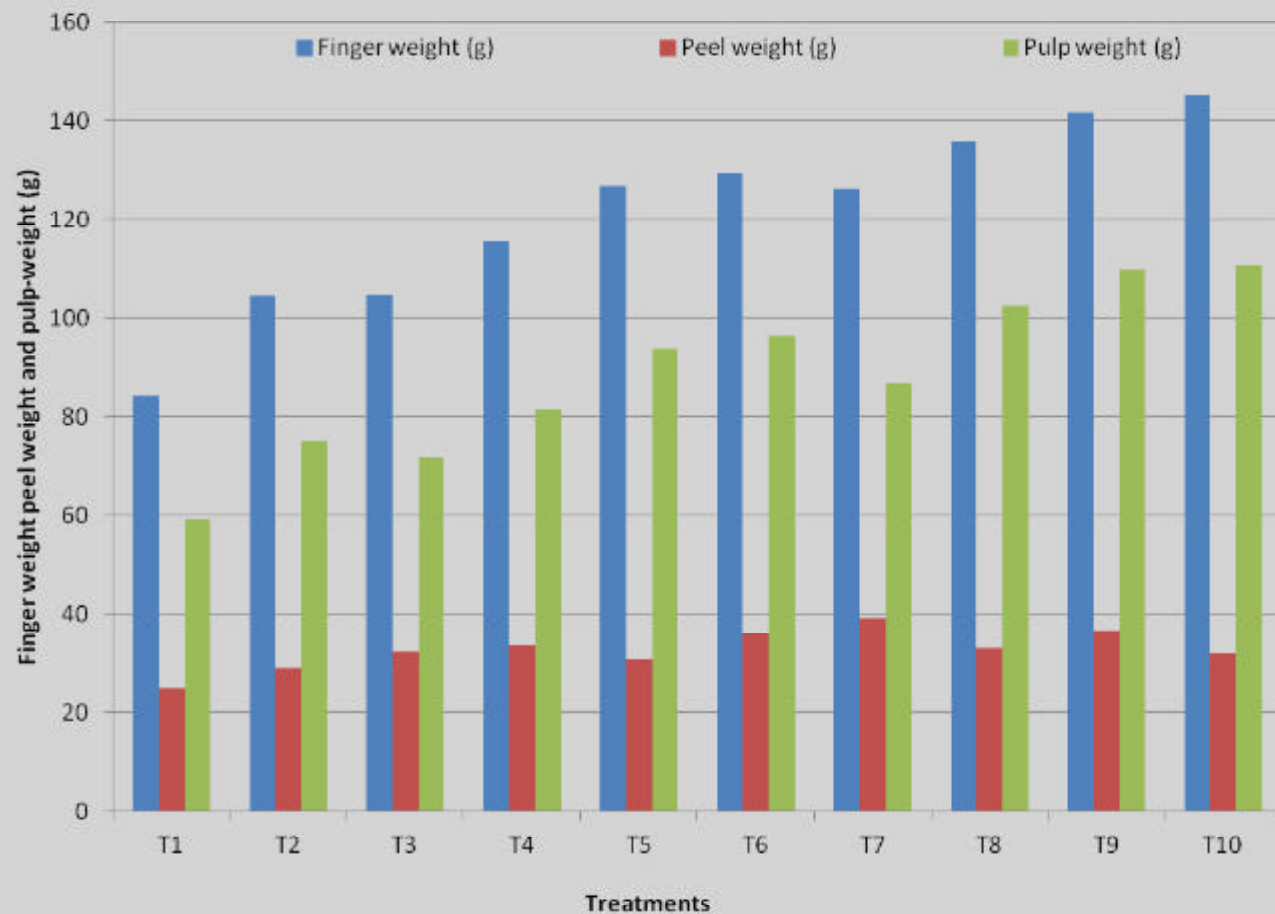


Table 10: Influence of Diatomaceous Earth on finger characteristics of banana

Treatments	Finger weight (g)	Finger length (cm)	Finger girth (cm)	Finger volume (ml)	Peel weight (g)	Pulp weight (g)	Pulp to peel ratio
T ₁ - Absolute control	84.16	12.99	3.44	96.57	25.06	59.13	2.35
T ₂ - RDF	104.42	14.92	3.56	118.25	29.08	75.07	2.63
T ₃ - Half of Recommended dose of fertilizer	104.79	13.64	3.38	112.01	32.27	71.99	2.22
T ₄ - D.E alone	115.65	13.93	3.29	113.06	33.64	81.60	2.42
T ₅ - Half of RDF+DE @ 250 kg/ha	126.83	14.67	3.47	119.44	30.90	93.88	3.09
T ₆ - Half of RDF+ DE @ 500 kg/ha	129.42	15.42	3.28	129.28	36.07	96.40	2.67
T ₇ - Half of RDF+ DE @ 750 kg/ha	126.23	16.17	3.42	132.85	39.23	86.87	2.21
T ₈ - RDF+ DE @ 250 kg/ha	135.88	17.56	3.63	136.55	33.08	102.58	3.14
T ₉ - RDF+ DE @ 500 kg/ha	141.67	18.73	3.75	136.83	36.60	109.96	3.01
T ₁₀ - RDF+ DE @ 750 kg/ha	145.19	22.51	3.73	138.51	32.23	110.96	3.52
S.Em±	4.73	0.87	0.07	4.96	1.85	5.23	0.18
CD (0.05)	14.08	2.59	0.23	14.72	5.50	15.56	0.52

RDF-Recommended dose of fertilizers



- T₁ – Absolute control
- T₂ – Recommended dose of fertilizers
- T₃ – Half of Recommended dose of fertilizers
- T₄ – DE alone
- T₅ – Half of RDF+DE @ 250 kg/ha
- T₆ – Half of RDF+ DE @ 500 kg/ha
- T₇ – Half of RDF+ DE @ 750 kg/ha
- T₈ – RDF+ DE @ 250 kg/ha
- T₉ – RDF+ DE @ 500 kg/ha
- T₁₀ – RDF+ DE @ 750 kg/ha

Fig. 3: Influence of Diatomaceous Earth on finger characteristics of banana

with T₉ (141.67 g) and T₈ (135.88 g) followed by T₆ (129.42 g), T₅ (126.83 g) and T₇ (126.23 g) while the minimum finger weight (84.16 g) was noticed in T₁.

4.5.2 Finger length (cm)

The finger length varied significantly among the different treatments. The maximum finger length (22.51 cm) was found in T₁₀ (RDF + 750 kg/ha DE) which was followed by T₉ (18.73 cm), T₈ (17.56 cm), T₇ (16.17) and T₆ (15.42 cm) while the minimum finger length (12.99 cm) was recorded in T₁.

4.5.3 Finger girth (cm)

The finger girth varied significantly among the different treatments. The highest finger girth (3.75 cm) was observed in T₉ (RDF + 500 kg/ha of DE) which was on par with T₁₀ (3.73 cm), T₈ (3.63) and T₂ (3.56) followed by T₅ (3.47 cm), T₁ (3.44 cm) and T₇ (3.42 cm) while the minimum finger girth (3.28 cm) was noticed in T₆.

4.5.4 Finger volume (ml)

Response of diatomaceous earth was significantly differed among the different treatments with respect to finger volume. The maximum finger volume (138.51 ml) was recorded in T₁₀ (RDF + 750 kg/ha of DE) which was on par with T₉ (136.83 ml), T₈ (136.55), T₇ (132.85) and T₆ (129.28 ml) while the minimum finger volume (96.57 ml) was noticed in T₁.

4.5.5 Pulp weight (g)

Effect of diatomaceous earth on pulp weight varied significantly among the different treatments. The highest pulp weight (110.96 g) was observed in T₁₀ (RDF + 750 kg/ha of DE) which was on par with T₉ (109.96 g), T₈ (102.58 g) and T₆ (96.40 g) followed by T₅ (93.88 g), T₇ (86.87 g) and T₄ (81.60 g), while the lowest pulp weight (59.13 g) was observed in T₁.

4.5.6 Peel weight (g)

The response of diatomaceous earth on peel weight varied significantly among the different treatments. The highest peel weight (39.23 g) was noticed in T₇ (Half of

RDF + 750 kg/ha of DE) which was on par with the treatment T₉ (36.60 g) and T₆ (36.07 g) followed by T₄ (33.64 g), T₈ (33.08 g) and T₃ (32.27 g) while the lowest peel weight (25.06 g) was noticed in T₁.

4.5.7 Pulp to Peel ratio

The results of diatomaceous earth on pulp to peel ratio varied significantly among the different treatments. The maximum pulp to peel ratio (3.52) was noticed in T₁₀ (RDF + 750 kg/ha DE) which was on par with T₈ (3.14), T₅ (3.09), T₉ (3.01), T₆ (2.67) and T₂ (2.63) while the minimum pulp to peel ratio was noticed in T₇ (2.21).

4.6 Quality parameters

Quality parameters *viz.*, days taken for ripening, shelf life, total soluble solids (TSS), acidity, reducing sugar, non-reducing sugar, total sugars, sugars to acid ratio and ascorbic acid content as influenced by diatomaceous earth on banana is presented in Table 11.

4.6.1 Days for ripening (days)

The perusal of the data indicates that the impact of diatomaceous earth on days for ripening was significant among the different treatments. The maximum number of days (9.55days) required for ripening was noticed in T₉ (RDF + 500 kg/ha DE) which was statistically on par with T₁₀ (9.41days), followed by T₈ (9.22days), T₇ (9.20days) and T₂ (9.08 days), while the minimum number of days (6.43 days) required for ripening were noticed in T₁ (Absolute control).

4.6.2 Shelf life (days)

The observations on shelf life showed significant variation among the treatments. The plants receiving RDF + 500 kg/ha of DE *i.e.* T₉ has recorded more shelf life (5.78days) which was followed by T₁₀ (5.36days), T₈ (5.23days) and T₇ (5.09days), while the less shelf life (3.50days) was noticed when the plants applied with T₅ *i.e.* half dose of RDF.

Table 11: Influence of Diatomaceous Earth on fruit quality parameters of banana

Treatments	Days taken for ripening	Shelf life(days)	TSS (°Brix)	Acidity (%)	Sugar: acid ratio	Reducing sugar (%)	Non reducing sugar (%)	Total sugars (%)
T ₁ - Absolute control	6.43	3.96	17.65	0.36	49.22	15.32	2.40	17.72
T ₂ - RDF	9.08	4.67	19.33	0.29	70.82	17.25	3.29	20.54
T ₃ - Half of RDF	6.77	3.50	17.94	0.34	54.82	15.94	2.33	18.64
T ₄ - D.E alone	6.75	4.16	18.31	0.32	58.43	16.33	2.37	18.70
T ₅ - Half of RDF+DE @ 250 kg/ha	8.25	4.19	19.51	0.30	63.56	16.34	2.72	19.07
T ₆ - Half of RDF+ DE @ 500 kg/ha	8.64	4.53	20.84	0.28	69.96	16.84	2.74	19.59
T ₇ - Half of RDF+ DE @ 750 kg/ha	9.20	5.09	20.56	0.30	71.30	17.55	3.84	21.39
T ₈ - RDF+ DE @ 250 kg/ha	9.22	5.23	20.99	0.28	78.92	18.57	3.53	22.10
T ₉ - RDF+ DE @ 500 kg/ha	9.55	5.78	22.06	0.25	90.68	19.11	3.72	22.67
T ₁₀ - RDF+ DE @ 750 kg/ha	9.41	5.36	22.70	0.21	117.23	20.81	3.81	24.62
S.Em±	0.21	0.13	0.84	0.06		0.19	0.07	0.22
C.D (0.05)	0.64	0.39	2.50	0.05		0.55	0.22	0.65

RDF-Recommended dose of fertilizers

4.6.3 Total soluble Solids (TSS)

There was a significant difference among the different treatments pertaining to TSS. The maximum TSS (22.70°B) was found when plants are applied with (RDF + 750 kg/ha DE) *i.e.* T₁₀ which was on par with T₉ (22.06 °B), T₈ (20.99 °B), T₆ (20.84 °B) and T₇ (20.56 °B) followed by the treatment T₅ (19.51 °B) and T₂ (19.33 °B) while the lowest TSS (17.65 °B) was observed in T₁.

4.6.4 Acidity (%)

The acidity varied significantly among the different treatments. The minimum acidity (0.21%) was found in T₁₀ (RDF + 750 kg/ha DE) which was on par with T₉ (0.25%) followed by the (0.28%) found in both in T₈ and T₆, T₂ (0.29%), and (0.30%) found in both in T₇ and T₅ while the maximum acidity (0.36%) was noticed in T₁.

4.6.5 Reducing sugars (%)

The reducing sugar varied significantly among the different treatments. Among the ten treatment, maximum content of reducing sugar (20.81%) was found in the fruits of T₁₀ (RDF + 750 kg/ha DE) which was followed by T₉ (19.11%), T₈ (18.57), T₇ (17.55), T₆ (16.84) and T₅ (16.34%) while the minimum content of reducing sugar (15.32%) was noticed in T₁.

4.6.6 Non-reducing sugar (%)

There was a significant difference among the different treatments pertaining to non-reducing sugar. Highest quantity of non-reducing sugar (3.84%) was found in the fruits of T₇ (Half of RDF + 750 kg/ha DE) which was on par with T₁₀ (3.81%) and T₉ (3.72%) followed by the treatment T₈ (3.53%), T₂ (3.29%) and T₆ (2.74%) while the least content of reducing sugar (2.33%) was noticed in T₃.

4.6.7 Total sugar (%)

The effects of diatomaceous earth on total sugars varied significantly among different treatments. Maximum content of total sugar (24.62%) was found in the fruits of T₁₀ (RDF + 750 kg/ha DE) which was followed by T₉ (22.67%), T₈ (22.10%), T₇ (21.39%) and T₂ (20.54) while the minimum content of total sugar (17.72%) was noticed in T₁.

4.7 Yield characteristics

The effect of diatomaceous earth on yield characteristics, *viz.*, bunch weight, yield per plot and yield per hectare is presented in Table 12.

4.7.1 Bunch weight (kg/plant)

There was a significant difference among the different treatments with regard to bunch weight. The plants which were applied with full dose of RDF + 750 kg/ha of DE *i.e.* treatment T₁₀ has showed maximum bunch weight (20.86 kg) which was on par with of T₈ (20.76 kg), T₉ (20.41 kg), T₃ (19.73 kg) and T₆ (18.83 kg) followed by T₂ (18.17 kg), T₇ (18.02 kg) and T₅ (18.00 kg), while minimum bunch weight (16.57 kg) was perceived in T₄.

4.7.2 Yield per plot (kg/plot)

There was a significant difference among the different treatments with regard to yield per plot. The plants which was applied with full dose of RDF + 750 kg/ha of DE *i.e.* treatment T₁₀ has showed highest yield per plot (333.76 kg) which was on par with T₈ (332.21 kg), T₉ (326.66 kg), T₃ (315.68 kg) and T₆ (301.86 kg) followed by T₂ (290.82 kg), T₇ (288.32 kg) and T₅ (288.10 kg), while minimum yield per plot (265.12 kg) was perceived in T₄.

4.7.3 Yield per hectare (t/ha)

Similarly the significant difference was found for yield per hectare (tonnes). Among ten treatment, highest yield (64.37 t/ha) was observed in T₁₀ (RDF + 750 kg/ha DE) which was on par with T₈ (64.08 t/ha), T₉ (63.01 t/ha), T₃ (60.88 t/ha) and T₆ (58.22 t/ha) followed by T₂ (56.09 t/ha), T₇ (55.61 t/ha) and T₅ (55.56 t/ha), while lowest yield per hectare (51.13 t/ha) was perceived in T₄.

According to the results the highest values for bunch weight (kg), yield per plot (kg) and yield per hectare (tonnes) was found in the plants which were applied with T₁₀ (RDF + 750 kg/ha DE), T₉ (RDF + 500 kg/ha DE) and T₈ (RDF + 250 kg/ha DE), whereas the lowest values were observed in T₄ (DE alone).

Table 12: Influence of Diatomaceous Earth on yield parameters of banana

Treatments	Bunch weight (kg/plant)	Yield (kg/ plot)	Yield (t/ ha)
T ₁ - Absolute control	16.66	266.61	51.42
T ₂ - RDF	18.17	290.82	56.09
T ₃ - Half of Recommended dose of fertilizer	19.73	315.68	60.88
T ₄ - D.E alone	16.57	265.12	51.13
T ₅ - Half of RDF+DE @ 250 kg/ha	18.00	288.10	55.56
T ₆ - Half of RDF+ DE @ 500 kg/ha	18.83	301.86	58.22
T ₇ - Half of RDF+ DE @ 750 kg/ha	18.02	288.32	55.61
T ₈ - RDF+ DE @ 250 kg/ha	20.76	332.21	64.08
T ₉ - RDF+ DE @ 500 kg/ha	20.41	326.66	63.01
T ₁₀ - RDF+ DE @ 750 kg/ha	20.86	333.76	64.37
S. Em±	0.81	12.98	2.50
C.D (0.05)	2.40	38.59	7.43

RDF-Recommended dose of fertilizers

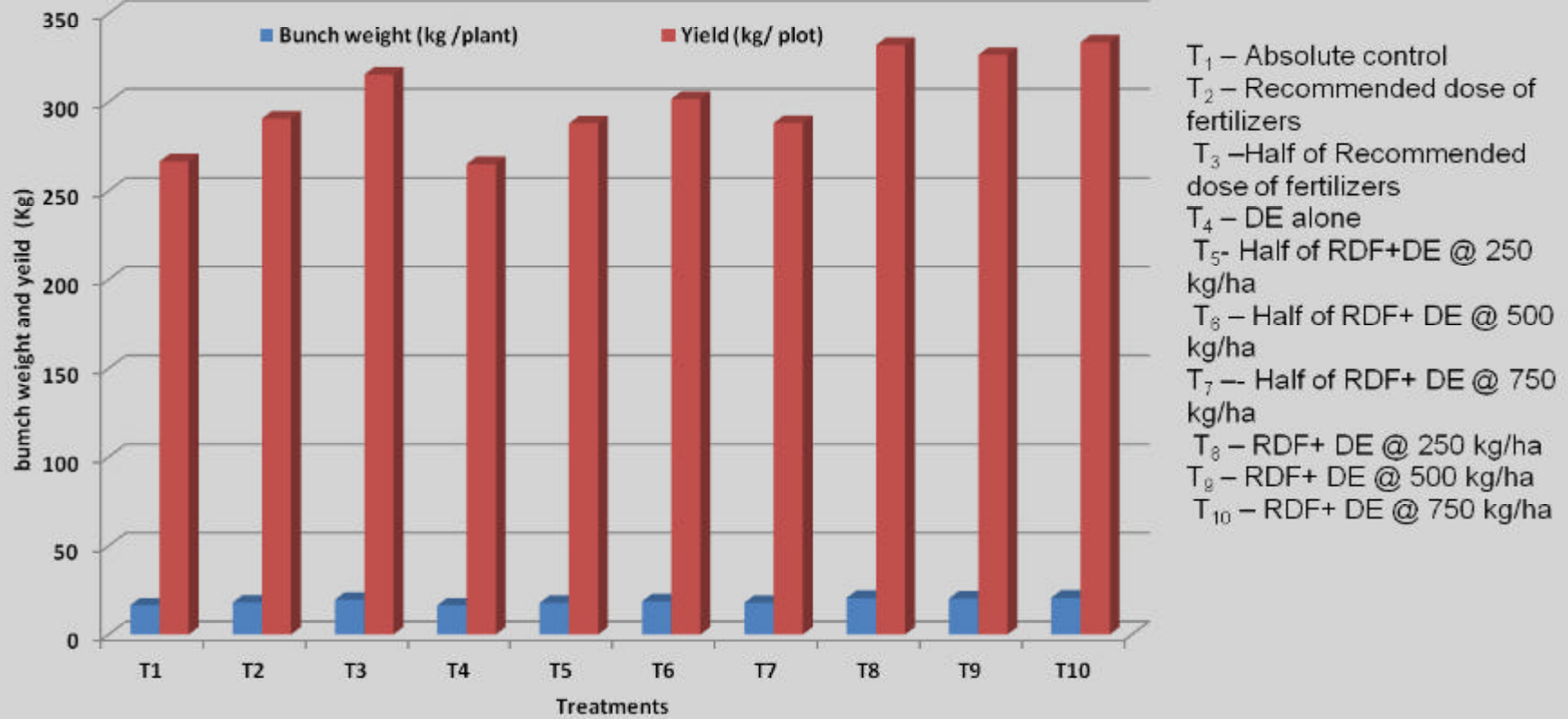


Fig. 4: Influence of Diatomaceous Earth on yield parameters of banana

4.8 Organoleptic evaluation

The data on organoleptic evaluation with respect to skin colour, colour and appearance, taste and flavour, texture, and overall acceptability of banana are influenced by treatments are presented in Table 13.

4.8.1 Skin colour

The maximum score (7.66) for skin colour was observed in T₁₀ (RDF + 750 kg/ha of DE) which was followed by T₉, T₈, T₆ and T₂ with the same score of (7.33) whereas least score (4.66) was found in T₄ (DE alone). However, the data was statistically non-significant.

4.8.2 Colour and appearance

The results indicate that there was a significant difference among the treatments with respect to colour and appearance of banana. Significantly maximum score (8.33) for colour and appearance was observed in T₁₀ (RDF + 750 kg/ha of DE) which was on par with T₉ (8.00), T₈ (8.00), T₆ (8.00) and T₇ (7.33) whereas minimum score (4.66) was found in T₄ (DE alone).

4.8.3 Texture

Highest score for texture (8.33) was observed in the treatment T₁₀ (RDF + 750 kg/ha of DE) followed by T₉ (8.00) and T₆ (8.00) while, lowest score (6.33) was found in T₅. However, the data was statistically non-significant.

4.8.4 Taste and flavour

The maximum score (8.33) for taste and flavour was observed in T₁₀, T₉, T₈, T₇ and which were followed by T₆ (8.00) and T₂ (8.00) whereas least score (7.00) was found in T₃. However, the data was statistically non-significant.

4.8.5 Overall acceptability

The results indicate that there was a significant difference among the treatments with respect to overall acceptability of banana. Significantly maximum score (8.33) for overall acceptability was observed in T₁₀, T₉, T₈ and T₂ which were

Table 13: Influence of Diatomaceous Earth on organoleptic scores of banana

Treatments	Skin colour	Colour and appearance	Texture	Taste and flavour	Overall acceptability
T ₁ - Absolute control	6.00	6.66	7.33	7.33	7.33
T ₂ - RDF	7.33	7.33	7.66	8.00	8.33
T ₃ - Half of RDF	6.33	6.33	7.00	7.00	7.00
T ₄ - D.E alone	4.66	4.66	6.66	7.33	5.33
T ₅ - Half of RDF+DE @ 250 kg/ha	5.66	6.33	6.33	6.33	6.33
T ₆ - Half of RDF+ DE @ 500 kg/ha	7.33	8.00	8.00	8.00	8.00
T ₇ - Half of RDF+ DE @ 750 kg/ha	6.00	7.33	7.66	8.33	7.66
T ₈ - RDF+ DE @ 250 kg/ha	7.33	8.00	7.66	8.33	8.33
T ₉ - RDF+ DE @ 500 kg/ha	7.33	8.00	8.00	8.33	8.33
T ₁₀ - RDF+ DE @ 750 kg/ha	7.66	8.33	8.33	8.33	8.33
SEm _±		0.61			0.52
CD (0.05)	NS	1.78	NS	NS	1.55

RDF-Recommended dose of fertilizers

on par with T₆ (8.00), T₇ (7.66), T₁ (7.33) and T₃ (7.00) whereas least score (5.33) was found in T₄ (DE alone).

4.9 White fly infestation

The assessment on pest infestation in banana with reference to number of whitefly colonies per leaf, numbers of whiteflies per colony and per cent leaf infestation of whitefly were presented in table 14. However, significant differences were accessible in the midst of treatments.

4.9.1 Number of whitefly colonies

The result pertaining at five month growth stage signify that significantly lower number of whiteflies colonies per leaf (2.17) were noticed in T₁₀ (RDF + DE @ 750 kg/ha) which was on par with T₉ (2.73), followed by T₈ (3.01), T₆ (3.42) and T₄ (3.53). Whereas the higher number of whitefly colonies per leaf (6.39) were noticed in T₁ (Absolute control).

4.9.2 Number of whiteflies per colony

It was observed that there was a significant difference between the treatments. In the midst of the treatments, T₁₀ (RDF + 750 kg/ha of DE) revealed lowest (2.40) number of whiteflies per colonies, which was on par with T₉ (2.61) followed by the treatment T₈ (3.24), T₇ (3.53) and T₄ (3.93) while highest number of whiteflies per colonies (6.75) were observed in T₁.

4.9.3 Per cent leaf infestation of whitefly

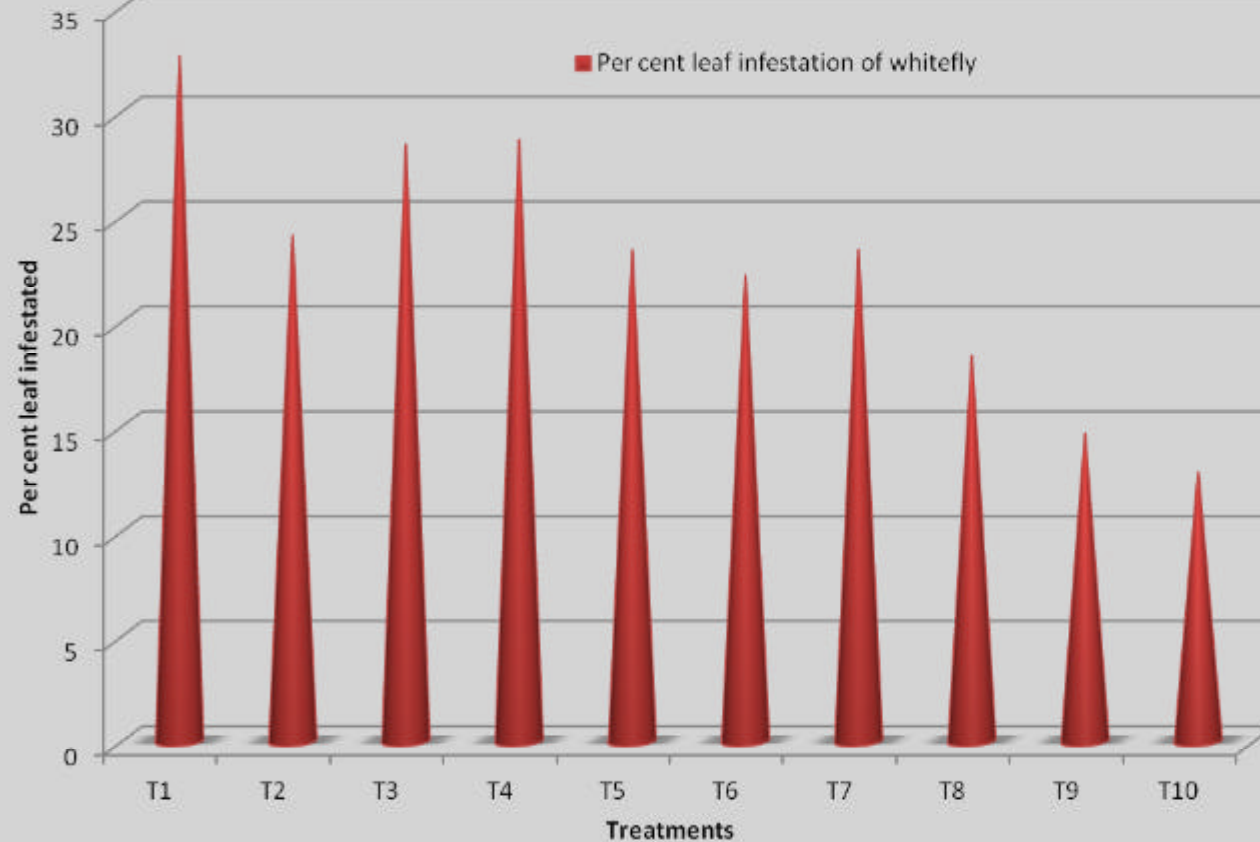
The result accessible showed that per cent leaf infestation on banana noticed the significant differences, whereas minimum per cent leaf infestation (12.81) was observed in T₁₀ (RDF + 750 kg/ha of DE) which was on par with T₉ (14.63). Whereas maximum per cent leaf infestation (32.63) was observed in T₁ (Absolute control).

The plants which were applied with T₁₀ (RDF + 750 kg/ha DE), T₉ (RDF + 500 kg/ha DE) and T₈ (RDF + 250 kg/ha DE) has recorded lowest whitefly incidence was compared to other treatment.

Table 14: Influence of Diatomaceous Earth on white fly infestation at five month growth stages of banana

Treatments	Number of whitefly colonies per leaf	Number of whiteflies per colony	Per cent leaf infestation of whitefly
T ₁ - Absolute control	6.39	6.75	32.63
T ₂ - Recommended dose of fertilizers	4.30	4.22	24.08
T ₃ - Half of Recommended dose of fertilizer	5.21	5.11	28.42
T ₄ - DE alone	3.53	3.93	28.63
T ₅ - Half of RDF+DE @ 250 kg/ha	4.29	4.30	23.39
T ₆ - Half of RDF+ DE @ 500 kg/ha	3.42	4.12	22.19
T ₇ - Half of RDF+ DE @ 750 kg/ha	3.73	3.53	23.39
T ₈ - RDF+ DE @ 250 kg/ha	3.01	3.24	18.34
T ₉ - RDF+ DE @ 500 kg/ha	2.73	2.61	14.63
T ₁₀ - RDF+ DE @ 750 kg/ha	2.17	2.40	12.81
S. Em±	0.28	0.24	1.20
C.D (0.05)	0.83	0.72	3.57

RDF-Recommended dose of fertilizers



- T₁ – Absolute control
- T₂ – Recommended dose of fertilizers
- T₃ – Half of Recommended dose of fertilizers
- T₄ – DE alone
- T₅ – Half of RDF+DE @ 250 kg/ha
- T₆ – Half of RDF+ DE @ 500 kg/ha
- T₇ – Half of RDF+ DE @ 750 kg/ha
- T₈ – RDF+ DE @ 250 kg/ha
- T₉ – RDF+ DE @ 500 kg/ha
- T₁₀ – RDF+ DE @ 750 kg/ha

Fig. 5: Influence of Diatomaceous Earth on white fly infestation at five month growth stages of banana

4.10 Sigatoka leaf spot index

The data on sigatoka leaf spot as influenced by diatomaceous earth on banana cv. Grand Naine are presented in Table 15. At five MAP, there was a significant difference among the different treatments. Lowest Sigatoka leaf spot intensity (19.86%) was recorded in T₁₀ (RDF + 750 kg/ha DE) which was on par with T₆ (20.26%), T₉ (20.69%) and T₈ (22.87%) followed by T₅ (23.57%), T₂ (26.42%) and T₇ (26.58%), while the highest Sigatoka leaf spot intensity (37.24%) was recorded in T₁ (Absolute control).

At harvesting stage, lowest Sigatoka leaf spot index (24.56%) was recorded in T₁₀ (RDF + 750 kg/ha DE) which was on par with T₉ (27.38%) and T₆ (28.32%) followed by T₄ (29.42%), T₅ (31.30%) and T₈ (31.45%) while the highest Sigatoka leaf spot index (44.21%) was recorded in T₁.

The plants which was applied with T₁₀ (RDF + 750 kg/ha DE), T₉ (RDF + 500 kg/ha DE), T₈ (RDF + 250 kg/ha DE) and T₆ (Half of RDF + 500 kg/ha DE) has recorded lowest Sigatoka leaf spot intensity was compared to other treatment.

4.11 Nutrient status of soil after harvesting of banana crop

The data pertaining to nutrient status of soil after harvesting of banana crop was accessible in Table 16 and 17.

4.11.1 pH of the soil

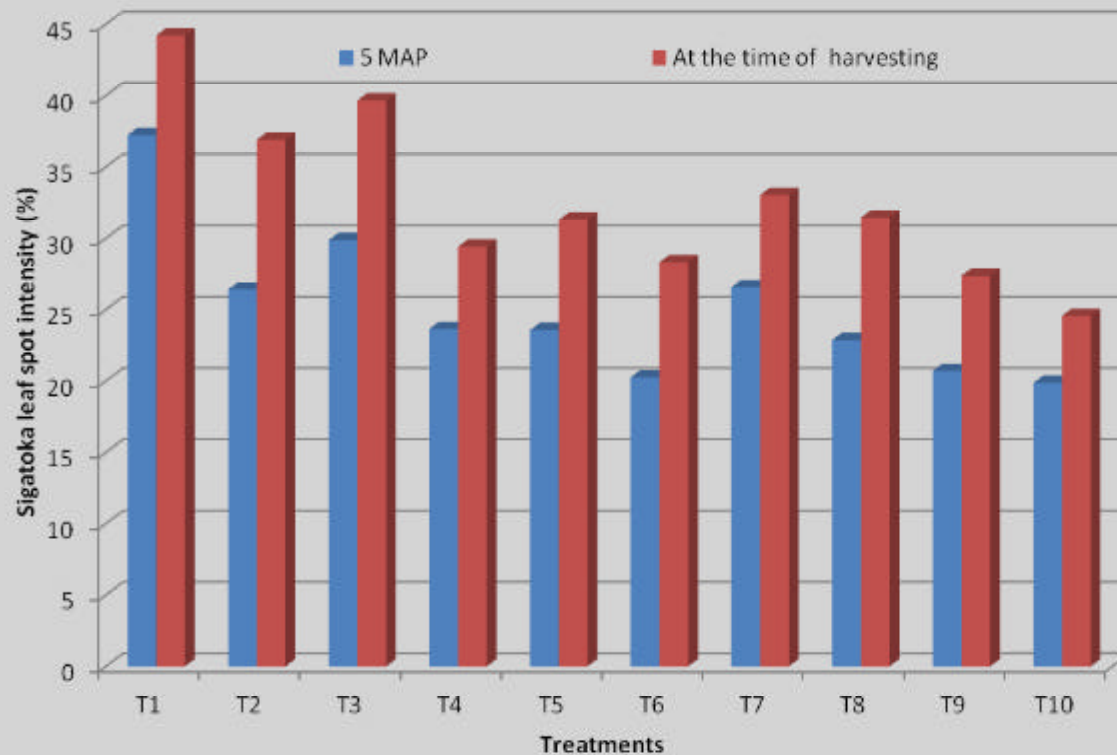
The result on pH of the soil showed the non significant difference between the treatments in which T₁₀ (8.56) showed the maximum pH content and minimum pH was found in T₁ (7.75).

4.11.2 Electrical conductivity (dS /m)

The values showed that there was a non significant difference noticed among the treatments with respect to the Electric conductivity (EC) of the soil whereas the highest EC was found in T₅ (0.31 dS /m)) and the least EC was found in T₂ (0.13 dS /m).

Table 15: Influence of Diatomaceous Earth on Sigatoka leaf spot disease intensity at 5 MAP and harvesting stage of banana

Treatments	Sigatoka leaf spot index	
	5 MAP	At the time of harvesting stage
T ₁ - Absolute control	37.24	44.21
T ₂ - Recommended dose of fertilizers	26.42	36.93
T ₃ - Half of Recommended dose of fertilizer	29.87	39.67
T ₄ - D.E alone	23.65	29.42
T ₅ - Half of RDF+DE @ 250 kg/ha	23.57	31.30
T ₆ - Half of RDF+ DE @ 500 kg/ha	20.26	28.32
T ₇ - Half of RDF+ DE @ 750 kg/ha	26.58	33.04
T ₈ - RDF+ DE @ 250 kg/ha	22.87	31.45
T ₉ - RDF+ DE @ 500 kg/ha	20.69	27.38
T ₁₀ - RDF+ DE @ 750 kg/ha	19.86	24.56
S.Em±	1.25	1.47
C.D (0.05)	3.71	4.38



- T₁ – Absolute control
- T₂ – Recommended dose of fertilizers
- T₃ – Half of Recommended dose of fertilizers
- T₄ – DE alone
- T₅ – Half of RDF+DE @ 250 kg/ha
- T₆ – Half of RDF+ DE @ 500 kg/ha
- T₇ – Half of RDF+ DE @ 750 kg/ha
- T₈ – RDF+ DE @ 250 kg/ha
- T₉ – RDF+ DE @ 500 kg/ha
- T₁₀ – RDF+ DE @ 750 kg/ha

Fig. 6: Influence of Diatomaceous Earth on Sigatoka leaf spot disease intensity (%) at 5 MAP and at harvesting stage of banana

4.11.3 Nitrogen content (kg/ha)

The nitrogen content in the soil embody the significant differences among the treatments due to the diatomaceous earth at final stages was designated in which the maximum nitrogen content in soil (641.30 kg/ha) was found in T₁₀ (RDF + 750 kg/ha DE) and the minimum nitrogen content in soil was noticed in T₈ (94.05 kg/ha).

4.11.4 Phosphorus content (kg/ha)

The significant difference in phosphorus content was noticed between the treatments, and the highest phosphorus content (35.75 kg/ha) was observed in T₁₀ (RDF + 750 kg/ha DE) whereas the least phosphorus content (20.23 kg/ha) was noticed in T₂ (RDF).

4.11.5 Potassium (kg/ha)

The potassium content shows the non significant difference among the treatments due to persuade of diatomaceous earth in which maximum potassium content (165.9 kg/ha) was found in T₂ and minimum potassium content (115.12 kg/ha) was noticed in T₄.

4.11.6 Iron (ppm)

The values on the iron content in soil noticed non significant difference among the treatments whereas the maximum iron content (6.51 ppm) was found in T₄ and the minimum (4.62 ppm) was noticed in T₉ (Table 17).

4.11.7 Manganese (ppm)

The data showed the non significant difference in manganese content among the treatments with respect to the application of diatomaceous earth whereas the maximum manganese content (6.14 ppm) was recorded in T₈ (RDF + 250 kg/ha DE) and minimum manganese content was found in T₉ (3.78 ppm).

4.11.8 Zinc (ppm)

The data showed the non significant difference of zinc content in soil among the treatments due to the influence of diatomaceous earth. The highest iron content

Table 16: Influence of Diatomaceous Earth on soil macro nutrient status after harvesting of banana

Treatments	pH	EC (dS /m)	N (kg/ha)	P ₂ O (kg/ha)	K ₂ O (kg/ha)
T ₁ - Absolute control	7.75	0.23	422.14	28.523	128.72
T ₂ - RDF*	8.45	0.13	407.68	20.230	165.9
T ₃ - Half of RDF	8.34	0.20	375.90	21.320	143.7
T ₄ - D.E alone	8.49	0.20	117.40	28.100	115.12
T ₅ - Half of RDF+DE @ 250 kg/ha	8.43	0.31	97.15	29.900	129.1
T ₆ - Half of RDF+ DE @ 500 kg/ha	8.36	0.26	385.71	22.733	165.00
T ₇ - Half of RDF+ DE @ 750 kg/ha	8.43	0.23	186.15	20.697	144.15
T ₈ - RDF+ DE @ 250 kg/ha	8.43	0.19	94.05	21.090	160.42
T ₉ - RDF+ DE @ 500 kg/ha	8.56	0.22	134.82	22.163	137.8
T ₁₀ - RDF+ DE @ 750 kg/ha	8.42	0.21	641.30	35.750	149.125
S.Em±	NS	NS	8.216	2.07	NS
C.D (0.05)			202.54	6.2	

RDF-Recommended dose of fertilizers

was noticed in T₁₀ (0.61 ppm) and minimum zinc content (0.29 ppm) was noticed in T₃ (Half of RDF).

4.11.9 Copper (ppm)

The copper content in the soil showed the non significant differences among the treatments due to the effect of diatomaceous earth. The maximum copper content (3.44 ppm) was noticed in T₄ and minimum copper content (2.72 ppm) was recorded in T₉.

4.11.10 Calcium (meq /100 g)

The data showed that the calcium content in soil was non-significant among the treatments due to the effect of diatomaceous earth. The maximum calcium content (0.191 meq/100 g) was noticed in T₉ and minimum copper content (0.105 meq/100 g) was recorded in T₄.

4.11.11 Magnesium (meq /100 g)

The data depicted on magnesium content in soil due to the effect of diatomaceous earth noticed the significant difference between the treatments in which the maximum magnesium content (0.048 meq/100 g) was observed in T₉ (RDF + 500 kg/ha DE) whereas the minimum magnesium content (0.035 meq/100 g) was noticed in T₁₀.

4.11.12 Ca: Mg ratio

The data showed the non significant difference for Ca:Mg ratio in the soil among the treatments due to the influence of diatomaceous earth. The highest Ca:Mg ratio was noticed in T₁₀ (4.43) and minimum Ca:Mg ratio was noticed in T₇ (2.41).

4.11.13 Silicon (kg/ha)

The silicon content in the soil showed the non significant difference among the treatments due to the effect of diatomaceous earth. The maximum silicon content (66.16 kg/ha) was noticed in the treatment T₁ and minimum silicon content (61.91 kg/ha) was recorded in T₉.

Table 17: Influence of Diatomaceous Earth on soil micro nutrient status after harvesting of banana

Treatments	Fe (ppm)	Mn (meq /100g)	Zn (ppm)	Cu (ppm)	Ca (meq/100g)	Mg (meq/100g)	Ca : Mg ratio	Si (kg/ha)
T ₁ - Absolute control	5.62	4.29	0.33	3.21	0.141	0.042	3.405	66.163
T ₂ - RDF*	6.11	5.51	0.35	3.09	0.144	0.036	4.017	64.230
T ₃ -Half of RDF	5.90	4.63	0.29	3.04	0.158	0.043	3.623	63.690
T ₄ - D.E alone	6.51	4.93	0.55	3.44	0.105	0.038	2.733	63.767
T ₅ - Half of RDF+DE @ 250 kg/ha	5.65	4.78	0.32	2.94	0.148	0.036	4.127	63.303
T ₆ - Half of RDF+ DE @ 500 kg/ha	5.35	5.22	0.41	2.80	0.132	0.037	3.550	63.303
T ₇ - Half of RDF+ DE @ 750 kg/ha	5.63	5.41	0.51	3.26	0.109	0.045	2.410	62.917
T ₈ - RDF+ DE @ 250 kg/ha	5.60	6.14	0.36	2.88	0.164	0.038	4.273	62.067
T ₉ - RDF+ DE @ 500 kg/ha	4.62	3.78	0.52	2.72	0.191	0.048	3.967	61.913
T ₁₀ - RDF+ DE @ 750 kg/ha	5.23	5.07	0.61	3.09	0.154	0.035	4.433	63.073
S.Em±	NS	NS	NS	NS	NS	0.002	NS	NS
C.D (0.05)						0.007		

RDF-Recommended dose of fertilizers

4.12 Economics

Data pertaining to the cost of cultivation, gross returns, net returns and benefits: cost ratio of the various treatment combinations involved in the study are presented in Table 18.

Among the different treatments, T₁ (control) has recorded highest benefit: cost ratio (7.01) and net profit (540040 Rs./ha). This was followed by T₄ (5.41 and 517810 Rs./ha respectively) which was applied with DE alone. While the lowest benefit: cost ratio was noticed in T₂ (3.72 and 530593 Rs./ha) in which recommended dose of fertilizers were added.

Table 18: Influence of Diatomaceous Earth on benefit cost ratio of banana

Treatments	Yield (t/ha)	Total cost of cultivation (Rs./ha)	Gross return (Rs./ha)	Net returns (Rs./ha)	B:C ratio
T ₁ - Absolute control	51.42	77000	617040	540040	7.01
T ₂ - RDF*	56.09	142487	673080	530593	3.72
T ₃ - Half of RDF	60.88	114003	730560	616557	5.34
T ₄ -D.E Alone	51.13	95750	613560	517810	5.41
T ₅ - Half of RDF+DE @ 250 kg/ha	55.56	120253	666720	546467	4.48
T ₆ - Half of RDF+ DE @ 500 kg/ha	58.22	126503	698640	572137	4.47
T ₇ - Half of RDF+ DE @ 750 kg/ha	55.61	132753	667320	534567	3.98
T ₈ - RDF+ DE @ 250 kg/ha	64.08	148737	768960	620223	4.16
T ₉ - RDF+ DE @ 500 kg/ha	63.01	154987	756120	601133	3.88
T ₁₀ - RDF+ DE @ 750 kg/ha	64.37	161237	772440	611203	3.79

RDF-Recommended dose of fertilizers

5. DISCUSSION

The whole complex of crop production with the resultant yield on a profitable basis is based mainly on balanced nutrition under congenial agro-ecological conditions. Banana is a heavy feeder of nutrients (Jones, 1998) and thus needs balanced nutrition for better growth, development, potential yield and quality of fruits. It also responds well to beneficial elements for its growth and development.

Several functions have been attributed to silicon in plants *viz.*, improvement of nutrient balance, reduction of mineral toxicities, improvement of mechanical properties of plant tissues and enhancement of resistance to the various abiotic and biotic stresses. The beneficial effects of silicon are usually small under optimal conditions and are more clearly expressed when plants are subjected to stress conditions, the most impressive evidence being found in field experiments (Epstein 1994).

Banana roots are able to induce silicate dissolution thereby increasing silicon availability in the rhizosphere (Hinsinger *et al.*, 2001 and Rufyikiri *et al.*, 2004). These data suggest that banana, like many other monocots, may possess beneficial effect of silicon accumulation, although evidences of such effect are essentially lacking. Therefore investigation on growth, yield and quality parameters as influenced by soil application of diatomaceous earth on banana cv. Grand Naine was carried out in the K. R. C. College of Horticulture, Arabhavi of Gokak taluk. The effects of diatomaceous earth on performance of banana are discussed in this chapter.

5.1 Effect of diatomaceous earth on growth parameters in banana

The data on pseudostem height render significantly higher when the plants were applied with T₁₀ (RDF + 750 kg/ha DE) with 21.31 cm, 38.33 cm, 54.11 cm, 80.22 cm, 110.39 cm, 153.28 cm, 171.89 cm, 192.33 cm and 208.29 cm at 1, 2, 3, 4, 5, 6, 7, 8 and 9 months after planting respectively (Table 1 and Fig 1). Similarly, T₉ (RDF + 500 kg/ha DE), was on par with T₁₀. Among all the treatments, T₁₀ (RDF + 750 kg/ha DE) has recorded highest values for pseudostem girth with 2.70 cm, 3.72 cm, 5.42 cm, 8.49 cm, 12.97 cm, 15.67 cm, 17.15 cm, 19.14 cm and 21.23 cm at 1,2, 3, 4, 5, 6, 7, 8 and 9 months after planting respectively (Table 2 and Fig. 1). Similarly, T₉ (RDF + 500 kg/ha DE), T₈ (RDF + 250 kg/ha DE) and T₂ (RDF) were on par with

T₁₀. Whereas, the lowest pseudostem height and girth was noticed in the treatment T₄ (DE alone) in entire growth stages.

The increase in pseudostem height and girth might be due to that silicon induces the shoot height in crop plants, through its role in both cell division and cell expansion by its effect on RNA and DNA synthesis. Similar results were observed by Kidane and Liang (2010), Henriet *et al.* (2006) and Roshdy *et al.* (2014) in banana, Bhavya (2010) in Bangalore Blue grapes, Matichenkov *et al.* (2001) in citrus, Cai and Rian (1995b) in apple, Wang and Galleta (1998) in strawberry, Miyake and Eiichi (1983) in cucumber, Adatia and Besford (1986) in tomato, Aziz *et al.* (2001) and Seome *et al.* (2008) in melon, Korndorfer *et al.* (2001) in rice, (2006) and Crusciol *et al.* (2008) in potato.

Number of leaves had increased with increase in age of the plant. The highest number of leaves was found in T₁₀ (RDF + 750 kg/ha DE) with 6.32, 9.49, 12.28, 14.37, 16.72, 18.56, 20.11, 21.23 and 22.17 at 1, 2, 3, 4, 5, 6, 7, 8 and 9 months after planting respectively (Table 3). However, T₁₀ was on par with T₉ (RDF + 500 kg/ha DE), T₈ (RDF + 250 kg/ha DE), T₇ (Half of RDF + 750 kg/ha DE), T₆ (Half of RDF + 500 kg/ha DE) and T₂ (RDF) whereas the lowest number of leaves was noticed in the treatment T₄ (D.E alone). The increase in number of leaves per plant might be due to the strengthening of the stem and holds the solar panel in perfect position and stimulation of growth was due to the silicon application along with recommended dose of fertilizers. High amount of Si application resulted in more number of leaves. These results were in accordance with Kidane and Liang (2010) and Roshdy *et al.* (2014) in banana, Adatia and Besford (1986) in tomato, Gillman *et al.* (2003) and Seung (2005) in rose and Ferreira *et al.* (2010) in lettuce.

The application of diatomaceous earth treatments had significant influence on leaf area than untreated control. Among all the treatments, T₁₀ (RDF + 750 kg/ha DE) has recorded highest values for leaf area with 0.34 m², 1.73 m², 3.47 m², 5.05 m², 7.21 m², 10.25 m², 13.42 m² and 16.49 m² at 2, 3, 4, 5, 6, 7, 8 and 9 MAP respectively. The lowest leaf area was noticed in the treatment T₄ (Table 4). It might be due to maintenance of upright growth habit which might have allowed maximum light interception and increased photosynthetic activity as well as leaf chlorophyll content. These findings are in contour with those of Roshdy *et al.* (2014) in banana, Bhavya

(2010) in Bangalore Blue grapes, Adatia and Besford (1986), Liu (1997) in tomato and Saeed *et al.* (2009) and Seung *et al.* (2005) in rose.

The leaf chlorophyll content was significantly influenced by soil application of diatomaceous earth. The maximum chlorophyll 'a' content (1.75 and 1.74 mg/g of leaf at five month after planting and at the time of harvesting respectively) was recorded by the treatment T₁₀ (RDF + 750 kg/ha DE). Significantly maximum chlorophyll 'b' content (0.68 and 0.82 mg/g of leaf at five month after planting and at the time of harvesting respectively) was recorded by the treatment T₉ (RDF + 500 kg/ha DE) which was on par with T₁₀ (RDF + 750 kg/ha DE). Maximum total chlorophyll (2.39 and 2.56 mg/g at five month after planting and at the time of harvesting respectively) was recorded by the treatment T₉ (RDF + 500 kg/ha DE) which was on par with the treatment T₁₀ (RDF + 750 kg/ha DE) at five month after planting and at the time of harvesting (Table 5). The increase in the leaf chlorophyll content was due to the plants supplied with silicon which resisted lodging (drooping, leaning, or becoming prostrate). It could increase mechanical strength of plants, which enabled them to achieve and maintain an upright growth habit and allowed maximum light interception and increased photosynthetic activity and due to the encroachment of other growth parameters such as maximum leaf area and number of leaves. These observations are in conformity with those of Wang and Galleta (1998) in strawberry, Bhavya (2010) in Bangalore Blue grapes, Wang *et al.* (2007) in cucumber, Crusciol *et al.* (2008) in potato, Liu (1997), Emrich *et al.* (2011) and Silva *et al.* (2012) in tomato.

With respect to number of sucker production, there was a significant difference among the treatment. The maximum number of sucker production with 2.43, 2.79, 3.44, 4.02, 4.44 and 5.39 at 4, 5, 6, 7, 8 and 9 month after planting was observed in the treatment T₁₀ (RDF + 750 kg/ha of DE), which were on par with the treatment T₉ (RDF + 500 kg/ha of DE), T₈ (RDF + 250 kg/ha of DE), T₇ (Half of RDF + 750 kg/ha DE), T₆ (Half of RDF + 500 kg/ha of DE) and T₂ (RDF) (Table 6). This might be due to that silicon helps in increasing chlorophyll content and helps in more absorption of other nutrients and increase the growth of plant. These observations are in conformity with those of Fallah (2000), Abbas (2011) in rice and Samipour *et al.* (2013) in *Lolium perenne*. It was detected that treatment with silicon could increase the level of cytokinin in wheat plants (Ahmed *et al.* 1997).

5.2 Effect of diatomaceous earth on nutrient status in banana leaf

Composition of nutrient in the leaf at the time of shooting indirectly reveals on growth, development and yield significantly in the present study indicated the influence of diatomaceous earth.

There was a non-significant difference between the treatments with respect to nitrogen content of the leaves. The highest nitrogen content in the leaf (3.86%) was observed in the treatment T₁ and lowest nitrogen content in the leaf (2.94%) was observed in the treatment T₄ (DE. alone).

There was a significant difference between the treatments relevant to phosphorous content of the leaves. The highest phosphorous content in the leaf (0.47%) was observed in the treatment T₁₀ (RDF + 750 kg/ha of DE) and T₉ (RDF + 500 kg/ha of DE) which were on par with the treatment T₅ (Half of RDF + 250 kg/ha of DE) followed by T₆, T₂ and T₄ whereas, lowest phosphorous content in the leaf was seemed in the treatment T₈ (0.37%) which was on par with T₁ (Table 7). This was probably through an increase in phosphorylation which rendered more phosphorus available to plants by reversing its fixation as silicon itself competed for phosphorus fixation and thus, slowly released phosphorus and helped in more uptakes. The above results are in conformity with the findings of Lalithya *et al.* (2014) in sapota, Brenchley and Maskell (1927) and Fisher (1929) in barley, Crusciol *et al.* (2008) in potato and Nesreen *et al.* (2011) in beans.

The soil application of diatomaceous earth on potassium content of leaf confers the significant difference compared to control. The maximum potassium content in the leaf lamina (1.74%) was recorded in the treatment T₁₀ (RDF + 750 kg/ha of DE) which was on par (1.52%) with the treatment T₉ (RDF + 500 kg/ha of DE), whereas, lowest potassium content in the leaf (0.95%) was seemed in the treatment T₆ (Table 7). This might be attributed to silicon helped in more uptake of potassium due to its synergistic effect. Nesreen *et al.* (2011) recorded that, the application of potassium silicate increased per cent K in leaf. Similar results were observed by Gorecki and Danielski (2009) in cucumber, Kamenidou *et al.* (2009) in Zinnia and Ornamental sunflower and Kamenidou and Toddy (2008) in Ornamental sunflower.

The content of silicon in leaf (1.26%) was found to be high in the treatment T₁₀ (RDF + 750 kg/ha of DE) which was followed by the treatment T₄ (DE. alone) and the lowest silicon content in leaf (0.56%) was found in T₃ (Table 7). Application of higher dose of diatomaceous earth leads to more absorption on silicon by leaves of banana plants. The results are in conformity with findings of Vladimir *et al.* (2001) in citrus, Ma and Yamaji (2006), Savvas *et al.* (2009) in tomato, Adatia and Besford (1986) in cucumber, in rice and Milne *et al.* (2012) in lettuce. The application of silicon fertilizer improved the lettuce nutritional status for Si and increased the percentage of healthy leaves (Ferreira *et al.*, 2010).

The data renders significant difference on iron content in the leaf among the treatments and the maximum iron composition in leaf (151.30 ppm) was noticed in T₃ (Half of RDF) which was on par with T₈ (RDF + 250 kg/ha of DE) whereas the minimum iron composition in leaf was found in T₇ (Half of RDF + 750 kg/ha of DE). This might be due to the fact that remobilization of stored nutrients has been observed from vegetative tissues, such as leaves and stem, to seeds, fruits or even young leaves. These provide a source–sink relationship that leads to a more efficient use of the absorbed iron micro nutrient whereas the analogous results were obtained by Gonzalo *et al.* (2013), Pavlovic *et al.* (2013) and Bityutskii *et al.* (2014) in Graminaceae crops.

The maximum zinc content (10.50 ppm) was observed in plants which received full dose of RDF *i.e.* T₂ which was on par with the treatment T₉ (9.90 ppm), T₁ (9.50 ppm), and T₄ (9.45 ppm). This might be due to silicon and zinc that were mainly located around the root endodermis, precipitated as zinc silicates, which may partially inhibit zinc xylem loading and transport this precipitate suffered a slow degradation to SiO₂ and then, zinc was accumulated in vacuoles in an unknown form and silicate precipitation on the plant cell wall increased the Zn²⁺ binding sites, which may enhance Zn²⁺ adsorption on the silicate deposits.

The highest calcium content (1.10%) was noticed in the treatment T₃ (Half of RDF) which was on par with the treatment T₉ (RDF + 500 kg/ha of DE) and T₅ (Half of RDF + 250 kg/ha of DE) whereas, lowest calcium content (0.71%) was observed in the treatment T₂ (Table 7). This is due to its help in more absorption of calcium in to the plant tissue. Similar results were noticed by Mary (2005) in rose, Kamenidou and Toddy (2008) in ornamental sunflower, Kamenidou *et al.* (2009) in zinnia and Kamenidou *et al.* (2010) in gerbera.

5.3 Effect of diatomaceous earth on crop duration in banana

The application of diatomaceous earth to soil showed significant difference on number of days taken for flowering in which minimum days (280.33 days) was noticed in treatment T₁₀ (RDF + 750 kg/ha of DE) which was statistically on par with T₉, T₈, T₇, T₆, T₅ and T₂ whereas the maximum days taken for flowering (345.61 days) was noticed in T₄ (DE. alone). However days taken for harvesting were showing non-significant difference among the treatment. With respect to total crop duration, treatment T₁₀ (RDF + 750 kg/ha of DE) has taken minimum days *i.e.* 408.94 days as compared to other treatment. Similarly, T₉ (RDF + 500 kg/ha DE), T₈ (RDF + 250 kg/ha DE), T₅ (Half of RDF + 250 kg/ha DE) and T₂ (RDF) were on par with the treatment T₁₀. The maximum number of days (455.77 days) was noticed in T₄ (Table 8 and Fig. 2).

As silicon might have influenced the plants to capture more light and increase chlorophyll content in leaf, this has led to more production of photosynthates and thus helps in early shooting. The mechanism involved in accelerated anthesis remained unclear, even though several studies associated with Si supplementation with increased photosynthesis, decreased transpiration and phytochrome changed especially on field crops (Ma and Takahashi, 2002). These results are in contrast with Kamenidou and Cavins (2008) in ornamental sunflower.

5.4 Effect of diatomaceous earth on bunch and finger characteristics in banana

The yield in case of banana can be measured in terms of bunch characters, finger characters and bunch weight per plant and yield per hectare. In this experiment, growth characters like plant height, pseudostem girth, number of leaves and leaf chlorophyll content had their influence on yield.

5.4.1 Bunch characters

The yield parameters *viz.*, number of hands per bunch and bunch characters were maximum in soil applied with diatomaceous earth treatments than in control treatment. Pandey and Yadav (1999) reported that spraying silicon increased yield of wheat and increased yield was attributed to increase in plant water status, chlorophyll

content, coupled with reduced values of water potential, increase in dry matter accumulation, dry matter production rate, leaf area and decrease in transpiration rate coupled with decrease in stomatal conductance. The highest bunch length (90.65 cm) was recorded in the treatment T₁₀ (RDF + 750 kg/ha DE) which was on par with the treatment T₉ (RDF + 500 kg/ha DE). However, the lowest bunch length (65.25 cm) was recorded in the treatment T₃ (Half of RDF). The maximum bunch width (44.87 cm) was noticed in the treatment T₁₀ (RDF + 750 kg/ha DE) which was on par with the treatment T₉, T₈, T₇, T₆, T₅ and T₂ (RDF). However, the minimum bunch width (35.17 cm) was recorded in the treatment T₁ (Table 9 and Fig. 3). The main reason for increase in bunch length and width could be increase in cell division and cell expansion by their effect on RNA and DNA synthesis (Hanafy *et al.*, 2008 in wheat) which consequently could have contributed for increase in bunch length and width. Similar observations were recorded by Kumbargire *et al.* (2015), Roshdy *et al.* (2014) in banana and Bhavya (2010) in Bangalore Blue grapes. It might be due to higher leaf area on which resulted in increased photosynthetic activity as observed by Henriet *et al.* (2006) in banana, Bhavya (2010) in Bangalore Blue grapes.

The maximum number of hands per bunch (13.43) was noticed in the treatment T₈ (RDF + 250 kg/ha DE) which was on par with the treatment T₉ (RDF + 500 kg/ha of DE) and T₁₀ (RDF + 750 kg/ha of DE). On the contrary, lowest number of hands per bunch (8.16) was noticed in the treatment T₁. Whereas, the maximum number of fingers in 3rd hand (20.97) was recorded in the plants with T₁₀ (RDF + 750 kg/ha DE) which was on par with the treatment T₉ (RDF + 500 kg/ha of DE) and the minimum number of fingers in 3^d hand (14.87) was recorded in the treatment T₁. However the maximum number of fingers per bunch (201.86) was recorded in the plants with T₁₀ (RDF + 750 kg/ha DE) which was on par with the treatment T₉ (RDF + 500 kg/ha of DE) and the minimum number of fingers per bunch (110.50) was recorded in the treatment T₁ (Table 9). As silicon helps in cell division and elongation, it resulted in production of more number of hands per bunch and more number of fruits. Similar observations were made by Kumbargire *et al.* (2015) in banana, Roshdy *et al.* (2014) in banana, Bhavya (2010) in Bangalore Blue grapes and Gorecki and Danielskibusch (2009) in green house cucumber. The results revealed that, increased yield attributed on the number of fruits. Nesreen *et al.* (2011) opined that silicon application increased the number of pods per plant in beans. Stamatakis *et*

al. (2003) reported that, silicon application increased number of fruits per plant in tomato.

5.4.2 Finger characters

The Finger characters *viz.* finger weight, finger girth, finger volume, finger length was maximum in soil application of diatomaceous earth treatments compared to control. The increase in finger size might be due to higher photosynthetic activity and biomass production in the plant which might have resulted in more metabolites in the plant. As the growth and development of the fingers advanced the large amount of water and other metabolites moved in to the fingers.

There was a significant difference with respect to finger weight among the treatments. The maximum finger weight (145.19 g) was recorded in the treatment T₁₀ (RDF + 750 kg/ha DE) which was on par with the treatment T₉ (RDF + 500 kg/ha DE) and T₈ (RDF + 250 kg/ha DE). On the contrary, lowest finger weight (84.16 g) was observed in the treatment T₁ (Table 10). The increase in finger weight was mainly due to cell division in the initial stages and later due to cell expansion associated with movement of water and other metabolites into the cell causing increase in overall weight of the finger. The similar findings have been reported by Kumbargire *et al.* (2015) in banana and Nam Sang young *et al.* (1996) in grape. Fruits from the silicate fertilizer plot were slightly heavier than those from any other treatment. Nesreen *et al.* (2011) recorded increase in pod weight in beans plant. Shukla *et al.* (2011) observed increase in fruit weight with application of calcium, (Ahmed *et al.*, 1997) and also supported by Mustafa *et al.* (2006) and Bhavya (2010) in Bangalore Blue grapes.

The finger length was found significantly superior in those plants which were applied Diatomaceous Earth. The maximum finger length (22.51 cm) was observed in the treatment T₁₀ (RDF + 750 kg/ha DE), lowest finger length was observed in the treatment T₁. However, maximum finger girth (3.75 cm) was noticed in the treatment T₉ (RDF + 500 kg/ha DE) which was on par with the treatment T₁₀ (RDF + 750 kg/ha DE), lowest finger girth (3.28 cm) was observed in the treatment T₆ (Table 10). Whereas maximum finger volume (138.51 cm) was observed in the treatment T₁₀ (RDF + 750 kg/ha DE), lower finger volume was observed in the treatment T₁. Similar findings were observed by Kumbargire *et al.* (2015) in banana, Roshdy *et al.*

(2014) in banana, Shukla., (2011) and Bhaya (2010) in grape reported that, this might be due to beneficial effect of nutrients which led to cell expansion.

Thus the finger characters were found to be influenced more by soil application of DE in improving the finger characters, which might be due to higher photosynthetic activity, biomass production in the plants which resulted in more metabolites and their translocation into the skins might have contributed to better finger quality.

The pulp to peel ratio was found to differ significantly among the treatments. The maximum pulp to peel ratio (3.52) was noticed in the treatment T₁₀ (RDF + 750 kg/ha DE) which was on par with T₉ (RDF + 500 kg/ha DE), T₈ (RDF + 250 kg/ha DE) and T₅ (Half of RDF + 250 kg/ha DE). Lowest pulp to peel ratio (2.21) was noticed in T₇, which indicated the beneficial role of silicon in getting good pulp recovery. A similar result was observed by Kumbargire *et al.* (2015) in banana and Kaluwa *et al.* (2010) in Avocado.

5.5 Effect of diatomaceous earth on quality parameters in banana

The maximum number of days taken for ripening (9.55days) was observed in treatment T₉ (RDF + 500 kg/ha). Whereas early ripening (6.43days) was recorded in control T₁ (Table 11) and higher shelf life (5.78 days) and lower shelf life (3.50 days) was found with T₉ and T₃ respectively. Babak and Majid (2011) reported that, the use of silicon increased vase life of carnation as it lowered the ethylene production and silicon formed complexes with organic compounds in the cell wall of epidermal cells thus, increased their resistance in degrading enzymes. Potassium improved fruit quality due to suppression of respiration and reduction in ethylene evolution. Similar results were noticed by Kumbargire *et al.* (2015) in banana, Kaluwa *et al.* (2010) in avocado, Shi *et al.* (2012) in longan, Rodrigues *et al.* (2010) and Stamatakis *et al.* (2003) in tomato reported that, application of silicon with higher concentration resulted in more fruit firmness.

The significant difference was noticed in the total soluble solids with soil application of silicon on banana. The maximum total soluble solids (22.70⁰ brix) was found in the treatment T₁₀ (RDF + 750 kg/ha of DE) which was statistically on par with the treatment T₉ (RDF + 500 kg/ha of DE), T₈ (RDF + 250 kg/ha of DE), T₇

(Half of RDF + 750 kg/ha of DE) and T₆ (Half of RDF + 500 kg/ha of DE). Whereas, the minimum total soluble solid (17.65⁰brix) content was recorded in control T₁ (Table 11). Silicon and potassium helped in synthesis of more sugars in the fruit and thus helped in increasing total soluble solids and the results are in accordance with Kumbargire *et al.* (2015) in banana, Stamatakis *et al.* (2003) and Roshdy *et al.* (2014) in banana and Bhavya (2010) in Bangalore Blue grapes.

There was a significant difference noticed with respect to acidity content of the fruit. The titratable acidity was less (0.21 per cent) in T₁₀ (RDF + 750 kg/ha of DE) which was on par with the treatment T₉ (RDF + 500 kg/ha of DE) (Table 11). The decrease in acidity might be due to increase in the total soluble solids and it was also because of boron which might have either involved in fast conversion of metabolites into sugar and their derivatives. Similar, observations were made by Kumbargire *et al.* (2015) in banana, Roshdy *et al.* (2014) in banana and Bhavya (2010) in Bangalore Blue grapes. The increased in total soluble solids in the berries leads to decrease in acidity content.

The reducing sugar content (20.81%) was more in treatment T₁₀ (RDF + 750 kg/ha DE) followed by the treatment T₉ (19.11%), T₈ (18.57%) and T₇ (17.55%) (Table 14). This progressive increase could be related to increase in total soluble solids. Since, the reducing sugars constituted a major part of solid present in banana. The maximum non-reducing sugar (3.84%) was noticed in (T₇) which was on par with the treatment T₁₀ (3.81) and T₉ (3.72) whereas the lowest (2.33%) was recorded in (T₃). Similar results are recorded by Kumbargire *et al.* (2015) in banana, Roshdy *et al.* (2014) in banana and Bhavya (2010) in Bangalore Blue grapes.

The quality parameters *viz.*, days taken for full ripening of the fruits, acidity, total soluble solids, shelf life, reducing sugar, non-reducing sugars of the fruit were significantly influenced by diatomaceous earth than control. Because of the increased total soluble solids and increased fruit firmness, the shelf life of the fruits was increased when stored at room temperature. Similar observation was made by Kumbargire *et al.* (2015), Roshdy *et al.* (2014) in banana, Savvas (2009) in tomato and Bhavya (2010) in Bangalore Blue grapes.

5.6 Effect of diatomaceous earth on yield parameters in banana

The yield in case of banana can be expressed as bunch weight per plant and yield per hectare. In this experiment silicon confers rigidity and strength making the banana plants erects facilitating effective interception of sunlight thus enhancing photosynthesis, photo assimilation and ultimately plant growth and yield.

The bunch yield per plant was greatly influenced by soil application of Diatomaceous Earth as compared to control. The maximum bunch weight (20.86 kg) was recorded in the treatment T₁₀ (RDF + 750 kg/ha DE) which was on par with the treatment T₉ (RDF + 500 kg/ha DE), T₈ (RDF + 250 kg/ha DE), T₆ (Half of RDF + 500 kg/ha DE) and T₃ (Half of RDF) whereas, the lowest bunch weight (16.57 kg) was noticed in the treatment T₄. The highest yield per hectare (64.37 t/ha) was recorded in the treatment T₁₀ (RDF + 750 kg/ha of DE) which was on par with the treatment T₉ (RDF + 500 kg/ha DE), T₈ (RDF + 250 kg/ha DE), T₆ (Half of RDF + 500 kg/ha DE) and T₃ (Half of RDF) whereas, the lowest yield per hectare (51.13 t/ha) was observed in the treatment T₄ (Table 12 and Fig. 4).

Silicon had many positive effects on the growth and yield as well physiology and metabolism of different crops. Increased yield might have due to leaf erectness which facilitated better penetration of sunlight leading to higher photosynthetic activity of plant, more formation of carbohydrates and more uptake of other nutrients. The similar results were also noticed by Kumbargire *et al.* (2015) in banana, Roshdy *et al.* (2014) in banana, Bhavya (2010) in Bangalore Blue grapes, Mathaba *et al.* (2009) in citrus, Reaple and Laane (2008) in papaya, Rani *et al.* (1997) and Singh *et al.* (2006) in rice plant, Savvas (2009) and Liu (1997) in tomato, Adatia and Besford (1986) in cucumber, Luz *et al.* (2008) in potato (Table 12). Soil application of silicon resulted in better growth, bunch and finger characters, which led to overall increase in the yield of banana cv. Grand Naine.

5.7 Effect of diatomaceous earth on organoleptic evaluation in banana

The results indicate that there was a significant difference among the treatments with respect to colour and appearance and overall acceptability (Table 13).

Significantly maximum score (8.33) for colour and appearance was observed in T₁₀ (RDF + 750 kg/ha of DE) which was on par with the treatment T₉ (8.00), T₈ (8.00), T₆ (8.00), T₇ (7.33) and T₂ (7.33), whereas the least score (4.66) was found in T₄ (Table 13). This might be due to increased antioxidant capacity under stress condition. Similar results were observed by Kumbargire *et al.* (2015) in banana, Tesfay *et al.* (2011) in avocado, Stamatakis *et al.* (2003), Khalid *et al.* (2005), Savvas (2009) and Anastasia *et al.* (2013) in tomato and Saeed *et al.* (2009) in rose. Significantly maximum score (8.33) for overall acceptability was observed in T₁₀ (RDF + 750 kg/ha of DE) which was on par with almost all the treatment except T₄ and T₅, whereas, least score (5.33) was found in T₄. Silicon helped in synthesis of more sugars in the fruit and thus helped in increasing total soluble solids. The results are in accordance with Bhavya (2010) in Bangalore Blue grapes, Stamatakis *et al.* (2003), Savvas (2009) and Rodrigues *et al.* (2010) in tomato. Whereas, skin colour, texture, taste and flavour recorded non significant difference among the treatments.

5.8 Effect of diatomaceous earth on whitefly infestation in banana

The application of diatomaceous earth as source of silicon has the significant difference among the treatment in which lowest number of whitefly colonies per leaf (2.17) was noticed in T₁₀ (RDF + DE @ 750 kg/ha) and highest number of whitefly colonies per leaf (6.39) was noticed in T₁ (Absolute control) whereas the minimum number of whiteflies per colony (2.40) was found in T₁₀ (RDF + DE @ 750 kg/ha) which was Non significant with the T₉ and the maximum (6.75) was found in T₁. The per cent leaf infestation was least in (12.81) which was significantly on par with the T₉ (14.63) and the highest per cent leaf infestation (32.63) was noticed in T₁ (Table 14 and Fig. 5).

The less infestation of white fly was due to most of the plant silicon occurs in the epidermis, which might dislodge young larvae before they can establish in the stem. Various studies have demonstrated that silicon increases the hardness of plant tissue, which negatively impacts insect larval boring and feeding ability and beneficial effects of Si is its role in triggering a range of natural defence.

Eswaran and Manivannan (2007) stated that, the main cause for the death of the insects (whitefly) upon ash (which contain silicon) application was wearing off of

the main feeding organs of the insects. The feeding organs were made functionless and insects remained without food. When such whiteflies were examined by dissection, the ash particles were found to settle at various point of their alimentary canal. This might have hindered the digestion of the food consumed along the pathway of the gut of whitefly in papaya. Similar results were observed by Puterka *et al.* (2000) in pear against psylla, Braham *et al.* (2007) in citrus against med fly and Saour (2005) in pecan nut against psylla. It has been reported that silicon suppresses insect's pests such as brown plant hopper, white backed plant hopper and non- insect pests such as spider mites by acting as physiological barrier (Savant *et al.* 1997 and Ma and Takahashi, 2002). Silicon depositions in monocots may provide a mechanical barrier against insect's pests. However, this passive role of silicon is now being contested and an active role of silicon have been shown in physiological resistance of crops to diseases. Silicon is now considered to have a catalytic role in the expression of physiological resistance through the production among other chemicals, tannic and phenolic compounds (Laing *et al.* 2005).

5.9 Effect of diatomaceous earth on Sigatoka leaf spot intensity in banana

Silicon has been shown to ameliorate the effects of abiotic and biotic stresses for many agronomically important species. In essence, silicon can affect soils, roots, and shoots benefiting plants in ways not solely confined to monocots. Whereas the effect of diatomaceous earth on Sigatoka leaf spot intensity in banana shows significant difference among the treatments at five months after planting and harvesting stage (Table 15 and Fig. 6).

The lowest Sigatoka leaf spot index was noticed (19.86%) in T₁₀ (RDF + 750 kg/ha DE) which was on par with T₉ (RDF + 500 kg/ha DE), T₈ (RDF + 250 kg/ha DE) and T₆ (Half of RDF + 500 kg/ha DE), whereas highest Sigatoka leaf spot index (37.24%) was noticed in the treatment T₁ at five month after planting. However, at harvesting stage lowest Sigatoka leaf spot index was noticed (24.56%) in T₁₀ (RDF + 750 kg/ha DE) which was on par with T₉ (RDF + 500 kg/ha DE) whereas, highest Sigatoka leaf spot index (44.21%) was noticed in T₁, due to Silicon protects the plant by other processes which can boost the defense mechanisms, including the accumulation of lignin, phenolic compounds, and phytoalexins. In case of an attack

by pathogenic fungi, Si triggers a rapid and extensive deployment of the natural defenses of the plant either indirectly by sequestering cations or directly by increasing some protein activity. In the case of powdery mildew, it had been shown that when infection occurs after Si fertilization, the pathogen usually remains, but the development of the infection is minimal. Extensive researches on epidermal cells have shown that in Si-fertilized plants.

Two hypotheses for the Si-enhanced resistance to diseases have been proposed. One is that Si deposited on the tissue surface acts as a physical barrier. It prevents physical penetration and / or makes the plant cells less susceptible to enzymatic degradation by fungal pathogens. This mechanism is supported by the positive correlation between the Si content and the degree of suppression of diseases. The other one was that Si functions as a signal to induce the production of phytoalexin (Feng, 2004). Similar results were noticed by Kumbargire *et al.* (2015), Kaiser *et al.* (2005), Kablan *et al.* (2012), Kidane and Laing (2010) and Vermeire *et al.* (2011) in banana, Anderson *et al.* (2005), Bekker *et al.* (2007), Bertling *et al.* (2009), Kaluwa *et al.* (2010) and Bosse *et al.* (2011) in avocado. Mayer *et al.* (2010) observed that silicon helped in powdery mildew control in grape, strawberry and cucumber, but in gerbera, the reduced uptake limited its role in disease.

5.10 Effect of diatomaceous earth on macro and micronutrient status after harvesting of banana

Among the different treatments, the treatments with DE are significantly showing lowest nitrogen and phosphorous content compare to control. Whereas, micronutrients are showing non significant difference between the treatments (Table 16 and 17). This might be due to the silicon applied plants have absorbed better macro and micro nutrients and also avoiding leaching losses, from the soil. Hence the availability of nutrients was more, (Table 19 and 20) Similar results were reported by Gorecki and Danielski (2009) in cucumber, Kamenidou *et al.* (2009) in Zinnia and Ornamental sunflower and Kamenidou and Toddy (2008) in Ornamental sunflower.

5.11 Effect of diatomaceous earth on benefit: cost ratio in banana

Among the different treatments, T₁ (control) has recorded highest benefit: cost ratio (7.01) and net profit (540040 Rs. / ha). This is followed by T₄ which was applied

with DE alone. While the lowest Benefit: Cost ratio was noticed in T₂ in which recommended dose of fertilizer was added (Table 18). Silicon may also helps in absorption of nutrients from the soil which in turn resulted in higher yield with reduced dose of fertilizers. Similar results were obtained by Miyake and Eiichi (1986) in strawberry, Cai and Rian (1995) in pecan nut, Reaple and Laane (2008) in papaya, Bhavya (2010) in Bangalore Blue grapes.

5.12 Future line of work

The Silicon is beneficial or quasi-essential to crops, during the last decade, diatomaceous earth as a source of silicon is gaining importance in some crops. Hence there is a scope to study the role and nutritional content of silicon in different crops especially fruit crops in the following areas.

1. Diatomaceous earth as source of silicon in combination with other micronutrients may be studied.
2. Analogous type of work can be carried out on other commercial varieties of banana.
3. Role of diatomaceous earth for the management of pest and disease needs to be studied.
4. Studies on residual accumulation of diatomaceous earth as a source of silicon on fruits.
5. Effect of split application of diatomaceous earth can be studied.

6. SUMMARY AND CONCLUSIONS

A field experiment was carried out at the Kittur Rani Channamma College of Horticulture, Arabhavi, in Gokak taluk in Belgaum District, Karnataka to study the effect of diatomaceous earth as a source of silicon on growth, yield and quality of banana cv. Grand Naine during 2013-14. The salient findings of the investigations are summarized in this chapter.

In the present experiment, the highest pseudostem height (208.29 cm), pseudostem diameter (21.23 cm), number of leaves per plant (22.17), total leaf area (16.49 m²), total chlorophyll content (2.39 and 2.56 mg/g at five MAP and at the time of harvesting) and number of suckers (5.39) were noticed T₁₀ (RDF + 750 kg/ha) which was on par with T₉, T₈, T₇ and T₂. Whereas the lowest values for pseudostem height (142.61 cm), pseudostem diameter (13.67 cm), number of leaves per plant (15.66), total leaf area (8.52 m²), total chlorophyll content (0.89 and 0.93 mg/g at five MAP and at the time of harvesting) and number of suckers (3.39) were recorded in T₄ (DE alone).

With respect to crop duration, the minimum number of days taken for flowering (280.33 days), and total duration (408.94 days) was recorded in T₁₀ (RDF + 750 kg/ha of DE). However, T₁₀ was on par with T₉ (RDF + 500 kg/ha DE), T₈ (RDF + 250 kg/ha DE) and T₂ (RDF only) and maximum days taken for flowering (345.61 days), and total duration (455.77 days) was recorded in T₄ (DE alone).

The highest bunch length and width (90.65 cm and 44.87 cm respectively) was recorded in T₁₀ (RDF + 750 kg/ha DE) which was on par with T₉ (RDF + 500 kg/ha DE). However, the minimum bunch length and width (66.31 and 35.17 cm respectively) was recorded in T₁. The maximum number of hands per bunch (13.43) was noticed in T₈ (RDF + 250 kg/ha DE) which was on par with T₉ (RDF + 500 kg/ha of DE) and T₁₀ (RDF + 750 kg/ha of DE). On the contrary, lowest number of hands per bunch (8.16) was noticed in T₁. In case of number of fingers in 3rd hand and total number of fingers per bunch were maximum in soil application of DE treatments T₁₀ (RDF + 750 kg/ha DE) which was on par with T₉ (RDF + 500 kg/ha DE) as compared to control and lowest value was found in T₁.

The highest finger weight (145.19 g), finger volume (138.51 ml), finger length (22.51 cm), pulp weight (110.96 g) and pulp to peel ratio (3.52) were recorded with T₁₀ (RDF + 750 kg/ha DE) and minimum values for finger weight (84.16 g), finger volume (96.57), finger length (12.99cm), pulp weight (59.13 g) were recorded in T₁ whereas, the highest value for finger diameter (3.75 cm) was found with T₉ (RDF + 500 kg/ha DE) which was on par with the treatment T₁₀.

The quality parameters *viz.* days for ripening, shelf life, TSS, acidity, reducing sugars, non reducing sugars, total sugars and sugars to acid ratio content were found to be increased with the soil application of DE compared to control. This revealed that soil applied with DE of 750 kg/ha, 500 kg/ha and 250 kg/ha proved to be better in improving the quality parameters.

The maximum bunch weight (20.86 kg) was recorded in T₁₀ (RDF + 750 kg/ha DE) which was on par with T₉ (RDF + 500 kg/ha DE), T₈ (RDF + 250 kg/ha DE), T₆ (Half of RDF + 500 kg/ha DE) and T₃ (Half of RDF) whereas, the lowest bunch weight (16.57 kg) was noticed in T₄. Similar pattern were followed for yield per plot and yield per hectare.

According to the results the highest values for (colour and appearance), and overall acceptability was found in the plants which were applied with T₁₀ (RDF + 750 kg/ha DE) whereas the lowest values were observed in the treatment T₄.

Significantly higher phosphorus (0.47%), potassium (1.74%) and silicon (1.26%) content in leaf of banana was recorded with T₁₀ (RDF + 750 kg/ha DE) and minimum values were recorded in T₁ (0.40%), T₆ (0.95%) and T₃ (0.56%) respectively. The highest zinc (10.50ppm) was noticed in T₂ (RDF), and highest silicon content (1.26%) was found in T₁₀ (RDF + 750 kg/ha DE) and lowest values (0.56%) were obtained in T₃.

The treatment T₁₀ (RDF + 750 kg/ha DE) recorded the minimum number of whitefly colonies per leaf (2.17), minimum number of whitefly per colony (2.40) and per cent leaf infestation of whitefly (12.81) found effectual in tumbling the whitefly incidence in banana whereas the maximum number of white fly colonies per leaf (6.39), maximum number of whitefly per colony (6.75) and per cent leaf infestation (32.63) whitefly infestation was recorded in T₁ (Absolute control).

Lowest Sigatoka leaf spot index (19.86% and 24.56%) was noticed in T₁₀ (RDF + 750 kg/ha DE) which was on par with T₉ (RDF + 500 kg/ha DE) and T₆ (Half of RDF + 500 kg/ha DE) whereas, highest Sigatoka leaf spot index (37.24% and 44.21%) was noticed in T₁ at 5 MAP and at harvesting time respectively.

Conclusion

Among the different treatment T₁₀ (RDF + 750 kg/ha DE) has recorded higher yield, quality and lower pest and disease intensity which was on par with the treatment T₉ (RDF + 500 kg/ha DE) and T₈ (RDF + 250 kg/ha DE).

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Appendix I: Meteorological data recorded for the experimental period**Location:** KRCCH, Arabhavi, Gokak**Year:** 2013-2014

Months	Temperature (°C)		Mean Relative Humidity (%)	Rainfall (mm)
	Minimum	Maximum		
May,2013	22.33	38.11	77.03	52.45
June	21.61	21.61	86.20	56.75
July	27.96	30.97	80.60	56.75
August	28.75	29.20	78.62	40.25
September	20.28	29.45	76.00	95.34
October	19.77	29.83	70.28	110.88
November	13.54	29.47	66.40	12.37
December	11.62	28.48	47.40	2.00
January ,2014	14.45	28.85	88.00	0.00
February	15.01	31.19	92.07	0.0
March	17.35	34.57	81.00	6.0
April	20.10	37.50	72.67	5.2
May	26.90	36.30	85.00	93.8
June	22.30	33.70	87.73	63.8
July	21.60	30.60	93.00	85.3

Appendix II: Initial soil analysis data of experimental site

Sl. No.	Soil parameters	Characterization
1	pH	7.7
2	EC (dS/m)	0.56
3	OC (%)	0.77
4	CEC (c Mol/ kg)	32.3
5	N (kg / ha)	135
6	P ₂ O ₅ (kg/ha)	9.6
7	K ₂ O (kg/ha)	92.00
8	Zn (ppm)	0.44
9	Cu (ppm)	1.17
10	Mn (ppm)	3.09
11	Fe (ppm)	2.14
12	Ca (meq/100 gm)	0.12
13	Mg (meq/100 gm)	0.041
14	Si (mg/kg)	75.63

Appendix III: Economics of banana cultivation

Treatment	Input cost (Rs.)				Other costs (Rs/ha)	Total cost of cultivation (Rs/ha)	Fruit yield (t/ha)
	FYM	NPK	Si	Planting material			
T ₁ – Absolute control	-	-	-	36000	41000	77000	51.42
T ₂ – RDF*	4000	52967	-	36000	49520	142487	56.09
T ₃ – Half of RDF	2000	26483	-	36000	49520	114003	60.88
T ₄ –D.E Alone	-	-	12500	36000	47250	95750	51.13
T ₅ – Half of RDF+DE @ 250 kg/ha	2000	26483	6250	36000	49520	120253	55.56
T ₆ – Half of RDF+ DE @ 500 kg/ha	2000	26483	12500	36000	49520	126503	58.22
T ₇ –Half of RDF+ DE @ 750 kg/ha	2000	26483	18750	36000	49520	132753	55.61
T ₈ – RDF+ DE @ 250 kg/ha	4000	52967	6250	36000	49520	148737	64.08
T ₉ – RDF+ DE @ 500 kg/ha	4000	52967	12500	36000	49520	154987	63.01
T ₁₀ – RDF+ DE @ 750 kg/ha	4000	52967	18750	36000	49520	161237	64.37

Inorganic inputs**Cost in Rs.**

Urea : 6.80/kg

SSP : 12.00/kg

MOP : 14.40/kg

Organic inputs**Cost in Rs.**

Neem cake : 4.00/kg

Banana : 6.00/kg

Tissue culture plant cost : 12.00/plant

**STUDY OF DIATOMACEOUS EARTH (AS A SOURCE OF SILICON) ON
GROWTH, YIELD AND QUALITY OF BANANA cv. GRAND NAINÉ
(*Musa AAA*)**

RAVI B.

2016

**Dr. G. S. K. SWAMY
Major Advisor**

ABSTRACT

A field research was carried out to study the effect of diatomaceous earth as a source of silicon on growth, yield and quality of banana cv. Grand Naine at Kittur Rani Channamma College of Horticulture, Arabhavi, in Gokak (Tq.), Belagavi (Dist.), Karnataka, during 2013-2014. An experiment was laid out in RBD with 10 treatments and replicated thrice on plants planted at 1.8 m X 1.8 m spacing.

Among the different treatments, treatment T₁₀ (RDF+750 kg/ha DE) showed the highest pseudostem height (208.29cm), pseudostem diameter (21.23cm), number of leaves per plant (22.17), total leaf area (16.49m²), total chlorophyll content (2.39 and 2.56 mg/gm at 5MAP and at the time of harvesting, respectively), number of suckers (5.39) and the lowest were noticed in the treatment T₄ at different stages of plant growth. With respect to total crop duration, same treatment has taken less number of days (408.94) as compared to other treatments.

The highest bunch length and width (90.65cm and 44.87cm respectively) were recorded in the treatment T₁₀ (RDF+750 kg/ha DE). Similar trend was also observed for highest finger weight (145.19g), finger volume (138.51ml), finger length (22.51cm), pulp weight (110.96g), pulp to peel ratio (3.52), bunch weight (20.86kg), yield per plot (333.76kg), yield per hectare (64.37t). With respect to quality parameters like total soluble solids (22.70⁰B), acidity (0.21%), reducing sugar (20.81%) and total sugars (24.62%) were noticed in the treatment T₁₀. Whereas minimum white fly incidence and Sigatoka leaf spot index also found with the treatment T₁₀.

Among the different treatments T₁₀ (RDF+750 kg/ha DE) has recorded maximum growth, yield and quality parameters of banana which was on par with the treatment T₉ (RDF+500 kg/ha DE) and T₈ (RDF+250 kg/ha DE), while, minimum was noticed in T₄ (500 kg/ha DE alone).

