STUDY ON EFFECT OF DIATOMACEOUS EARTH (AS A SOURCE OF SILICON) ON GROWTH, YIELD AND QUALITY OF POMEGRANATE Cv. Kesar

ANAND SADASHIV KALATIPPI

DEPARTMENT OF FRUIT SCIENCE
KITTUR RANI CHANNAMMA COLLEGE OF HORTICULTURE, ARABHAVI – 591 218
UNIVERSITY OF HORTICULTURAL SCIENCES, BAGALKOT- 587 102

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By
ANAND SADASHIV KALATIPPI

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

This is to certify that the thesis entitled “STUDY ON EFFECT OF DIATOMACEOUS EARTH (AS A SOURCE OF SILICON) ON GROWTH, YIELD AND QUALITY OF POMEGRANATE Cv. Kesar” submitted by ANAND SADASHIV KALATIPPI 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.

Place: Arabhavi
Date: June, 2014

(G. S. K. SWAMY)
Chairman
Professor,
Department of Fruit Science
K.R.C. College of Horticulture, Arabhavi

Approved by
Chairman: ______________________________
(G. S. K. SWAMY)

Members: 1.__________________________
(P.M. GANGADHARAPPA)

2.__________________________
(S. L. JAGADEESH)

3.__________________________
(N. THAMMAIAH)

4.__________________________
(L. B. ASHOK)

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JUNE, 2014 (ANAND SADASHIV KALATIPPI)

Affectionately dedicated to

Parents

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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.	ppm	Parts per million
14.	Si	Silicon
15.	DE	Diatomaceous Earth

1. INTRODUCTION

Pomegranate (*Punica granatum* L.) is one of the important arid region fruit crop and being grown from ancient times for its sweet-acidic fruits, ornamental and medical purposes. It belongs to order Punicaceae with family Punicaceae. Punica is only known genus of this family. The two species belongs to genus *Punica* are *Punica granatum* (cultivated one) and *Punica protopunica* (wild type). *Punica granatum* has been classified into two sub-species like *Punica chlorocarpa* and *Punica porophyrocarpa.*

It is commonly known as 'Dalimbe' in Kannada and ''Anar' in Hindi. It is indigenous to Iran and is cultivated extensively in mediterranean countries like Spain, Morocco, Egypt, Iran and Afghanistan. In India pomegranate is commercially cultivated in Maharashtra, Karnataka, Gujarat, Rajasthan, Tamil Nadu, Andhra Pradesh, Punjab and Haryana. In India, pomegranate occupies an area of 113.20 thousand hectares with a production of 745.00 thousand metric tons and productivity of 6.6 metric tons/ha. Maharashtra is the leading producer in India which produces 54.80 per cent of total production followed by Karnataka (20.20 %). In Karnataka, it is grown over an area of about 15.10 thousand hectares with 150.30 thousand metric tons production and productivity of 10.00 metric tons/ha (Anon, 2013).

Pomegranate is used as table fruit; for Preparation of juice, wine, jelly and syrup; for extraction of tanin and phenols; preparation of anarrab (pomegranate jam), anardana (seeds used as spice) ; rind powder is used in leather, pharmacetical, dying and herbal industries.

The crop production of pomegranate can be increased by balanced nutrition on the profitable basis even though it is growing in the arid condition. The growth, yield and quality of pomegranate can be increased by application of manures and fertilizers because it is well respond to application of fertilizers.

Pomegranate can be grown on diverse types of soil. Tree can also be grown in soils which are unsuitable for other fruit crops. It can tolerate soils which are limey and slightly alkaline. The loamy or alluvial soils are ideal for pomegranate cultivation. Pomegranate grows well in soils of low fertility, but yield and quality can be increased by application of manures, fertilizers and beneficial elements.

Pomegranate can be grown in the plains as well as on the hills upto an elevation of about 1840 meters. The tree is deciduous in low temperature condition and evergreen or partially deciduous in tropical and sub-tropical condition. The tree requires hot and dry climate during the period of fruit development. Humid climate will affect the fruit quality. It is winter hardy and drought tolerant plant, frequent anomalies of the climate cause leaf shedding and fruit cracking.

Silicon is the most abundant element in the earth's crust region next to oxygen and comprises 28 per cent of its weight out of which 3-17 per cent is present in soil solution (Epstein 1999). It is most commonly found in soils in the form of solution as silicic acid (H_4SiO_4) and is taken up directly as silicic acid (Ma *et al.,* 2001). Being a dominant component of soil minerals it has many important functions in environment, although silicon is not considered as an essential plant nutrient because of its ubiquitous presence in the biosphere and most plants can be grown from seed to seed without its presence (Epstein, 1999).

Among the plants, silicon concentration is found to be higher in monocotyledons than in dicotyledons and its level increased from legumes < fruit crops < vegetables < grasses < grain crops.

The role of silicon in plant biology is to reduce multiple stresses including biotic and abiotic stresses. It is also known to increase drought tolerance in plants by maintaining plant water balance, photosynthetic activity, erectness of leaves and structure of xylem vessels under high transpiration rates (Melo *et al.,* 2003). Silicon application improved water economy and dry matter yield (Gong *et al.,* 2003). It enhanced the leaf water potential under water stress conditions, reduced the incidence of micronutrient and metal toxicity (Matoh *et al.,* 1991).

The presence of Silicon also been reported to affect the absorption and translocation of several macro and micro-nutrients. Si is accumulated in plants to total concentrations in dry matter similar to those of essential macro-nutrients such as Potassium, Calcium, Magnesium, Sulphur and Phosphorous (Epstein, 1999). More recently, silicon amendments were shown to reduce the leaching of phosphate, nitrate and potassium (Matichenkov and Bocharnikova, 2010).

Silicon has positive growth effect including increased dry mass and yield, enhanced pollination and most commonly increased disease resistance (Gillman *et al.,* 2003).

Silicon is known to effectively mitigate various abiotic stresses such as manganese, aluminium and heavy metal toxicities, salinity, drought, chilling and freezing stresses (Liang *et al.,* 2007).

Numerous laboratory, greenhouse and field experiments have showed the benefits of silicon fertilizers on agriculture and horticulture crops and the importance of silicon fertilizers as a component in sustainable agriculture was reported by Ma and Takahashi (2002).

Realizing the beneficial effects of silicon in sustainable crop production and the response of several crops to silicon nutrition for sustained crop yields, it has become a component of integrated nutrient management in certain countries.

With this brief 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 pomegranate cv. Kesar with the following objectives:

1. To study the effect of Diatomaceous earth (DE) on growth and yield of pomegranate.

2. To study the effect of Diatomaceous earth (DE) on quality of pomegranate.

3. To study the effect of Diatomaceous earth (DE) on intensity or incidence of disease in pomegranate.

2. REVIEW OF LITERATURE

Pomegranate is one of the important fruit crops, known to receive medium quantities of nutrients and supply of nutrients to the plant which is very important to attain higher growth, yield and quality of fruits.

Silicon (Si) is not yet classed as an essential nutrient but it exists in all plants grown in soil. Silicon is taken up at levels equal or greater than essential nutrients such as Nitrogen and Potassium in certain plants such as rice and sugarcane, for which it is considered agronomically essential for sustainable crop production (Savant *et al,* 1999). Silicon can benefit the plant in terms of growth and crop quality, stimulates photosynthesis, reduces transpiration rate and increases plant resistance to abiotic and biotic stresses (Ma and Takahashi, 2002). Plant available silicon forms deposits of amorphous silica, known as phytoliths (sometimes in association with cellulose and proteins), in the plant tissues (Neumann *et al,* 1997). Silicon accumulates in greater concentrations with increasing age of the tissues, dependent on the species, cultivar1 and the external availability of plant available silicon. Silicon impregnates the walls of epidermal and vascular tissues where it appears to strengthen the tissues, retard fungal infection and reduces water loss (Tisdale *et al.,* 1993). Most of the research conducted on the benefits of silicon is in field crops, but the role of silicon in the nutrition of horticulture crops especially in fruit crops has not been well investigated in comparison to agricultural crops like rice (Iler, 1979).

The research on use of silicon on pomegranate production is very much limited. The work done on similar aspects of horticulture 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 parameters of horticultural crops

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

2.4 Influence of silicon on pest and diseases.

2.5 Influence of silicon on physiological disorders of fruit crops.

2.1 Influence of silicon on disease management, growth and quality parameters

2.1.1 Influence of silicon on growth of horticultural crops

Although, silicon is not considered as an essential element, but has positive effect on growth including increased dry mass and yield, enhanced pollination and most commonly increased disease resistance (Gillman *et al.,* 2003). The plant height was quadratically related to the rate of silicon application, while it related linearly with crop plant stem diameter (Elawad *et al.,* 1982).

2.1.1.1 Fruit crops

Plants continuously subjected to 50 ppm 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 pecan nut could increase the concentration of chlorophyll in the leaves, strong shoot development, double the nut formation and dry weight of the nut. Study conducted by Cai and Rian (1995b) observed that silicon fertilizer applied at the rate of 15 kg per tree to soil with concentration of available range from 314 to 404 mg SiO_2/Kg enhanced healthy growth and had stronger shoot, thicker and darker green leaves in apple.

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 was observed in 10 ppm of soluble silica and root weight increased in 20 ppm of soluble silica (David and Vladimir, 1999). Optimization of silicon nutrition was responsible for a significant increase in mass of roots and green mass of germinated marsh grape fruit seedlings (Vladimir *et al.,* 2001).

Passion fruit seedlings responded well to the calcium silicate application. The 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 along with application of calcium silicate (Prado and Natale, 2005).

Three different genotypes *viz. 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 silicon supply (0-1.66 mm Si) to quantify the silicon uptake and distribution in banana, as well as to study the effect of silicon on banana growth. The rate of silicon uptake and the concentration in plant tissues increased markedly with the silicon 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 SA at 10 days interval (6 sprays) and 6 ml/L 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 effect of 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 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) observed the modifications in leaf anatomy of banana plants cultivar 'Maçã' subjected to different silicon sources under *in vitro* condition. The addition of calcium silicate resulted in greater thickness of upper and lower epidermis, mesophyll, palisade parenchyma and increased photosynthetic rate. The use of silicon improved the micro propagated anatomy of banana plant cultivar 'Maçã' leaves.

Manjunatha *et al.* (2014) reported that, among the micronutrient combinations, application of $ZnSO_4$ (0.25 %) + Borax (0.1 %) + $FeSO_4$ (0.5 %) followed by $ZnSO_4$ (0.25 %) + Borax (0.1 %) and soluble silicic acid at 5 ml/L were best treatment combinations with respect to vegetative and reproductive parameters.

2.1.1.2 Vegetables

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

Application of silicate fertilizer promoted the growth and yield of cucumber plants, and also reduced the damage caused by wilt disease. However, successive application of silicate fertilizer resulted in the increase of soil pH year after year and adversely affected the growth of cucumber plants (Miyake and Eiichi, 1983).

Adatia and Besford (1986) reported 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 silicon 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 application to the growth media significantly improved the growth of melon plant.

Wang *et al.* (2007) studied the effect of silicon fertilizer on cucumber photosynthesis in protected field. The results showed that the content of chlorophyll, photosynthesis rate, and water use efficiency of the cucumber leaves increased first, and then decreased with the growing input of silicon fertilizer, and reached the highest at the level of 125 mg/kg silicon fertilizer, whereas on the contrary, the transpiration rate changed oppositely.

Seome *et al.* (2008) reported that, application of silicon as slag increased the plant growth, leaf area and yield in potato 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 phosphorous and silicon soil availability and plant uptake (Pulz *et al.,* 2008). Luz *et al.* (2008) stated that application of K_2SiO_3 at 1 per cent increased the chlorophyll a, b and total chlorophyll content, increased plant height and leaf area in all parts of the potato plant canopy.

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

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

Emrich *et al.* (2011) evaluated 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, root length, shoot dry weight and root dry weight were significantly increased by silicon solutions as compared with sulphate solutions in French bean. Lettuce (*Lactuca sativa* L. 'Eish') grown in soilless culture resulted significant increase in fresh root, shoot length and shoot weight compared to control. Applications of 2 and 4 mM silicon increases plant weight and thus benefited 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.

Among the soil application of sodium silicate at different rates like 0, 5, 10 and 15 mg Si/Kg soil in broad Bean (*Vicia faba* L.), 15 mg/Kg soil Si have shown the best results. The characteristics measured are day to flowering, flower number, pod weight, seed number, plant fresh weight, plant dry weight and chlorophyll index (Ghasemi, 2013).

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

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

2.2.1 Fruit plants

Strawberry plants applied at 50 ppm SiO_2 recorded increased top weight, fruit weight, fruit yield and also showed increased pollen fertility (Miyake and Eiichi, 1986).

Cai and Rian (1995b) reported that apple tree receiving silicon fertilizer at 15 Kg/tree to soil with a concentration of 314 to 404 mg SiO_2/Kg, enhanced yield (10 %) and fruits become red 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. Cai and Rian (1995a) reported that silicon fertilization to pecan nut tree could increase the nut yield.

Potassium silicate (K_2Si0_3) applied to grapes cv. Bacchus. 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 per cent in courgette, with strawberry, a clear reduction was observed in the incidence of powdery mildew. This improved crop yield and quality was obtained with silicon (1 mM Si/L) amendment.

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

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

Bertling *et al.* (2009) placed 'Hass' avocado fruit into 5, 13 and 25x 10^3 ppm silicon (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 silicon concentrations in fruit fresh weight declined significantly faster in control than in Si-treated fruit, with the highest silicon application maintaining the highest weight.

Bhavya (2010) reported that application of 4 ml and 6 ml/L foliar SA at 10 days interval (6 sprays) and 6 ml/L foliar SA at 20 days interval (3 sprays) significantly influenced yield and quality parameters over control in Bangalore blue grape.

The different sources of silicon (potassium silicate, non toxic-silica, calcium silicate, sodium metasilicate and bio silicate) were used as post-harvest dips and pre-harvest soil drenches. The results revealed that post-harvest applications of silicon 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 (Kaluwa *et al.,* 2010).

Chitu *et al.* (2010) studied the effect of foliar applied clay on the apple fruit quality. Kaolin treatments reduced the losses significantly 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.

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 that 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 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. Post-harvest 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.

2.2.2 Vegetables

Adatia and Besford (1986) reported increased number of fruits, average fruit weight due to the application of silica solution at 3 mM 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/L 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 silicon concentration. Thus, silicon amendment resulted in delaying foliage senescence increased pumpkin yield by 60 per cent without increasing the cost of production (Heckman *et al.,* 2003).

Gang and Jiashu (2005) studied the effects of silicon on earliness and photosynthetic characteristics of melon. Plants grown in the presence of silicon showed a significant increase in early yield, which was resulted from earlier flowering, lower fruiting node and decreasing fruit abortion. Addition of silicon in the solution caused a significant increase in chlorophyll contents in both varieties and silicon contents in leaves and roots, but an obviously reduction in transpiration.

Wang *et al.* (2007) studied the effect of silicon fertilizer on yield of cucumber in protected field. The yield of cucumber increased with the growing input of silicon fertilizer when the silicon fertilizer was below 100 mg/kg. The yield of cucumber increased by 10.2 per cent. Meanwhile, the yield of cucumber decreased with the growing input of silicon fertilizer when the silicon fertilizer was above 100 mg/kg level.

Tesfagiorgis *et al.* (2008) reported increased plant yield due to with the application of 50 to 100 mg/L of silicate fertilizer by optimal disease in control and maximum growth in zucchini.

Luz *et al.* (2008) reported that increase in the yield up to 22.4 per cent could be obtained with the application of one per cent K_2SiO_3 in potato plants.

Crusciol *et al.* (2009) studied the effects of silicon and drought stress on tuber yield and leaf biochemical characteristics in potato. They observed that silicon application and water deficit resulted in the greatest silicon concentration in potato leaves. Proline concentrations increased under lower water availability and higher silicon availability in the soil, which indicates that silicon may be associated with plant osmotic adjustment. Water deficit and silicon application decreased total sugars and soluble proteins concentrations in the leaves. Silicon application reduced stalk lodging and increased mean tuber weight and, consequently, tuber yield, especially in the absence of water stress.

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 silicon 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).

Savvas (2009) reported that application of silicon 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 silicon 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 was found at the highest potassium silicate rate with p^H 5.5 compared to the control. Yield increased by 30 and 43 per cent respectively, as the potassium silicate rates increased from 0 to 60 g/L with p^H 5.5 and 10.5.

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

Kayaa *et al.* (2011) studied the effects of silicon and high boron on growth and yield of tomato (*Lycopercison 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 Si 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 Si used for treatment of potato tubers before sowing at low application rates of 20-40 kg/ha, has a favorable action on the yield and quality of the tubers. In comparison with the control, the additional yield achieved on the background of Si (20-40 kg/ha) was 18-20 per cent. The best biochemical composition was for the tubers wetted with water and Si-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. Si can be recommended for potato cultivation under conditions of conventional and organic agriculture.

Fernando *et al.* (2012) studied the effect 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/m^2) in the plots that were fertilized with silicon.

Miyake and Eiichi (2012) studied the effect of silicon on reproductive growth of tomato plant. The plant was supplied with 100 ppm of silicon 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).

Kardoni *et al.* (2013) studied the effect of salinity stress and silicon application on yield and component yield of faba bean (Viciafaba) and result showed that the increase in salinity level caused the significant reduction in number of seeds in pod, number of pod and dry matter. The interaction effect of silicon application and salinity stress was significant on 100-seed weight and yield of bean. The highest and lowest yield was found in 1mM Si concentration under 1ds/m salinity stress and without Si treatments in 5 ds/m salinity stress. Silicon application significantly increased 100 seed weight and yield of faba bean under saline environments. Finally concluded that use of Si in salinity condition reduced harmful effects of salinity on the yield component in bean plant.

Parande *et al.* (2013) conducted an experiment including the treatments like 5 levels of soil salinity (1, 2, 3, 4, 5 ds/m) and 4 levels silicon (0, 0.5, 1, 2 mM). Results showed that the increase in salinity caused significant reduction in number of seeds in pod, number of fertile pod and dry matter. The interaction effect of silicon application and salinity stress was significant on 100-seed weight and yield of bean. The highest 100 seed weight (56.1) and grain yield (144.2 g/m2) was obtained in concentration of 1mM Si in level of 1ds/m salinity.

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

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 potassium silicate which gave the highest K (%) values in plant tissue compared to other treatments (Nesreen *et al.,* 2011).

2.3.1 Fruit 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).

Six different grapevine cultivars were grown in recirculating nutrient solutions supplied with different amounts (112, 10 and 0 ppm) of SiO_2; the solutions were changed weekly. The average $Si0_2$ content of leaf dry matter at harvest time (0.1-2 %) was correlated with leaf age and the $Si0_2$ concentration of the nutrient solution, whereas in stems and petioles it was less than 0.1 %. Significant varietal difference was found only for cv. Regent which accumulated about 20 % more $Si0_2$ than the other varieties from the 112 ppm solutions (Blaich and Grundhofer, 1997).

Silicon content of grapefruit seedlings treated with amorphous silica increased from 0.07 to 0.16 per cent in shoot and from 0.16 to 0.43 per cent in root (David and Vladimir, 1999).

Silicon rich substances applied to the soil enhanced the initial growth of grapefruit seedlings and the silicon content of orange and grapefruit leaves increased with leaf age and related to the silicon status of the soil (Snyder, 1999).

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 in banana.

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 silicon 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. Grand Naine) were grown in hydroponics at variable silicon supplies (0.08, 0.42, 0.83 and 1.66 mM Si). Results were expressed as delta 29Si relative to the NBS28 standard, with an average precision of + or -0.08 per mil (+or-2 sigma D). The fractionation factor 29 epsilon between bulk banana plantlets and source solution is -0.40 + or -0.11 per mil.

Soylemezoglu *et al.* (2009) studied the effect of silicon on antioxidant and stomatal response of grapevine (*Vitis vinifera* L.) rootstock grown in boron toxic, saline and boron toxic-saline soil. The results reveal that, rootstock supplied with silicon (4 mM) counteracted the deleterious effect of salinity and boron toxicity on shoot growth by lowering the accumulation of Na in 1103P and B and Cl in both rootstock.

Thomas *et al.* (2010) studied the effect of various foliar sprays on some fruit quality attributes and leaf nutritional status of the peach cultivar 'Andross. Foliar application of agriphos, chelan-K, silene-K, and KNO_3 resulted in an increase of K concentration of leaves compared to the control.

Su *et al.* (2011) studied the effect 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.

Lalithya *et al.* (2014) conducted an experiment and concluded with results that, application of silicon sources like potassium silicate and calcium silicate on sapota crop showed the results as of macro nutrients like nitrogen (1.583 %), phosphorous (0.175 %) and the potassium (1.20 %), Silicon content (1.20 %) was more in the treatment with foliar application of potassium silicate at 8 ml per litre resulted in more yield and quality of sapota fruits.

2.3.2 Vegetables

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).

Horst and Marschner (2002) studied the effect of silicon on manganese tolerance of bean plants (*Phaseolus vulgaris* L. var. 'Red Kidney') grown in water culture at different levels of manganese supply. In the presence of silicon, a higher proportion of the leaf manganese could be found in the press sap, *i.e.*, had been transported into the vacuoles, than in the absence of silicon. The increase in manganese tolerance of bean leaves by silicon therefore seems to be primarily caused by the prevention of local manganese accumulation within the leaf tissue which leads to local disorders of the metabolism and, correspondingly, growth depression.

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

Khalid *et al.* (2005) studied the influence of silicon supply on chlorophyll content, chlorophyll fluorescence, and antioxidative enzyme activities in tomato plants under salt stress. The results indicated that silicon partially offset the negative impacts of NaCl stress with increased the tolerance of tomato plants to NaCl salinity by raising SOD and CAT activities, chlorophyll content, and photochemical efficiency of PSII.

Mercedes *et al.* (2006) investigated the role of silicon in alleviating the deleterious effects of salinity on plant growth of tomato cultivar Moneymaker. They concluded that silicon improves the water storage within plant tissues, which allows a higher growth rate that, in turn, contributes to salt dilution into the plant, mitigating salt toxicity effects.

Gunes *et al.* (2007) reported that, spinach plants were grown with 0 or 30 mg kg^{-1} boron combined with 0 and 150 mg kg^{-1} Si. The severity of leaf symptoms of B toxicity was lower when the plants were grown with 150 mg kg^{-1} Si. Silicon supplied to the soil with high B counteracted the deleterious effects of B on root and shoot growth, decreased B concentration in the shoots but increased it in the roots, Stomatal conductance of the plants increased, concentrations of H_2O_2 and proline were decreased, ameliorated the membrane deterioration, decreased non-enzymatic antioxidant activity (AA) and the activities of major antioxidant enzymes like superoxide dismutase (SOD), catalase (CAT) and ascorbate peroxidise (APX).

Application of silicon reversed the negative effects of excess manganese (Mn) like inhibition of net photosynthetic rate (Pn), stomatal conductance, yield of the photosystem II photochemical reactions (Fv/Fm) and the quantum yield of photosysytem II electron transport (PSII). In the further investigation, it was observed that application of Si significantly increased the activities of enzymes related with ascorbate-glutathione cycle including ascorbate peroxidase (APX), dehydroascorbate reductase (DHAR) and glutathione reductase (GR) in cucumber chloroplast under excess Mn, this could be responsible for the lower accumulation of H_2O_2 and lower lipid peroxidation of chloroplast induced by Mn, and resulted in keeping higher photosynthesis (Jian-peng, 2009).

Cucumis sativus cv. Jinchun 4 was hydroponically cultivated and watered with different concentrations of silicon (0, 0.1 and 1 mmol L^{-1}) and separately exposed to normal (25/18°C) or chilling (15/8°C) temperatures for six days under low light (100 µmol m-2 s-1). Compared to normal temperatures, chilling resulted in partially withered leaves and increased malondialdehyde content. When 0.1 or 1 mmol L^{-1} exogenous silicon was combined with chilling, the withering of the cucumber leaves was reduced, the endogenous silicon content was increased and antioxidants such as superoxide dismutase (SOD), glutathione peroxidase (GSH-Px), ascorbate peroxidase (APX), monodehydroascorbate reductase (MDHAR), glutathione reductase (GR), reduced glutathione (GSH) and ascorbate (AsA) were more active. The levels of malondialdehyde (MDA), hydrogen peroxide (H_2O_2), superoxide radical were lower (Jiao-jing *et al.,* 2009).

Gonzalo *et al.* (2013) reported that, cucumber plants grown in hydroponic culture under iron limiting conditions were treated with different Si doses (0.0, 0.5 and 1.0 mM). Si addition in cucumber delayed the decrease of stem dry weight, stem length, node number and iron content in stems and roots independently of the dose, but no-effect was observed in chlorosis symptoms alleviation in leaves.

Khoshgoftarmanesh *et al.* (2013) conducted an experiment to study the effect of silicon (Si) on salinity-induced oxidative damages of cucumber in a greenhouse by using two cucumber cultivars (Cucumis sativus L. cvs. Negin and Super Dominus) exposed to two salinity levels (0 and 50 mM NaCl) and two Si levels (0 and 1 µM). Leaf malondialdehyde (MDA) content increased in 'Super Dominus' while it remained unchanged in 'Negin' by salt stress. Silicon increased activity of catalase (CAT), ascorbate peroxidase (APX) and guaiacol peroxidase (GPX) in the leaves of cucumber.

Pilon *et al.* (2013) reported that, soil application of soluble Si (50 mg dm^{-3} Si) increased the Si concentration in leaves, stems, roots, phosphorous concentration in leaves, dry weight of leaves and stems, while foliar application of soluble Si (three sprays of 1.425 mM Si water solution, prepared with a soluble concentrate stabilized silicic acid) resulted in greatest Si concentration in leaves. Silicon application, regardless of the application method, increased leaf area, specific leaf area, and pigment concentration (chlorophyll *a* and carotenoids) as well as photosynthesis and transpiration rates of well watered potato plants.

2.4 Influence of silicon on pest and diseases

Shen *et al.* (2010) studied the inhibitory effects of potassium silicate on five soil-borne phytopathogenic fungi *in vitro*. Results showed that the growth of four of the fungal isolates (*Rhizoctonia solani*, *Pestalotiopsis clavispora*, *Fusarium oxysporum* and *Fusarium oxysporum* f. sp. *fragariae*) was significantly inhibited on potassium silicate amended PDA plates.

2.4.1 Fruit crops

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 silicon deposits.

Puterka *et al.* (2000) had successfully used formulated kaolin against the pear psylla *C. pyricola*. It has six mechanisms or mode of action *i.e* repellence, ovipositional deterenrrence, reduced feeding efficacy, impeded grasping of the host, host camouflage and direct mortality.

Donald *et al.* (2002) studied the foliar fertilization of mango cv. Haden for the control of malformation. Of the seven applied foliar treatments, NV5 containing micronutrient and silicon reduced by 50 per cent the damage caused by the witch's broom and foliar spray containing honey and honey combined with silicon was quite effective.

Takeshi *et al.* (2004) tested potassium silicate (SiO_2) at different concentrations *i.e.*, 0, 25, 50 and 100 mg/L in hydroponics to control the powdery mildew in strawberry. They found that the powdery mildew was spread in the control plot, but little mildew developed in the plot with 25 mg/L silicate, and none in plots with more than 50 mg/L silicate.

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.

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 SiO_2) had completely suppressed the fungi in avocado.

Tian *et al.* (2005) studied the synergistic effects of biocontrol yeasts *Cryptococcus laurentii* and *Rhodotorula glutinis* combined with silicon against *Alternaria alternate* and *Penicillium expansum.* Molds were investigated in jujube fruit (Chinese date, *Zizyphus jujuba*) stored at 20 and 0 ^{0}C, respectively. Combinations of *C. laurentii* and *R. glutinis* at 5 x 10^7 cells/ml with 2 per cent silicon was most effective in controlling the diseases caused by *A. alternate* and *P. expansum* on jujube fruit stored at 20 ^{0}C. When fruits were stored at 0 ^{0}C, combining *C. laurentii* and *R. glutinis* with silicon was as effective against *P. expansum* as was silicon or the yeasts applied alone and was more effective in controlling *A. alternata.*

Kaiser *et al.* (2005) studied the use of liquid potassium silicate for activity against several types of phytopathogenic fungi in avocado. Inhibition of mycelial growth was dose-dependent with 100 per cent inhibition at 80 ml (pH 11.7) and 40 ml (pH 11.5) soluble silicon (20.7% silicon dioxide) per litre of agar, for all fungi tested in two experiments with the exception of *Drechslera* at 40 ml in one experiment. In addition, for the first experiment, *Colletotrichum coccodes, Mucorpusillus, Sclerotium rolfsii, Sclerotinia sclerotiorum and Phytophthora cinnamomi* were completely inhibited at 5, 10 and 20 ml of soluble silicon per litre of agar.

Eswaran and Manivannan (2007) studied the effect of foliar application of lignite fly ash on the management of papaya leaf curl disease. The study revealed that foliar application of LFA (Lignite fly ash) dust at 2 kg/plant at 90 and 120 DAT was very effective in controlling papaya leaf curl virus and its vector.

Braham *et al.* (2007) studied the efficacy of kaolin, spinosad and malathion against *Ceratitis capitata* in sweet orange orchards. The results suggest that three applications of kaolin (concentration of 5 kg formulated product /100 L) are sufficient for the control of *C. capitata* in sweet orange orchards.

Yang *et al.* (2010) studied the synergistic effect of oligochitosan and silicon on inhibition of *Monilinia fructicola* infections in apple. The results showed that the combination of oligochitosan and silicon had a synergistic effect on the control of disease caused *by M. fructicola* in apple fruit at 25 °C.

Banana plants 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 biocontrol organisms, silicon and mulching can provide an effective control option for banana growers dealing with Fusarium wilt in their plantations (Kidane and Laing, 2010).

Liu *et al.* (2010) studied the plasma membrane damage contributes to antifungal activity of silicon against *Penicillium digitatum*. The findings suggest that the damage on plasma membrane of *P. digitatum* played a crucial role in the antifungal effect of silicon. Moreover, silicon was effective in controlling green mold caused by *P. digitatum* in citrus fruit.

Bosse *et al.* (2011) studied the effect of potassium silicate on anthracnose of avocado. Fruits were treated with phosphorous acid (500 ppm) and potassium silicate (1000 ppm) Post-harvest treatments showed that both potassium silicate and phosphorous acid decreased the presence of anthracnose in stored fruit. Both compounds also influenced PAL activity, with potassium silicate having greater effects.

Umana *et al.* (2011) investigated the control of Rots of tropical Fruits with generally regarded as safe (GRAS) compounds. Application of silicon on mango fruit 24 h prior to inoculation with *Colletotrichum gloeosporioides* resulted in reduced anthracnose; severity decreased as the concentration of silicon increased.

Kablan *et al.* (2012) studied the effect of silicon on black sigatoka development in banana var. Grand Naine. The tissue culture plants were transplanted to the pots and silicon was supplied as silicic acid with the concentration of 2 mM. The results suggest that silicon has the potential to reduce the severity of black sigatoka development and could help in enhancing disease 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 Foc, 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 behaviors of *P. expansum* isolates against the combined treatments.

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.

2.4.2 Vegetables

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

Mc Avoy and Bible (1995) reported that, use of sodium silicate ($NaSiO_3$) sprays was beneficial in a study on poinsettias. The severity and occurrence of bract necrosis decreased greatly when NaSi was sprayed 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 $CaCl_2$ sprays at 400 ppm for up to five weeks after the flower began to open.

Liang *et al.* (2005) studied the effect of foliar and root applied silicon on resistance to infection by *Podosphaera xanthii* (syn. *Sphaerotheca fuliginea*) and the production of pathogenesis-related proteins (PRs). Based on the findings in this study and previous reports, it was concluded that foliar applied Si can effectively control infections by *P. xanthii* only via the physical barrier of silicon deposited on leaf surfaces, and/or osmotic effect of the silicate applied, but cannot enhance systemic acquired resistance induced by inoculation, while continuously root-applied silicon can enhance defense resistance in response to infection by *P. xanthii* in cucumber.

Rajendran and Saritha (2005) studied the effect of essential nutrients application for the management of root-knot nematode *Meloidogyne incognita* on tomato. Treatment with silica resulted in the greatest shoot length (45.0 cm), root length (9.2 cm), shoot weight (44.4 g) and root weight (6.6 g), and in the lowest number of females/g of root (6.5), number of egg masses/g of root (3.5), nematode population/250 g of soil (226.5) and gall index (2.0).

Kanto *et al.* (2006) conducted a study to examine the liquid potassium silicate to suppress the occurrence of strawberry powdery mildew on leaves. Liquid potassium silicate 500 mg/L as SiO_2 was applied at an average rate of 0.95 g SiO_2 with a liquid fertilizer auto feeder during the cultivation period.

Palmer *et al.* (2006) studied the effect of foliar-applied Ca and silicon on the severity of powdery mildew in two strawberry cultivars. Powdery mildew symptoms were reduced only when both fungicide and potassium silicate were applied while potassium silicate alone or calcium chloride had no significant effect.

Vitanovic *et al.* (2006) studied the effectiveness of diatomaceous earth in controlling olive fruit fly. Treatment with diatomaceous earth reduced infestation by 51.4 per cent compared to the untreated control (to 45.4% actual infestation).

Gregor *et al.* (2007) revealed the effect of silicon supply on the infection and spread of *Pythium aphanidermatum* in the roots of tomato (*Solanum lycopersicum*) and bitter gourd (*Momordica charantia*). It was concluded that continuous silicon supply significantly inhibited the basipetal spread of the pathogen from the infected root apex in bitter gourd but not in tomato. This is due to accumulation of silicon in the root cell walls which does not represent a physical barrier to the spread of *P. aphanidermatum* in bitter gourd and tomato roots. The maintenance of elevated symplastic silicon contents is a prerequisite for silicon enhanced resistance against *P. aphanidermatum.*

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

Dugui *et al.* (2010) studied the effect of silicon in managing *Meloidogyne incognita* in cucumber. At 200 ppm, one application of silicon both on the leaves and roots significantly reduced the number of galls in inoculated plants. This was comparable to the same concentration applied continuously on the roots and at higher concentration (400 ppm) applied continuously on the leaves and on the roots. On the other hand, single root application of silicon at the rate of 400 ppm gave the lowest number of egg masses, however, it was comparable to the same silicon concentration applied singly on the leaves and applied continuously both on the leaves and roots. These treatments, however, were at par with continuous application of the lower rate of silicon (200 ppm) on the leaves and both leaves and roots.

Vermeiren *et al.* (2011) studied the effect of silicon 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 desilicated ferralsol and amended, or not, with 2 mM of soluble silicon under green house conditions in Guadeloupe. A reduction of about 50 per cent of root necrosis was observed 14 days after inoculation in the silicon supplied plants compared with those not supplied with silicon. The silicon amendment also alleviated growth reduction caused by the pathogen.

Yusuf *et al.* (2011) studied the effect of foliar spray of potassium silicate on powdery mildew of tomato caused by *Leveillu lataurica.* Potassium silicate concentration (1 g/L water) used in the study was not phytotoxic to plant foliage. The inhibitory effectiveness of potassium silicate makes it a useful biocompatible fungicide and possibly ideal foliar fertilizer for disease control in the field.

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

Wolff *et al.* (2012) evaluated the foliar applications of silicon fertilizers to inhibit powdery mildew development in greenhouse cucumber. The products Carbon Silpower and Carbon Defense 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 Silpower solution (with 56 mM Si) applied twice per week, reducing the disease severity by as much as 87 per cent compared to the control.

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.

Silicon solutions made from potassium silicate (K_2SiO_3) were applied as foliar sprays or soil drenches to pepper (*Capsicum annum* L.) plants, and their effects on chilli thrips (*Scirtothrips dorsalis* Hood) populations showed the minimal effects on visual leaf damage and numbers of thrips recovered from infested plants (Dogramaci *et al.,* 2013).

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 coloring 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 revealed significant reduction in leaf and fruit temperature (2.5 ^{0}c) as compared to the control (4.9%). Sunburn damage of fruit reduced from 21.9 per cent in untreated control to 9.4 per cent in the surround kaoline treated fruits.

Gao *et al.* (2006) studied the effects of silicon application on apple intermal 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 *(Punica granatum* L.*).* Application 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 application, 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 ($ZnSO_4$) 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 the controlled irrigation combined with zinc sulphate ($ZnSO_4$) 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 of *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 on *Musa* sp. cv. Rastali.

2.6 Influence of silicon on disease management, growth and quality parameters

Bekker *et al.* (2005) investigated to know the *in vitro* inhibition of mycelial growth of *Phytophthora cinnamomi* by soluble silicon at concentration of 40 and 80 ml/ pda, soluble silicon (20.7 SiO_2) which had completely suppressed the fungi.

2.6.1 Fruit crops

Strawberry plants continuously subjected to 50 ppm SiO_2 treatment and another treatment of 50 ppm SiO_2 applied only during reproductive stage showed increased dry weight of stem (19.4 g) and fruit fresh weight of (528.7 g/plant) and higher number (91.00) and also showed increased pollen fertility ratio as compared to untreated control (Miyake and Eiichi, 1986).

Bowen *et al.* (1992) reported the effect of Si & K_2HPO_4 sprays on powdery mildew colony development on Grape leaves. In this study, rooted cuttings of grape was potted in sawdust at spacing of $0.5m^2$/plant. 24 hours later inoculation on leaves was done with *Uncinula. necator* conidia. Colonies became visible and were counted after 13 days of inoculation. The results indicates that the colony development on silicon sprayed leaves was 33 per cent of that on water sprayed leaves and the severity of *Uncinula..necator* was unaffected by K_2HP0_4 on the leaves

Cai and Rian (1995a) reported that salicylic acid fertilizer application to pecan nut could increase the concentration of chlorophyll in the leaves, strong shoot development, double the nut formation, dry weight of the nut and also increase the nut yield. A study conducted by Cai and Rian (1995b) in apple observed that salicylic acid fertilizer applied at the rate of 15kg per tree to soil with concentration of available range from 314 to 404 mg SiO_2 Kg^{-1} enhanced healthy growth and had stronger shoot, thicker and darker green leaves. They also reported that the trees treated with these treatments was enhanced yield (10%) and fruits become red 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.

David and Vladmir (1999) studied the effect of different forms of silica application in citrus grown on sandy soil. Among the different forms, it was found that soluble forms of silica were more effective than powder form of silica. This resulted in maximum increase in shoot weight (0.29 gm) at 10 ppm and root weight (0.27 gm) at 20 ppm.

Kanto *et al.* (2006) reported that, the study was conducted to examine the role of liquid potassium silicate to suppress the occurrence of strawberry powdery mildew on leaves. Liquid potassium silicate 500 mg/l as SiO_2 was applied at an average rate of 0.95g SiO_2-m−2-day−1 with a liquid fertilizer auto feeder during the cultivation period. Feeding with liquid potassium silicate started on December 4, when no symptoms of powdery mildew were observed on strawberry. Disease severity of strawberry leaves on Toyonoka was assessed three times during the growing season. In Toyonoka, differences between control plots and those with silicate treatment (Si+) appeared on January 11, about 1 month after silicate treatment. Disease severity in the control plots was 7.1, but for Si+ plots, it was only 0.8. On

April 1, it was 16.5 in the control plots, but only 1.8 in the Si+ plots, indicating that silicate application significantly suppressed powdery mildew (*t*-test; $P < 0.05$).

Bertling *et al.* (2009) placed ‘Hass’ avocado fruits in 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 flesh 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/lit foliar silicic acid at 10 days interval (6 sprays) and 6 ml/lit foliar SA at 20 days interval (3 sprays) significantly influenced growth and yield parameters over control.

3. MATERIAL AND METHODS

The present investigation was carried out in the farmers field of Sri. Ashok Sansi at Lokapur village, taluk Mudhol, Bagalkot district, during 2013-2014 to study the effect of Diatomaceous Earth on growth, yield and quality of pomegranate cv. Kesar. The material used, techniques adopted and observations recorded during this investigation are furnished in this chapter.

3.1 Geographical location of experimental site

Lokapur is situated in Northern Dry Zone of Karnataka state at $16^0$16' North latitude and $75^0$36' East longitude and at an altitude of 541 m above the mean sea level.

3.2 Climate

Lokapur which is 70 km away from Arabhavi is considered to have the benefit of both south-west and north-east monsoons. The mean annual rainfall of Lokapur is 530 mm distributed over a period of September (2013) to February (2014) with prominent peak during October. The meteorological data is presented in Appendix I.

3.3 Soil characteristics

The experiment was laid out on red loamy soil and the available N, P, K and soil pH are presented in Appendix II.

3.4 Experimental details

3.4.1 Cultivar – Kesar (Bhagwa)

The ‘Kesar’ variety of pomegranate is presently cultivated commercially in Maharashtra, Gujarat and Karnataka. The variety has been recommended for its cultivation by the Mahatma Phule Krishi Vidyapeeth, Rahuri. The ‘Kesar’ variety of pomegranate is heavy yielder and possesses desirable fruit characters. Bigger fruit size, sweet, bold and attractive arils, glossy, very attractive saffron coloured thick skin makes it suitable for distant marketing. This variety was found less susceptible to fruit spots and thrips as compared to other varieties.

Fruits are with attractive seeds having cherry red coloured and bold arils, which is suitable for both table and processing purposes. Fruits are moderately susceptible to black spots. Fruits are free from blackening of arils even in case of late harvesting of fruits up to 7 months, which reduces market value of fruits.

3.4.2 Orchard details

Experiment was carried out in an established pomegranate orchard of 5 year old plants with spacing of 3.5 m x 3.5 m and shown in the Plate 1.

3.4.3 Imposing the treatments

The source of silicon used is Diatomaceous earth (DE), applied as basal dose to the respective treatment in this experiment. The dosage of DE used in this experiment was 300, 600 and 900 kg/ha.

The inorganic nutrient *i.e.* nitrogen was applied in the form of urea (46% N), phosphorous applied in the form of Diamonium phosphate (18% N: 46% P: 0% K), and

potassium applied in the form of muriate of potash (60% K). These nutrients were applied to the respective treatment according to the package of practice of UHS, Bagalkot.

Time of application (Days after bahar treatment)	Nitrogen (g/plant)	Phosphorous (g/ plant)	Potassium (g/ plant)
0	133.33	66.66	66.66
45	133.33	66.66	66.66
90	133.33	66.66	66.66

3.4.4 Irrigation

Drip irrigation method was adopted and operated regularly to maintain the soil moisture.

3.4.5 Weeding

Hand weeding was done at fortnightly interval after bahar treatment to keep the plot free from weeds.

3.4.6 Plant protection measures

The plant protection chemicals viz., Chloropyriphos (2ml/l), streptomycin sulphate (0.5 g/l) + COC (3 g/l) were sprayed on the foliage to manage sucking pests and diseases at monthly interval.

3.4.7 Design of experiment

The design adopted for the experiment was Randomised Block Design (RBD) with nine treatments. The experiment was replicated thrice.

Number of treatments	: 9
Number of replications	: 3
Spacing	: 3.5 x 3.5 m
Number of plants/treatment	: 15
Number of plants/replication	: 5
Total number of plants	: 135
Variety	: Kesar

3.4.8 Treatments details

T_1 - Absolute control

T_2 - Recommended dose of fertilizer (400:200:200 g NPK/plant)

T_3 - Half of Recommended dose of fertilizer

T_4 - Half of RDF + 300 kg/ha of DE

T_5 - Half of RDF + 600 kg/ha of DE

T_6 - Half of RDF + 900 kg/ha of DE

T_7 - RDF + 300 kg/ha of 1DE

T_8 - RDF + 600 kg/ha of DE

T_9 - RDF + 900 kg/ha of DE

3.5 Observations recorded

Plants of uniform growth were selected for recording observations in each replication under each treatment.

3.5.1 Vegetative growth parameters

Vegetative growth parameters were recorded at monthly interval from initial to harvesting.

3.5.1.1 Plant height (cm)

The height of the plant was measured before imposing the treatments (initial value) and at monthly interval, from the collar region to the top of the canopy using a measuring tape and expressed in cm.

3.5.1.2 Plant spread (cm)

The plant spread in East- West and North- South directions was measured initially and at monthly interval using a measuring tape and expressed in cm.

3.5.1.3 Chlorophyll content (mg/g)

Chlorophyll content of leaf was analyzed by collecting the healthy, matured leaves after imposing the treatment. Chlorophyll ‘a’, ‘b’ and total chlorophyll content of leaf tissue were determined by method of chlorophyll estimation using dimethyl sulphoxide (DMSO) as suggested by Shoaf and Lium (1976).

The harvested leaves were brought in polyethylene bags from field and were cut into small pieces. Known weight of sample (1g) was incubated in 7.0 ml DMSO at 65^0C for 60 minutes. After the incubation, supernatant was collected by decanting. Then the volume of supernatant was made up to 10 ml using DMSO.

The absorbance of extract was measured at 645 ηm and 663 ηm using DMSO as a blank in spectrophotometer. The chlorophyll ‘a’, chlorophyll ‘b’ and total chlorophyll content were calculated by using the following formula and expressed in mg/g.

$$\text{Chlorophyll a} = 12.7\,(A_{663}) - 2.69\,(A_{645}) \times \frac{V}{1000 \times W}$$

$$\text{Chlorophyll b} = 22.9\,(A_{645}) - 4.68\,(A_{663}) \times \frac{V}{1000 \times W}$$

$$\text{Total chlorophyll} = 20.2\,(A_{645}) - 8.02\,(A_{663}) \times \frac{V}{1000 \times W}$$

Where,

A	=	Absorbance at specific wavelength like 663 and 645nm
V	=	Final volume of chlorophyll extract
W	=	Fresh weight of tissue extracted

3.5.2 Yield parameters

Yield parameters in terms of number of days for flowering, number of flowers per plant, fruit per plant, number of days from flowering to harvesting, total crop duration, fruit weight (g), fruit volume (ml), fruit length (mm), fruit girth (mm) and fruit yield per hectare were recorded.

3.5.2.1 Number of days for flowering

Number of days taken for first flower initiation after imposing of treatment was recorded.

3.5.2.2 Number of flowers per plant

The number of flowers per plant was recorded at fortnightly interval after imposing the treatments and mean values of five plants was recorded.

3.5.2.3 Number of days from flowering to harvesting

Treatment wise days taken from first flower initiation to harvesting were recorded as number of days from flowering to harvesting.

3.5.2.4 Total crop duration

Number of days taken from treatment imposition to harvesting was recorded as total crop duration with respective treatments.

3.5.2.5 Fruit per plant

At the time of harvest the total number of fruits produced per plant was recorded.

3.5.2.6 Fruit weight (g)

The fruits were harvested at matured stage and fruit weight was taken in terms of grams.

3.5.2.7 Fruit volume (ml)

The mean fruit volume of five fruits were recorded taking the amount of water displaced by the fruit when the fruit was placed in water filled beaker and expressed in ml.

3.5.2.8 Fruit length (cm)

An average fruit length of five fruits observation was recorded using digital vernier califer. Fruit length was measured from the fruit pedicel to the opposite end.

3.5.2.9 Fruit girth (cm)

An average fruit girth of five fruits observation was recorded by using digital vernier caliper.

3.5.2.10 Fruit yield per hectare

The plant yield (kg) was recorded, based on the production of fruit per plant and data were converted into yield per hectare.

3.5.3 Quality parameters

Quality parameters ware recorded in terms of Total soluble solids (^{o}B), Titrable Acidity (%), TSS : Acid ratio, Reducing sugar (%), Non reducing sugars (%), Total sugars (%), Seed weight (g), Rind weight (g), Juice percentage (%) and aril colour.

3.5.3.1 Total soluble solids (^{o} B)

The total soluble solids (TSS) of pomegranate juice was measured by hand refractrometer with respect to treatments and expressed in degree brix (^{0}B).

3.5.3.2 Titrable Acidity (%)

A known volume of juice sample (5ml) was taken and titrated against standard NaOH using phenolphthalein indicator. The appearance of pink colour was marked as the end point. The value was expressed in terms of citric acid as per cent acidity of juice and expressed in per cent.

3.5.3.3 TSS : Acid ratio

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

3.5.3.4 Reducing sugar (%)

Reducing sugar in the fruit juice preserved in 80 per cent alcohol was estimated as per the DinitroSalicylic acid (DNSA) method. The value obtained was expressed as per cent on fresh weight basis and expressed in per cent.

3.5.3.5 Non reducing sugars (%)

The per cent of non reducing sugar was obtained by subtracting the values of reducing sugar from that total sugar and multiply the same with 0.95 as correction factor and expressed in per cent.

3.5.3.6 Total sugars (%)

The total sugar in the sample was estimated by same method as that of reducing sugar after inversion of the non reducing sugar using dilute hydrochloric acid and expressed in per cent.

3.5.3.7 Seed weight (g)

The seeds of the pomegranate were collected in each treatment and weight was recorded in gram.

3.5.3.8 Aril weight (g)

From each fruit the arils were weighted using a weighing balance and observation was recorded gram.

3.5.3.9 100 Aril weight (g)

From each fruit 100 arils were weighted using a weighing balance and observation was recorded in each treatment in gram.

3.5.3.10 Rind weight (g)

The arils of the fruit were taken out and the rind portion was weighed using a weighing balance in gram.

3.5.3.11 Juice percentage (%)

The arils of the fruits were taken out and the juice from the arils of each fruit was squeezed by using a muslin cloth. This extracted juice was taken in a measuring cylinder and observations were recorded for each fruit in each treatment and expressed in per cent per 100 g.

3.5.4 Organoleptic evaluation

Organoleptic evaluation of fresh pomegranate fruits was carried out by a team of judges consisting of teachers of Kittur Rani Channamma College of Horticulture, Arabhavi. The fruit characters like colour, texture, taste and overall acceptability of pomegranate fruits were evaluated on a five point hedonic scale using following score card. The mean scores given by judges used for statistical analysis.

Hedonic scale	Score
Highly acceptable	4.0-5.0
Acceptable	3.0-4.0
Fairly acceptable	2.0-3.0
Poorly acceptable	1.0-2.0
Not acceptable	1

3.5.5 Leaf analysis

Leaf samples (8th leaf) were collected from the designated plants of each treatment in each replication after 4 months of bahar treatment. After cleaning with distilled water, leaf samples were oven- dried at 50^{0}C till they attain constant weight and analyzed for nutrient status. Estimation of total nitrogen, phosphorus, potash and micronutrients was done by following the standard procedures.

3.5.5.1 Nitrogen

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

3.5.5.2 Phosphorus

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

3.5.5.3 Potassium

The potassium content was estimated by reading the Flame photometer values of triple acid extract (Jackson, 1967).

3.5.5.4 Calcium

The calcium content was estimated by using EDTA (disodiumdihydrogen-ethylenediaminetetraacetate) method.

3.5.5.5 Magnesium

The calcium magnesium was estimated by subtracting the magnesium from the combination of calcium and magnesium which was estimated by EDTA titration to EBT (Eriochrome Black T) endpoint.

3.5.5.6 Copper

The copper content was estimated by Diethylenetriaminepentaacetic acid (DTPA) method (Lindasay and Norwell, 1978).

3.5.5.7 Zinc

The zinc content was estimated by Diethylenetriaminepentaacetic acid (DTPA) method (Lindasay and Norwell, 1978).

3.5.6 Soil analysis

Soil samples were collected from different spots in the experimental site before imposing of treatments and after harvesting (from each treatment in all replications). Samples were air-dried and analyzed for nutrient status in the soil. The data on nutrient status of soil before and after crop is presented in Appendix **II** and **III**.

3.5.7 Anthracnose incidence

3.5.7.1 Number of fruits infected

The total number of fruits infected in the labelled plants were counted in each treatment and the mean was calculated.

3.5.7.2 Per cent coverage on fruits

The ten random fruits were selected from labelled plants and per cent coverage of disease on fruits was recorded. The mean was calculated.

3.5.8 Bacterial blight incidence

3.5.8.1 Number of fruits infected

The total number of fruits infected in the labelled plants were counted in each treatment and the mean was calculated.

3.5.8.2 Number of lesions per leaf

The number of lesions per leaf was counted in ten leaves of labelled plants and the average value was recorded.

3.5.8.3 Per cent coverage on fruits

The ten random fruits were selected from labelled plants and per cent coverage of disease on fruits was recorded. The mean was calculated.

3.5.9 Economics

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

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

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

3.6 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 effect of Diatomaceous Earth on growth, yield and quality of pomegranate was studied during 2013-2014 and the results are presented in this chapter.

4.1 Vegetative growth parameters

The vegetative growth parameters like plant height and spread were recorded at monthly interval after imposition of treatments.

4.1.1 Plant height (cm)

The data in Table 1 reveals that, in all the treatments, plant height increased linearly with the advancement of growth from the treatment imposition to harvesting. Initially in all the treatments the plant height was non-significant. Significant difference was observed in all the treatments after 1 month of treatment imposition.

At one month after treatment, the highest plant height (228.00 cm) was recorded in T_9 (RDF + 900 kg of DE) which was on par with T_8 (RDF + 600 kg/ha of DE) whereas, the least height (215.20 cm) was recorded in T_1 (Absolute control).

At second month after treatment, maximum plant height (242.53 cm) was recorded in T_9, followed by treatment T_8 (235.46 cm), T_7 (234.73 cm), T_4 (232.66 cm) and T_6 (230.40 cm) whereas, minimum height (221.73 cm) was recorded in the T_1.

At third month, maximum height (255.73 cm) was recorded in T_9, followed by the treatment T_8 (247.20 cm), T_7 (246.73 cm), T_4 (241.63 cm) and T_6 (240.80 cm) whereas, minimum height (226.73 cm) was recorded in the treatment T_1.

After fourth month, maximum height (268.30 cm) was noticed in the treatment T_9, followed by the treatment T_8 (257.66 cm), T_7 (256.43 cm), T_4 (250.73 cm) and T_6 (249.93 cm) whereas, minimum height (231.26 cm) was recorded in the treatment T_1.

However at fifth month, maximum plant height (279.86 cm) was recorded in T_9, followed by the treatment T_8 (267.53 cm), T_7 (265.86 cm), T_6 (258.00 cm) and T_4 (257.63 cm) whereas, minimum height (235.20 cm) was recorded in the treatment T_1.

The values for plant height were significantly higher when the plants were applied with T_9 (RDF + 900 kg of DE) which was followed by the treatments T_8 (RDF + 600 kg of DE), T_7 (RDF + 300 kg of DE), T_6 (half of RDF + 900 kg of DE) and T_4 (half of RDF + 300 kg of DE).

4.1.2 Plant spread

4.1.2.1 North - South

The data on plant spread (North - South) is presented in Table 2. Plant spread in all the treatments increased linearly with the advancement of growth from the treatment imposition to harvesting. Initially in all the treatments, the plant spread was non-significant and the significant difference was observed in all the treatments after one month of treatment imposition.

At one month, the highest plant spread (252.40 cm) was recorded in T_9 (RDF + 900 kg of DE), followed by T_6 (244.93 cm) which is on par with T_7 (239.93 cm), T_8 (237.06 cm), T_2

Table 1: Effect of Diatomaceous Earth on plant height of pomegranate cv. Kesar.

Treatments	Initial (cm)	One MAT (cm)	Second MAT (cm)	Third MAT (cm)	Fourth MAT (cm)	Fifth MAT (cm)
T_1 - Absolute control	207.93	215.20 (7.27)	221.73 (6.53)	226.73 (5.00)	231.26 (4.53)	235.20 (3.94)
T_2 - Recommended dose of fertilizer (RDF)	208.86	218.86 (10.00)	227.40 (8.54)	235.33 (7.93)	241.53 (6.20)	245.66 (4.13)
T_3 - Half of Recommended dose of fertilizer	206.26	215.26 (9.00)	222.53 (7.27)	229.53 (7.00)	234.40 (4.87)	238.53 (4.13)
T_4 - Half of RDF + 300 kg/ha of DE	211.10	222.43 (11.33)	232.66 (10.23)	241.63 (8.97)	250.73 (9.10)	257.63 (6.90)
T_5 - Half of RDF + 600 kg/ha of DE	206.83	218.23 (11.40)	229.83 (11.60)	239.40 (9.57)	247.50 (8.10)	253.53 (6.03)
T_6 - Half of RDF + 900 kg/ha of DE	206.60	219.00 (12.40)	230.40 (11.40)	240.80 (10.40)	249.93 (9.13)	258.00 (8.07)
T_7 - RDF + 300 kg/ha of DE	209.83	222.66 (12.83)	234.73 (12.07)	246.73 (12.00)	256.43 (9.70)	265.86 (9.43)
T_8 - RDF + 600 kg/ha of DE	209.80	223.20 (13.40)	235.46 (12.26)	247.20 (11.74)	257.66 (10.46)	267.53 (9.87)
T_9 - RDF + 900 kg/ha of DE	212.73	228.00 (15.27)	242.53 (14.53)	255.73 (13.20)	268.30 (12.57)	279.86 (11.56)
S.Em±	NS	1.75	1.80	1.88	1.94	1.95
CD @ 5%		5.26	5.39	5.66	5.82	5.86

NS = Non significant MAT - Month after treatment () - Increment in height

Table 2: Effect of Diatomaceous Earth on north-south plant spread of pomegranate cv. Kesar.

Treatments	Initial (cm)	One MAT (cm)	Second MAT (cm)	Third MAT (cm)	Fourth MAT (cm)	Fifth MAT (cm)
T_1 - Absolute control	205.46	210.40 (4.94)	220.00 (9.60)	229.40 (9.40)	238.60 (9.20)	246.33 (7.73)
T_2 - Recommended dose of fertilizer (RDF)	222.26	231.93 (9.67)	242.13 (10.20)	251.80 (9.67)	260.93 (9.13)	269.60 (8.67)
T_3 - Half of Recommended dose of fertilizer	215.86	225.26 (9.40)	235.33 (10.07)	245.66 (10.33)	254.73 (9.07)	263.20 (8.47)
T_4 - Half of RDF + 300 kg/ha of DE	213.60	222.83 (9.23)	231.76 (8.93)	241.83 (10.07)	250.83 (9.00)	259.50 (8.67)
T_5 - Half of RDF + 600 kg/ha of DE	221.26	230.23 (8.97)	240.40 (10.17)	248.90 (8.50)	257.23 (8.33)	266.56 (9.33)
T_6 - Half of RDF + 900 kg/ha of DE	234.00	244.93 (10.93)	254.80 (9.87)	264.26 (9.46)	273.13 (8.87)	281.33 (8.20)
T_7 - RDF + 300 kg/ha of DE	228.43	239.93 (11.5)	251.20 (11.27)	261.20 (10.00)	270.23 (9.03)	278.63 (8.40)
T_8 - RDF + 600 kg/ha of DE	224.53	237.06 (12.53)	248.53 (11.47)	259.00 (10.47)	269.20 (10.20)	278.33 (9.13)
T_9 - RDF + 900 kg/ha of DE	238.86	252.40 (13.54)	265.46 (13.06)	277.13 (11.67)	288.03 (10.90)	298.13 (10.10)
S.Em±	NS	7.56	7.38	7.30	7.20	7.20
CD @ 5%		22.69	22.15	21.90	21.60	21.60

NS = Non significant MAT - Month after treatment () - Increment in spread

(231.93 cm) and T_5 (230.23 cm) whereas, least spread (210.40 cm) was recorded in T_1 (Absolute control).

At second month after treatment, maximum plant spread (265.46 cm) was recorded in T_9, which was on par with treatment T_6 (254.80 cm), T_7 (251.20 cm), T_8 (248.53 cm), followed by treatment T_2 (242.13 cm), T_5 (240.40 cm) and T_3 (235.33 cm) whereas, minimum height (220.00 cm) was recorded in the treatment T_1.

At third month, maximum plant spread (277.13 cm) was recorded in T_9, which was on par with treatment T_6 (264.26 cm), T_7 (261.20 cm), T_8 (259.00 cm), followed by treatment T_2 (251.20 cm), T_5 (248.90 cm) and T_3 (245.66 cm) whereas, minimum height (229.40 cm) was recorded in the treatment T_1.

After fourth month, maximum plant spread (288.03 cm) was recorded in T_9, which was on par with treatment T_6 (270.23 cm), T_7 (269.20 cm), T_8 (259.00 cm), followed by treatment T_2 (260.93 cm), T_5 (257.23 cm) and T_3 (254.73 cm) whereas, minimum height (238.60 cm) was recorded in the treatment T_1.

However at fifth month, maximum plant spread (298.13 cm) was recorded in T_9, which was on par with treatment T_6 (281.33 cm), T_7 (278.63 cm), T_8 (278.33 cm), followed by treatment T_2 (269.60 cm), T_5 (266.56 cm) and T_3 (254.73 cm) whereas, minimum height (245.33 cm) was recorded in the treatment T_1.

The values for plant spread were significantly higher when the plants were applied with T_9 (RDF + 900 kg of DE) which was on par with the treatments T_6 (half of RDF + 900 kg of DE), T_7 (RDF + 300 kg of DE), T_8 (RDF + 600 kg of DE) and followed by T_2 (RDF only), T_5 (half of RDF + 600 kg of DE) and T_3 (half of RDF).

4.1.2.2 East - West

The Table 3 presenting the data on plant spread (East - West) revealed that, plant spread in all the treatments increased linearly with the advancement of growth from the treatment imposition to harvesting. Initially in all the treatments, the plant spread was non-significant and significant differences were observed in all the treatments after one month of treatment imposition.

At one month, the highest plant spread (251.13 cm) was recorded in T_9 (RDF + 900 kg of DE), which was on par with T_7 (248.4 cm), T_8 (246.73 cm), T_6 (236.66 cm) and T_5 (236.30 cm), followed by T_2 (225.60 cm), T_4 (224.33 cm) and T_3 (222.73 cm) whereas, least spread (216.60 cm) was recorded in T_1 (Absolute control).

At second month after treatment, maximum plant spread (263.33 cm) was recorded in T_9, which was on par with T_7 (259.90 cm), T_8 (258.60 cm), T_6 (246.66 cm) and T_5 (246.66 cm), followed by T_2 (234.06 cm), T_4 (233.03 cm) and T_3 (229.53 cm) whereas, least spread (224.20 cm) was recorded in T_1 (Absolute control).

At third month, maximum plant spread (275.06 cm) was recorded in T_9, which was on par with T_7 (269.83 cm), T_8 (269.20 cm), T_6 (256.33 cm) and T_5 (255.86 cm), followed by T_2 (242.33 cm), T_4 (242.73 cm) and T_3 (237.73 cm) whereas, least spread (230.93 cm) was recorded in T_1 (Absolute control).

After fourth month, maximum plant spread (286.20 cm) was recorded in T_9, which was on par with T_8 (280.00 cm), T_7 (266.20 cm), T_6 (265.76 cm) and T_5 (251.50 cm), followed by T_2 (250.00 cm), T_3 (245.73 cm) and T_4 (243.66 cm) whereas, minimum spread (237.86 cm) was recorded in T_1 (Absolute control).

However at fifth month, maximum plant spread (295.63 cm) was recorded in T_9, which was on par with T_8 (289.33 cm), T_7 (289.10 cm), T_6 (280.60 cm) and T_5 (274.16 cm), followed by T_4 (259.83 cm), T_2 (258.20 cm) and T_3 (252.40 cm) whereas, least spread (244.00 cm) was recorded in T_1 (Absolute control).

The values for plant spread were significantly higher when the plants were applied with T_9 (RDF + 900 kg of DE) which was on par with the treatments T_6 (half of RDF + 900 kg of DE), T_7 (RDF + 300 kg of DE), T_8 (RDF + 600 kg of DE) and followed by T_2 (RDF only), T_3 (half of RDF) and T_4 (half of RDF + 300 kg of DE).

4.1.3 Chlorophyll content

The data on the Chlorophyll content as influenced by Diatomaceous Earth on pomegranate cv. Kesar are presented in Table 4. The data indicates that, the influence of Diatomaceous Earth on chlorophyll content was significant.

4.1.3.1 Chlorophyll ‘a’ (mg/g of tissue)

The highest value for chlorophyll ‘a’ content (0.29 mg/g) was recorded in T_9 (RDF + 900 kg/ha of DE) and T_7 (RDF + 300 kg/ha of DE) which was on par with the treatments T_8 (0.28 mg/g), T_6 (0.26 mg/g), T_5 (0.26 mg/g) and T_1 (0.27 mg/g) followed by the treatment T_2 (0.24 mg/g) and T_4 (0.20 mg/g), while least value was recorded in T_3 (0.19 mg/g).

4.1.3.2 Chlorophyll ‘b’ (mg/g of tissue)

The chlorophyll ‘b’ content was found non-significant in all the treatments. However higher value recorded in T_7 (0.31) and least value recorded in T_1 (0.11).

4.1.3.3 Total chlorophyll (mg/g of tissue)

A significant difference in total chlorophyll content was observed. The highest total chlorophyll content was recorded in T_7 (0.61 mg/g), followed by the treatment T_9 (0.48 mg/g), T_5 (0.46 mg/g) and T_6 (0.46 mg/g) each, T_8 (0.45 mg/g), T_4 (0.44 mg/g), T_2 (0.42 mg/g) and T_1 (0.39 mg/g). The lowest value (0.33 mg/g) was recorded in T_3 (half of RDF).

The plants which were applied with Diatomaceous Earth showed significantly superior results for chlorophyll ‘a’ and total chlorophyll.

4.2 Nutrient status of pomegranate leaves

Effect of different treatments on nutrient status of leaves *viz.*, nitrogen, phosphorus, potassium, calcium, magnesium, zinc, iron and silica is presented in Table 5.

4.2.1 Nitrogen (%)

There was significant difference among the different treatments. The highest nitrogen content (2.25 %) was noticed in the plants, which were applied with RDF + 900 kg/ha of DE (T_9), which was on par with the treatment T_8 (2.10 %) and T_6 (2.06 %). These results were followed by the treatment T_7 (1.98 %), T_5 (1.94 %) and T_4 (1.87 %) while minimum nitrogen content (1.32 %) was observed in T_1 (Absolute control).

4.2.2 Phosphorous (%)

Phosphorus content of leaf varied significantly among the different treatments. Highest phosphorus content (0.58 %) was observed in T9 (RDF + 900 kg/ha of DE), which was followed by treatment T_2 (0.42 %), T_6 (0.42 %), T_8 (0.41 %) and T_7 (0.37 %), while minimum phosphorous content (0.22 %) was observed in T_1.

4.2.3 Potassium (%)

There was significant difference among the different treatments with respect to potassium content of leaf. The maximum potassium content (0.64 %) was observed in T_9 (RDF + 900 kg/ha of DE), which was followed by treatment T_8 (0.54 %), T_2 (0.53 %) and T_6 (0.52 %). While minimum potassium content (0.36 %) was observed in T_4.

4.2.4 Calcium (%)

There was significant difference among the different treatments with respect to calcium content of the leaf. The maximum calcium content (3.30 %) was observed in T_9 (RDF + 900 kg/ha of DE), which was followed by treatment T_8 (2.93 %), T_7 (2.79 %) and T_6 (2.45 %). While minimum calcium content (1.91 %) was observed in T_1.

4.2.5 Magnesium (%)

It was observed that there was a significance difference between the treatments. The maximum magnesium content (0.58 %) was observed in T_9 (RDF + 900 kg/ha of DE), which was followed by treatment T_8 (0.54 %), T_7 (0.52 %) and T_6 (0.49 %). While minimum magnesium content (0.31 %) was observed in T_1.

4.2.6 Zinc (ppm)

There was significant difference among the different treatments with respect to zinc content of leaf. The maximum zinc content (15.43 ppm) was observed in T_9 (RDF + 900 kg/ha of DE), which was followed by treatment T_8 (14.10 ppm), T_7 (12.73 ppm) and T_6 (11.33 ppm). While minimum zinc content (6.03 ppm) was observed in T_1.

4.2.7 Iron (ppm)

There was significant difference among the different treatments with respect to iron content of leaf. The maximum iron content (226.40 ppm) was observed in T_9 (RDF + 900 kg/ha of DE), which was followed by treatment T_8 (220.10 ppm), T_6 (216.26 ppm) and T_7 (213.06 ppm). While minimum iron content (164.63 ppm) was observed in T_1.

4.2.8 Silicon (ppm)

There was significant difference among the different treatments with respect to silicon content of leaf. The maximum silicon content (0.27 ppm) was observed in T_5 (Half of RDF + 600 kg/ha of DE), which was on par with T_4 (0.26 ppm) and T_8 (0.22 ppm), these results were followed by T_1 (0.18 ppm), T_6 (0.17 ppm) and T_9 (0.15 ppm). While minimum silicon content (0.13 ppm) was observed in T_2.

4.3 Flowering parameters

The Table 6 depicts the effect of Diatomaceous Earth on crop duration (Days for first flowering after bahar treatment, days from flowering to harvesting and total crop duration). The data shows significant results among the treatments and general view was presented in Plate 2.

4.3.1 Days taken for flowering

There was a significant variation observed among the different treatments with regard to early flowering. Early flowering (9.60 days) was found in the plant receiving treatment T_9 (RDF + 900 kg/ha of DE) which was on par with the treatment of T_8 (10.60 days), followed by the treatment T_4 (10.86 days), T_5 (11.20 days), T_7 (11.33 days), T_3 (11.60 days) and T_6 (11.66 days), while delayed flowering (13.06 days) was observed in T_1 (Absolute control).

4.3.2 Days from flowering to harvesting

The days to harvest after flowering varied significantly among the different treatments. The treatment T_9 (RDF + 900 kg/ha of DE) recorded the early maturity (129.93

days) which was on par with the treatment of T_8 (130.86 days) and followed by T_4 (131.33 days), T_7 (131.40 days), T_3 (131.66 days), T_5 (131.80 days), T_6 (132.13 days) and T_2 (132.40 days), while delayed harvesting (133.40 days) was noticed in the treatment T_1.

4.3.3 Total crop duration

The total crop duration differed significantly due to treatments. The treatment T_9 (RDF + 900 kg/ha of DE) recorded the early crop duration (139.53 days) which was followed by the treatments T_4 (142.20 days), T_7 (142.80 days), T_5 (143.00 days), T_3 (143.26 days), T_6 (143.80 days) and T_2 (144.53 days), while delayed harvesting (146.46 days) was noticed in the treatment T_1.

4.3.4 Number of flowers

The data on the number of flowers as influenced by Diatomaceous Earth on pomegranate cv. Kesar is presented in Table 7. The data indicates that, the influence of Diatomaceous Earth on number of flowers was significant.

After 15 days of treatment imposition, more number of flowers (145.60) were recorded in T_9 (RDF + 900 kg/ha of DE), which is on par with T_8 (123.90), T_7 (113.06), T_6 (113.66), T_5 (130.50), T_4 (116.90), T_3 (105.40) and T_2 (114.60), while minimum number of flowers (45.66) were recorded in T_1 (Absolute control).

After 30 days, maximum number of flowers (371.76) were recorded in T_9 (RDF + 900 kg/ha of DE), which is on par with T_6 (313.10) and T_4 (301.26), followed by the treatments T_2 (277.73), T_5 (277.73), T_8 (274.70), T_7 (257.06) and T_3 (245.00), while less number of flowers (143.66) were recorded in T_1 (Absolute control).

After 45 and 60 days, number of flowers produced have shown the non-significant results with respect to all treatments, However, maximum number of flowers (708.20) were recorded in T_9 (RDF + 900 kg/ha of DE), followed by T_5 (567.53), T_4 (530.56), T_6 (526.40), T_8 (523.73), T_2 (503.93), T_3 (488.80) and T_7 (448.66), while minimum number of flowers (266.00) were recorded in T_1 (Absolute control).

4.4 Yield characteristics

The effect of Diatomaceous Earth on yield characteristics, *viz.*, number of fruits per plant, yield (Kg/plant) and yield per hectare is presented in Table 8.

4.4.1 Number of fruits per plant

There was a significant difference among the different treatments with regard to number of fruits per plant. The plants which were applied with full dose of RDF + 900 kg/ha of DE (T_9) has showed maximum number of fruits per plant (71.36) which was on par with the treatment T_8 (65.73) and T_2 (62.10), followed by the treatment T_5 (56.93), T_6 (51.83), T_7 (54.36), T_4 (51.83) and T_3 (44.56), while minimum number of fruits per plant (34.33) was recorded in the treatment T_1.

4.4.2 Yield (Kg/plant)

There was a significant difference among the treatments with regard to yield (Kg/plant). The plants which were applied with full dose of RDF + 900 kg/ha of DE (T_9) has showed highest yield (21.33 kg/plant) which was followed by T_8 (15.60 kg), T_6 (15.33 kg), T_2 (15.10 kg), T_7 (14.13 kg), T_5 (14.10 kg), T_4 (13.36 kg) and T_3 (10.73 kg) while minimum yield (6.60 kg) was recorded in the treatment T_1.

Table 3: Effect of Diatomaceous earth on east-west plant spread of pomegranate cv. Kesar

Treatments	Initial (cm)	One MAT (cm)	Second MAT (cm)	Third MAT (cm)	Fourth MAT (cm)	Fifth MAT (cm)
T_1 - Absolute control	207.60	216.60 (9.00)	224.20 (7.60)	230.93 (6.73)	237.86 (6.93)	244.00 (6.14)
T_2 - Recommended dose of fertilizer (RDF)	216.06	225.60 (9.54)	234.06 (8.46)	242.33 (8.27)	250.00 (7.67)	258.20 (8.20)
T_3 - Half of Recommended dose of fertilizer	213.00	222.73 (9.73)	229.53 (6.80)	237.73 (8.20)	245.73 (8.00)	252.40 (6.67)
T_4 - Half of RDF + 300 kg/ha of DE	215.10	224.33 (9.23)	233.03 (8.70)	242.73 (9.70)	243.66 (8.78)	259.83 (8.35)
T_5 - Half of RDF + 600 kg/ha of DE	225.73	236.30 (10.57)	246.66 (10.36)	255.86 (9.20)	251.50 (9.94)	274.16 (8.36)
T_6 - Half of RDF + 900 kg/ha of DE	225.66	236.66 (11.00)	246.66 (10.00)	256.33 (9.67)	265.76 (9.43)	280.60 (14.84)
T_7 - RDF + 300 kg/ha of DE	238.06	248.40 (10.34)	259.90 (11.50)	269.83 (9.93)	266.20 (10.60)	289.10 (8.67)
T_8 - RDF + 600 kg/ha of DE	235.20	246.73 (11.53)	258.60 (11.87)	269.20 (10.60)	280.00 (10.80)	289.33 (9.33)
T_9 - RDF + 900 kg/ha of DE	238.83	251.13 (12.30)	263.33 (12.20)	275.06 (11.73)	286.20 (11.14)	295.63 (9.43)
S.Em±		7.63	7.56	7.64	7.51	7.43
CD @ 5%	NS	22.88	22.68	22.90	22.53	22.29

NS = Non significant MAT - Month after treatment () - Increment in spread

Table 4: Effect of Diatomaceous Earth on chlorophyll content (mg/g) of pomegranate cv. Kesar.

Treatments	Chlorophyll content (mg/g)		
	a	**b**	**Total**
T_1 - Absolute control	0.27	0.11	0.39
T_2 - Recommended dose of fertilizer (RDF)	0.24	0.18	0.42
T_3 - Half of Recommended dose of fertilizer	0.19	0.14	0.33
T_4 - Half of RDF + 300 kg/ha of DE	0.20	0.23	0.44
T_5 - Half of RDF + 600 kg/ha of DE	0.26	0.18	0.46
T_6 - Half of RDF + 900 kg/ha of DE	0.26	0.20	0.46
T_7 - RDF + 300 kg/ha of DE	0.29	0.31	0.61
T_8 - RDF + 600 kg/ha of DE	0.28	0.16	0.45
T_9 - RDF + 900 kg/ha of DE	0.29	0.19	0.48
S.Em±	0.02		0.04
CD @ 5%	0.05	NS	0.13

NS – Non-significant

Table 5: Effect of Diatomaceous earth on nutrient status of pomegranate leaf

Treatments	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Zn (ppm)	Fe (ppm)	Si (ppm)
T_1 - Absolute control	1.32	0.22	0.43	1.91	0.31	6.03	164.63	0.18
T_2 - Recommended dose of fertilizer (RDF)	1.74	0.42	0.53	2.20	0.41	9.60	207.66	0.13
T_3 - Half of Recommended dose of fertilizer	1.54	0.29	0.42	2.19	0.40	9.66	196.40	0.14
T_4 - Half of RDF + 300 kg/ha of DE	1.87	0.28	0.36	2.31	0.44	10.06	198.20	0.26
T_5 - Half of RDF + 600 kg/ha of DE	1.94	0.37	0.44	2.38	0.46	10.76	210.14	0.27
T_6 - Half of RDF + 900 kg/ha of DE	2.06	0.42	0.52	2.45	0.49	11.33	216.26	0.17
T_7 - RDF + 300 kg/ha of DE	1.98	0.37	0.48	2.79	0.52	12.73	213.06	0.14
T_8 - RDF + 600 kg/ha of DE	2.10	0.41	0.54	2.93	0.54	14.10	220.10	0.22
T_9 - RDF + 900 kg/ha of DE	2.25	0.58	0.64	3.30	0.58	15.43	226.40	0.15
S.Em±	0.07	0.03	0.02	0.01	0.01	0.35	0.30	0.02
CD @ 5%	0.21	0.09	0.06	0.03	0.03	1.07	0.90	0.06

Table 6: Effect of Diatomaceous Earth on crop duration (number of days) of pomegranate cv. Kesar.

Treatments	Number of days for flowering	Number of days from flowering to harvesting	Total crop duration
T_1 - Absolute control	13.06	133.40	146.46
T_2 - Recommended dose of fertilizer (RDF)	12.13	132.40	144.53
T_3 - Half of Recommended dose of fertilizer	11.60	131.66	143.26
T_4 - Half of RDF + 300 kg/ha of DE	10.86	131.33	142.20
T_5 - Half of RDF + 600 kg/ha of DE	11.20	131.80	143.00
T_6 - Half of RDF + 900 kg/ha of DE	11.66	132.13	143.80
T_7 - RDF + 300 kg/ha of DE	11.33	131.40	142.80
T_8 - RDF + 600 kg/ha of DE	10.60	130.86	141.73
T_9 - RDF + 900 kg/ha of DE	9.60	129.93	139.53
S.Em±	0.31	0.36	0.44
CD @ 5%	0.95	1.10	1.33

Table 7: Effect of Diatomaceous earth on number of flowers of pomegranate cv. Kesar

Treatments	Number of flowers				
	15 DAT	30 DAT	45 DAT	60 DAT	Total number of flowers
T_1 - Absolute control	45.66	143.66	45.00	31.66	266.00
T_2 - Recommended dose of fertilizer (RDF)	114.60	277.73	60.86	50.73	503.93
T_3 - Half of Recommended dose of fertilizer	105.40	245.00	79.53	58.86	488.80
T_4 - Half of RDF + 300 kg/ha of DE	116.90	301.26	65.93	46.46	530.56
T_5 - Half of RDF + 600 kg/ha of DE	130.50	277.33	98.93	60.76	567.53
T_6 - Half of RDF + 900 kg/ha of DE	113.66	313.10	99.00	66.66	526.40
T_7 - RDF + 300 kg/ha of DE	113.06	257.06	53.93	50.53	448.66
T_8 - RDF + 600 kg/ha of DE	123.90	274.70	74.83	46.56	523.73
T_9 - RDF + 900 kg/ha of DE	145.60	371.76	130.13	60.70	708.20
S.Em±	13.76	26.18			45.74
CD @ 5%	41.26	78.51	NS	NS	137.15

NS – Non-significant

Table 8: Effect of Diatomaceous Earth on yield of pomegranate cv. Kesar.

Treatments	Number of fruits per plant	Yield (Kg/plant)	Yield (t/ha)
T_1 - Absolute control	34.33	6.60	5.36
T_2 - Recommended dose of fertilizer (RDF)	62.10	15.10	12.33
T_3 - Half of Recommended dose of fertilizer	44.56	10.73	8.73
T_4 - Half of RDF + 300 kg/ha of DE	51.83	13.36	10.86
T_5 - Half of RDF + 600 kg/ha of DE	56.93	14.10	11.50
T_6 - Half of RDF + 900 kg/ha of DE	54.73	15.33	11.40
T_7 - RDF + 300 kg/ha of DE	54.36	14.13	11.80
T_8 - RDF + 600 kg/ha of DE	65.73	15.60	12.73
T_9 - RDF + 900 kg/ha of DE	71.36	21.33	17.40
S.Em±	4.81	1.83	1.47
CD @ 5%	14.43	5.50	4.40

4.4.3 Yield per hectare (t/ha)

Similarly, significant difference was found for yield per hectare (tonnes). Among nine treatment, highest yield (17.40 t/ha) was observed in the treatment T_9 (RDF + 900 kg/ha DE) which was followed by T_8 (12.73 t/ha), T_2 (12.33 t/ha), T_7 (11.80 t/ha), T_5 (11.50 t/ha), T_6 (11.40 t/ha), T_4 (10.86 t/ha) and T_3 (8.73 t/ha) while lowest yield (5.36 t/ha) was recorded in the treatment T_1.

The results indicate that the highest values for number of fruits per plant, yield (Kg/plant) and yield per hectare (tonnes) was found in the plants which were applied with T_9 (RDF + 900 kg/ha DE), T_8 (RDF + 600 kg/ha DE), whereas the lowest values were observed in the treatment T_1 (Absolute control).

4.5 Fruit characters

4.5.1 Physical parameters

4.5.1.1 Fruit weight (g)

The data on fruit weight (g) are presented in Table 9 and view of fruits was presented in Plate 3. The results showed significant difference among the treatments. The highest fruit weight (298.66 g) was observed in the plants applied with treatment T_9 (RDF + 900 kg/ha of DE), which was on par with T_7 (264.08 g), T_4 (260.63 g) and T_6 (255.36 g) followed by T_5 (247.90 g), T_2 (246.86 g), T_3 (239.75 g) and T_8 (232.41 g), whereas lowest fruit weight was observed in control (193.99 g).

4.5.1.2 Fruit volume (ml)

The results of fruit volume as influenced by DE on different treatments is presented in Table 9. The treatments showed the significant difference among the fruit volume. The highest fruit volume (315.00 ml) was recorded in T_9 (RDF + 900 kg/ha of DE), which was on par with T_7 (296.63 ml), T_6 (284.40 ml), T_4 (283.30 ml), T_2 (272.20 ml) and T_5 (263.83 ml) followed by T_3 (258.30 ml) and T_8 (255.50 ml), whereas lowest fruit volume (197.43 ml) was observed in T_1 (Absolute control).

4.5.1.3 Fruit girth

The data on fruit girth (mm) is presented in Table 9 and the results showed significant difference among the treatments. The highest fruit girth (82.69 mm) was recorded in T_9 (RDF + 900 kg/ha of DE), which was on par with T_7 (79.17 mm), T_4 (78.47 mm), T_2 (76.48 mm) and T_3 (76.35 g), followed by T_8 (76.33 mm), T_5 (76.32 mm) and T_6 (71.93 mm), whereas lowest fruit girth (70.90) was recorded in T_1.

4.5.1.4 Fruit length

The results of fruit length showed the significant difference among the treatments and presented in Table 9. The highest fruit length (83.68 mm) was recorded in T_9 (RDF + 900 kg/ha of DE), which was on par with T_4 (80.75 mm), T_7 (80.67 mm), T_5 (79.26 mm) and T_6 (77.95 g), followed by T_2 (76.26 mm), T_3 (76.26 mm) and T_8 (75.91 mm), the lowest fruit length (70.13) was recorded in T_1.

4.5.1.5 100 aril weight

Results of 100 aril weight are significant with each other and highest 100 aril weight (35.66 g) was recorded in T_9 (RDF + 900 kg/ha of DE), which was on par with T_8 (34.66 g), T_6 (33.66 mm), T_5 (31.66 g), T_4 (31.00 g) and T_7 (31.00 g), followed by T_2 (29.66 g) and T_3 (29.33 g), whereas lowest 100 aril weight (26.00 g) was recorded in T_1.

Table 9: Effect of Diatomaceous earth on fruit weight, volume, girth and length of fruits of pomegranate cv. Kesar

Treatments	Weight (g)	Volume (ml)	Girth (mm)	Length (mm)
T_1 - Absolute control	193.99	197.43	70.90	70.13
T_2 - Recommended dose of fertilizer (RDF)	246.86	272.20	76.48	76.26
T_3 - Half of Recommended dose of fertilizer	239.75	258.30	76.35	76.26
T_4 - Half of RDF + 300 kg/ha of DE	260.63	283.30	78.47	80.75
T_5 - Half of RDF + 600 kg/ha of DE	247.90	263.83	76.32	79.26
T_6 - Half of RDF + 900 kg/ha of DE	255.36	284.40	71.93	77.95
T_7 - RDF + 300 kg/ha of DE	264.08	296.63	79.17	80.67
T_8 - RDF + 600 kg/ha of DE	232.41	255.50	76.33	75.91
T_9 - RDF + 900 kg/ha of DE	298.66	315.00	82.69	83.68
S.Em±	16.91	18.52	2.11	1.99
CD @ 5%	50.72	55.54	6.34	5.99

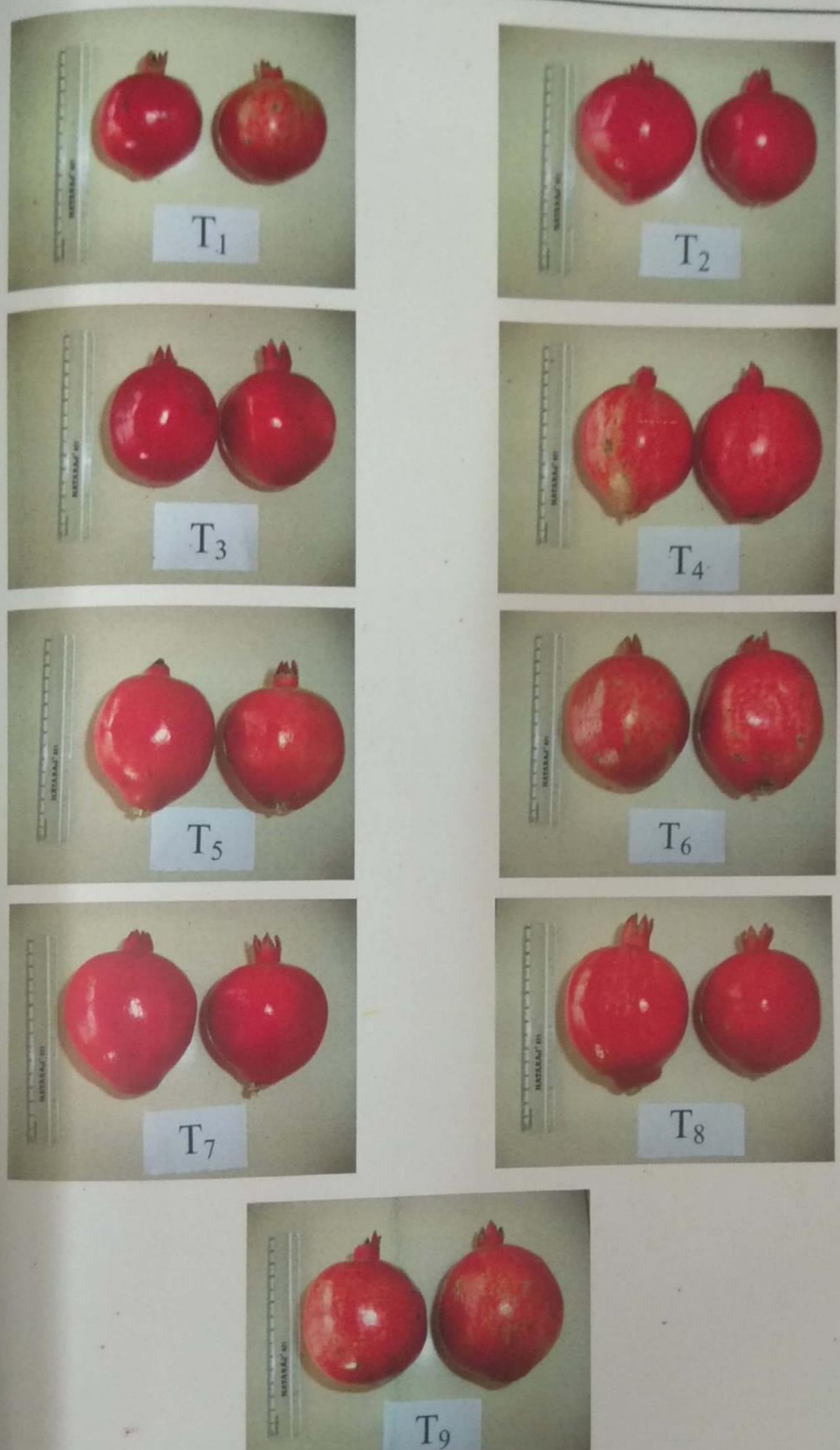


Plate 3: Pomegranate fruits with different DE treatments

4.5.1.6 Total aril weight

The data on total aril weight showed the significant difference among the treatments and presented in Table 10. The highest aril weight (203.66 g) was recorded in T_9 (RDF + 900 kg/ha of DE), which is followed by T_8 (173.33 g), T_7 (161.00 g) and T_6 (156.33 g), T_5 (152.00 g), T_2 (151.66 g), T_4 (145.33 g), T_3 (132.33 g) are on par with each other. Whereas lowest aril weight (113.33 g) was recorded in T_1 (Absolute control).

4.5.1.7 Seed weight

Regarding seed weight, significant difference was observed between the treatments and results were presented in Table 10. Highest seed weight (15.00 g) was recorded in T_9 (RDF + 900 kg/ha of DE), which is on par with T_6 (14.66 g), T_8 (14.00 mm), T_5 (13.66 g), T_2 (13.33 g), T_7 (13.33 g) and T_4 (13.00 g), whereas lowest seed weight (9.00 g) was recorded in T_1.

4.5.1.8 Rind weight

The data on rind weight showed the significant difference among the treatments and presented in Table 10. The highest rind weight (107.00 g) was recorded in T_8 (RDF + 600 kg/ha of DE), which is on par with T_6 (106.33 g), T_2 (102.66 g), T_7 (91.00 g), T_4 (90.00 g), T_9 (86.00 g) and T_3 (74.00 g), whereas lowest rind weight (65.66 g) was recorded in T_1 (Absolute control).

4.5.2 Biochemical parameters

Biochemical parameters *viz.*, total soluble solids (TSS), titrable acidity, reducing sugar, total sugars and TSS to acid ratio as influenced by Diatomaceous Earth on pomegranate is presented in Table 11.

4.5.2.1 Total soluble Solids (^{0}B)

There was a significant difference among the different treatments pertaining to TSS. The maximum TSS (16.23 ^{o}B) was found when plants are applied with (RDF + 900 kg/ha DE) *i.e.* T_9 which was on par with the treatment T_8 (15.60 ^{o}B), T_7 (15.53 ^{o}B), T_6 (15.03 ^{o}B) and T_5 (14.80 ^{o}B), followed by the treatments T_2 (14.60 ^{o}B), T_4 (14.33 ^{o}B) and T_3 (13.76 ^{o}B) while the lowest TSS (13.56 ^{o}B) was observed in the treatment T_1.

4.5.2.2 Titrable acidity (%)

The titrable acidity varied significantly among the different treatments. The minimum acidity (0.85 %) was found in T_9 (RDF + 900 kg/ha DE) which was on par with the treatment T_6 (1.28 %), T_5 (1.28 %) and T_8 (1.28 %) followed by the treatment T_4 (1.49 %), T_7 (1.70 %), T_3 (1.70 %) and T_2 (1.92 %), while the maximum acidity (2.34 %) was noticed in the treatment T_1.

4.5.2.3 TSS to Acid ratio

The effects of Diatomaceous Earth on sugars to acid ratio varied significantly among the different treatments. The maximum sugars to acid ratio (21.03) was appeared in the treatment T_9 (RDF + 900 kg/ha DE) which was on par with the treatment T_8 (14.96), T_7 (14.75), T_6 (14.53) and T_5 (14.19), followed by the treatments T_4 (9.95), T_2 (8.38) and T_3 (8.32) while the lowest value (5.86) was observed in the treatment T_1.

4.5.2.4 Reducing sugars (%)

The reducing sugar varied significantly among the different treatments. Among the nine treatment, maximum content of reducing sugar (11.13 %) was found in the fruits of T_9

Plate 4: Vertical view of DE treated pomegranate fruits

Table 10: Effect of Diatomaceous earth on aril, seed and rind weight of pomegranate cv. Kesar

Treatments	100 aril weight (g)	Total aril weight (g)	Seed weight (g)	Rind weight (g)
T_1 - Absolute control	26.00	113.33	9.00	65.66
T_2 - Recommended dose of fertilizer (RDF)	29.66	151.66	13.33	102.66
T_3 - Half of Recommended dose of fertilizer	29.33	132.33	10.33	74.00
T_4 - Half of RDF + 300 kg/ha of DE	31.00	145.33	13.00	90.00
T_5 - Half of RDF + 600 kg/ha of DE	31.66	152.00	13.66	83.00
T_6 - Half of RDF + 900 kg/ha of DE	33.66	156.33	14.66	106.33
T_7 - RDF + 300 kg/ha of DE	31.00	161.00	13.33	91.00
T_8 - RDF + 600 kg/ha of DE	34.66	173.33	14.00	107.00
T_9 - RDF + 900 kg/ha of DE	35.66	203.66	15.00	86.00
S.Em±	1.77	8.76	1.15	8.80
CD @ 5%	5.31	26.27	3.47	26.40

Table 11: Effect of Diatomaceous earth on quality of pomegranate cv. Kesar

Treatments	TSS (^{0}B)	Titrable acidity (%)	TSS:Acid ratio	Reducing sugars (%)	Non reducing sugars (%)	Total sugars (%)	Juice percentage/ 100 g
T_1 - Absolute control	13.56	2.34	5.86	9.36	0.20	9.50	53.28
T_2 - Recommended dose of fertilizer (RDF)	14.60	1.92	8.38	9.56	0.65	10.23	61.73
T_3 - Half of Recommended dose of fertilizer	13.76	1.70	8.32	9.46	0.35	9.80	60.98
T_4 - Half of RDF + 300 kg/ha of DE	14.33	1.49	9.95	9.80	0.39	10.16	62.22
T_5 - Half of RDF + 600 kg/ha of DE	14.80	1.28	14.19	9.80	0.41	10.16	63.50
T_6 - Half of RDF + 900 kg/ha of DE	15.03	1.28	14.53	10.03	0.66	10.66	64.09
T_7 - RDF + 300 kg/ha of DE	15.53	1.70	14.75	10.33	0.56	10.86	64.66
$_8$ - RDF + 600 kg/ha of DE	15.60	1.28	14.96	10.46	0.60	11.03	65.83
$_9$ - RDF + 900 kg/ha of DE	16.23	0.85	21.03	11.13	0.64	11.76	71.36
S.Em±	0.50	0.18	2.88	0.12	0.03	0.11	2.29
CD @ 5%	1.50	0.53	8.64	0.34	0.08	0.36	6.87

(RDF + 900 kg/ha DE) which was followed by T_8 (10.46 %), T_7 (10.33 %), T_6 (10.03 %), T_5 (9.80 %), T_4 (9.80 %), T_2 (9.56 %) and T_3 (9.46 %) while the minimum content of reducing sugar (9.36 %) was noticed in the treatment T_1.

4.5.2.5 Non reducing sugars (%)

The non reducing sugar varied significantly among the different treatments. Among the nine treatment, maximum content of non reducing sugar (0.66 %) was found in the fruits of T_6 (Half of RDF + 900 kg/ha DE) which was on par with T_2 (0.65 %) and T_9 (0.64 %), while the minimum content of non reducing sugar (0.20 %) was noticed in the treatment T_1.

4.5.2.6 Total sugar (%)

The effects of Diatomaceous Earth on total sugars varied significantly among different treatments. Maximum content of total sugar (11.76 %) was found in the fruits of T_9 (RDF + 900 kg/ha DE) which was followed by T_8 (11.03 %), T_7 (10.86 %), T_6 (10.66 %), T_2 (10.23 %), T_5 (10.16 %), T_4 (10.16 %) and T_3 (9.80 %) while the minimum content of total sugar (9.50 %) was noticed in the treatment T_1.

4.5.2.7 Juice percentage

The data on Juice percentage is presented in Table 11. There is significant differences among the treatments. The highest juice percentage (71.36) was observed in T_9 (RDF + 900 kg/ha DE) which was on par with the treatment T_8 (65.83) and T_7 (64.66), followed by T_6 (64.09), T_5 (63.50), T_4 (62.22), T_2 (62.73) and T_3 (60.98) while the minimum juice percentage (53.28) was noticed in the treatment T_1.

4.6 Organoleptic evaluation

The data on effect of DE on organoleptic evaluation with respect to rind colour, aril colour, taste and overall acceptability of pomegranate cv. Kesar is presented in Table 12 and view of arils presented in Plate 5 with respect to treatment wise.

4.6.1 Rind colour

The results indicate the significant difference among the treatments with respect to rind colour of pomegranate. The maximum score (4.56) for rind colour was observed in T_9 (RDF + 900 kg/ha of DE) which was on par with the treatment T_7 (4.16) and followed by the treatments T_8 (3.93), T_4 (3.83), T_3 (3.76), T_5 (3.26), T_6 (3.10) and T_2 (2.90) whereas least score (2.16) was recorded in T_1 (Absolute control).

4.6.2 Aril colour

Highest score for aril color (4.60) was observed in the treatment T_9 (RDF + 900 kg/ha of DE) which is on par with T_7 (4.43), T_8 (4.23) and T_5 (4.23), followed by the treatment T_4 (3.86), T_2 (3.30) and T_3 (3.23), while lowest score (2.66) was recorded in the treatment T_1.

4.6.3 Taste

Significantly maximum score (4.36) for taste was observed in T_8 (RDF + 600 kg/ha of DE) which was on par with the treatments T_5 (4.30), T_9 (4.20) and T_7 (4.06), followed by T_4 (3.73), T_3 (3.66), T_6 (3.46) and T_2 (3.40) whereas least score (2.83) was recorded in T_1.

4.6.4 Overall acceptability

The results indicate that there was a significant difference among the treatments with respect to overall acceptability of pomegranate. Maximum score (4.40) for overall acceptability was observed in T_9 (RDF + 900 kg/ha of DE) which was on par with the

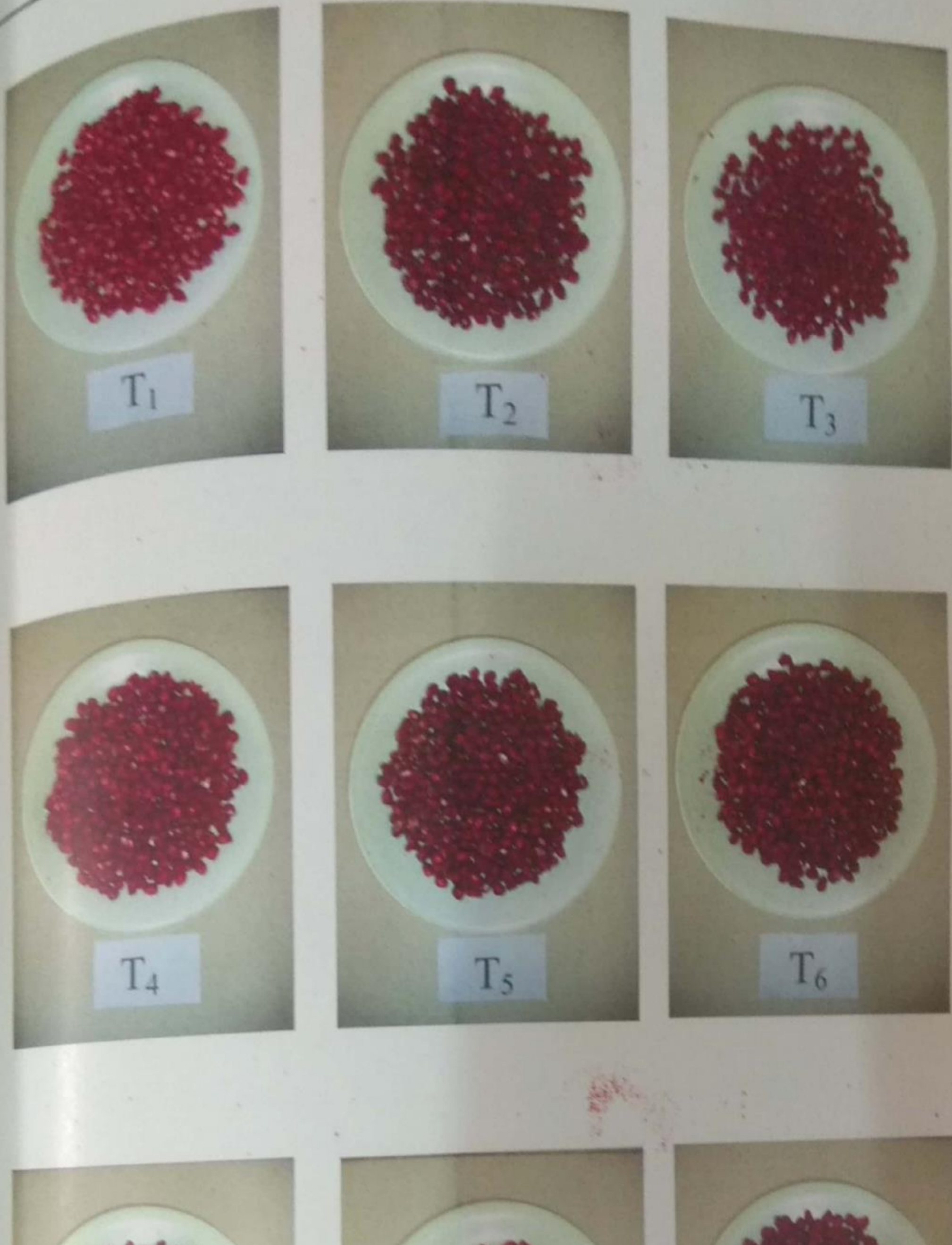


Plate 5: Arils of DE treated pomegranate fruit

Table 12: Organoleptic scores for colour, texture, taste and overall acceptability of pomegranate cv. Kesar

Treatments	Rind colour	Aril colour	Taste	Overall acceptability
T_1 - Absolute control	2.16	2.66	2.83	2.83
T_2 - Recommended dose of fertilizer (RDF)	2.90	3.30	3.40	3.36
T_3 - Half of Recommended dose of fertilizer	3.76	3.23	3.66	3.66
T_4 - Half of RDF + 300 kg/ha of DE	3.83	3.86	3.73	3.76
T_5 - Half of RDF + 600 kg/ha of DE	3.26	4.23	4.30	4.10
T_6 - Half of RDF + 900 kg/ha of DE	3.10	2.73	3.46	3.16
T_7 - RDF + 300 kg/ha of DE	4.16	4.43	4.06	4.00
T_8 - RDF + 600 kg/ha of DE	3.93	4.23	4.36	4.06
T_9 - RDF + 900 kg/ha of DE	4.56	4.60	4.20	4.40
S.Em±	0.18	0.20	0.17	0.14
CD @ 5%	0.55	0.63	0.54	0.45

Table 13: Effect of Diatomaceous earth on nutrient status of pomegranate fruit

Treatments	N (%)	P (%)	K (%)	Cu (%)	Ca (%)	Mg (%)	Zn (ppm)	Fe (ppm)	Si (ppm)
T_1 - Absolute control	0.61	0.26	0.35	2.38	1.60	0.29	4.54	8.86	0.56
T_2 - Recommended dose of fertilizer (RDF)	0.93	0.26	0.58	5.39	2.12	0.24	5.83	10.14	0.31
T_3 - Half of Recommended dose of fertilizer	0.85	0.31	0.44	4.49	1.96	0.29	4.22	9.80	0.41
T_4 - Half of RDF + 300 kg/ha of DE	0.87	0.35	0.56	5.68	2.23	0.36	5.86	10.93	0.34
T_5 - Half of RDF + 600 kg/ha of DE	1.06	0.37	0.59	5.45	2.25	0.41	6.23	11.53	0.68
T_6 - Half of RDF + 900 kg/ha of DE	1.03	0.34	0.61	6.90	2.28	0.44	6.65	12.60	0.85
T_7 - RDF + 300 kg/ha of DE	1.05	0.36	0.55	6.48	2.53	0.48	6.76	13.80	0.34
T_8 - RDF + 600 kg/ha of DE	1.36	0.39	0.64	6.86	2.66	0.45	6.85	14.56	0.26
T_9 - RDF + 900 kg/ha of DE	1.57	0.41	0.67	7.18	2.92	0.50	8.58	16.23	0.36
S.Em±	0.05	0.003	0.006	0.33	0.01	0.013	0.04	0.07	0.02
CD @ 5%	0.14	0.01	0.02	0.99	0.03	0.04	0.11	0.20	0.06

Table 14: Effect of Diatomaceous earth on nutrient status of soil after harvesting of pomegranate

Treatments	pH	EC (dS/m)	OC (%)	P (kg/ha)	K (kg/ha)	Ca (%)	Mg (%)	Copper (ppm)	Zinc (ppm)	Fe (ppm)	Si (ppm)
T_1 - Absolute control	8.22	0.08	1.14	7.29	85.60	0.21	0.04	7.19	1.85	4.79	73.78
T_2 - Recommended dose of fertilizer (RDF)	8.07	0.14	1.37	6.93	55.42	0.30	0.03	5.61	1.49	4.33	74.02
T_3 - Half of Recommended dose of fertilizer	8.15	0.12	0.94	6.43	83.39	0.31	0.04	4.75	1.37	5.33	91.96
T_4 - Half of RDF + 300 kg/ha of DE	7.83	0.11	1.21	5.83	85.98	0.31	0.07	6.79	1.49	4.61	77.56
T_5 - Half of RDF + 600 kg/ha of DE	8.04	0.11	0.99	6.14	94.03	0.27	0.08	9.40	1.97	5.75	76.14
T_6 - Half of RDF + 900 kg/ha of DE	8.12	0.12	0.56	3.94	84.71	0.30	0.05	6.97	1.94	5.66	79.56
T_7 - RDF + 300 kg/ha of DE	8.03	0.13	1.09	4.64	79.53	0.34	0.02	6.86	2.08	6.89	57.10
T_8 - RDF + 600 kg/ha of DE	7.08	0.12	1.55	4.79	83.37	0.39	0.05	3.89	2.52	7.75	68.79
T_9 - RDF + 900 kg/ha of DE	7.59	0.17	1.32	3.91	94.49	0.35	0.07	7.83	2.11	6.66	63.90
S.Em±	0.11	0.01	0.09	0.02	1.43	0.02	0.01	0.70	0.15	0.44	4.28
CD @ 5%	0.38	0.03	0.27	0.06	4.28	0.08	0.02	2.11	0.47	1.33	12.85
Initial values	7.66	0.13	-	5.37	64.36	0.25	0.45	3.51	0.96	8.85	-

Table 15: Effect of Diatomaceous earth on anthracnose disease of pomegranate cv. Kesar

Treatments	Per cent area covered by the disease on fruits	Number of fruits infected
T_1 - Absolute control	31.16	14.86
T_2 - Recommended dose of fertilizer (RDF)	27.73	12.06
T_3 - Half of Recommended dose of fertilizer	29.86	12.86
T_4 - Half of RDF + 300 kg/ha of DE	25.10	11.46
T_5 - Half of RDF + 600 kg/ha of DE	23.10	12.00
T_6 - Half of RDF + 900 kg/ha of DE	22.50	12.26
T_7 - RDF + 300 kg/ha of DE	20.63	10.93
T_8 - RDF + 600 kg/ha of DE	21.30	10.93
T_9 - RDF + 900 kg/ha of DE	19.06	10.20
S.Em±	2.31	0.64
CD @ 5%	6.94	1.93

Table 16: Effect of Diatomaceous earth on bacterial blight disease of pomegranate cv. Kesar

Treatments	Per cent infection on fruits	Number of fruits infected	Number of lesions per leaf
T_1 - Absolute control	26.50	14.40	4.76
T_2 - Recommended dose of fertilizer (RDF)	23.40	13.10	4.20
T_3 - Half of Recommended dose of fertilizer	17.03	12.86	4.16
T_4 - Half of RDF + 300 kg/ha of DE	12.00	13.06	4.30
T_5 - Half of RDF + 600 kg/ha of DE	24.33	12.83	3.83
T_6 - Half of RDF + 900 kg/ha of DE	21.40	12.96	4.03
T_7 - RDF + 300 kg/ha of DE	24.70	13.83	4.26
T_8 - RDF + 600 kg/ha of DE	21.13	13.16	3.73
T_9 - RDF + 900 kg/ha of DE	11.33	12.30	3.70
S.Em±	3.00	0.35	0.19
CD @ 5%	9.00	1.06	0.59

treatments T_5 (4.10), T_8 (4.06) and T_7 (4.00), followed by T_4 (3.76), T_3 (3.66), T_2 (3.36) and T_6 (3.73) whereas least score (2.83) was recorded in T_1.

According to the results the highest scores for rind colour, aril colour, taste and overall acceptability was found with the plants which were applied with T_9 (RDF + 900 kg/ha DE), T_8 (RDF + 600 kg/ha DE) and T_7 (RDF + 300 kg/ha DE), whereas the lowest score was observed in the treatment T_1 (Absolute control).

4.7 Nutrient status of pomegranate fruit

Effect of different treatments on nutrient status of fruit *viz.*, nitrogen, phosphorus, potassium, calcium, magnesium, zinc, iron and silica is presented in Table 13.

4.7.1 Nitrogen (%)

There was significant difference among the different treatments. The highest nitrogen content (1.57 %) was noticed in the plants, which were applied with RDF + 900 kg/ha of DE (T_9), which was followed by the treatment T_8 (1.36 %), T_5 (1.06 %) and T_7 (1.05 %) while minimum nitrogen content (0.61 %) was observed in T_1 (Absolute control).

4.7.2 Phosphorous (%)

Phosphorus content of fruit varied significantly among the different treatments. Highest phosphorus content (0.41 %) was observed in T9 (RDF + 900 kg/ha of DE), which was followed by treatment T_8 (0.39 %), T_5 (0.37 %) and T_7 (0.36 %), while minimum phosphorous content (0.26 %) was observed in T_1.

4.7.3 Potassium (%)

There was significant difference among the different treatments with respect to potassium content of fruit. The maximum potassium content (0.67 %) was observed in T_9 (RDF + 900 kg/ha of DE), which was followed by treatment T_8 (0.64 %), T_6 (0.61 %) and T_5 (0.59 %). While minimum potassium content (0.35 %) was observed in T_1.

4.7.4 Copper (%)

There was significant difference among the different treatments with respect to copper content of the fruit. The maximum copper content (7.18 %) was observed in T_9 (RDF + 900 kg/ha of DE), which was followed by treatment T_6 (6.90 %), T_8 (6.86 %) and T_7 (6.48 %). While minimum copper content (2.38 %) was observed in T_1.

4.7.5 Calcium (%)

There was significant difference among the different treatments with respect to calcium content of the fruit. The maximum calcium content (2.92 %) was observed in T_9 (RDF + 900 kg/ha of DE), which was followed by treatment T_8 (2.66 %), T_7 (2.53 %) and T_6 (2.28 %). While minimum calcium content (1.60 %) was observed in T_1.

4.7.6 Magnesium (%)

It was observed that there was a significance difference between the treatments. The maximum magnesium content (0.50 %) was observed in T_9 (RDF + 900 kg/ha of DE), which was followed by treatment T_7 (0.48 %), T_8 (0.45 %) and T_6 (0.44 %). While minimum magnesium content (0.24 %) was observed in T_2.

4.7.7 Zinc (ppm)

There was significant difference among the different treatments with respect to zinc content of fruit. The maximum zinc content (8.58 ppm) was observed in T_9 (RDF + 900 kg/ha of DE), which was followed by treatment T_8 (6.85 ppm), T_7 (6.76 ppm) and T_6 (6.65 ppm). While minimum zinc content (4.22 ppm) was observed in T_3.

4.7.8 Iron (ppm)

There was significant difference among the different treatments with respect to iron content of fruit. The maximum iron content (16.23 ppm) was observed in T_9 (RDF + 900 kg/ha of DE), which was followed by treatment T_8 (14.56 ppm), T_7 (13.80 ppm) and T_6 (12.60 ppm). While minimum iron content (8.86 ppm) was observed in T_1.

4.7.9 Silicon (ppm)

There was significant difference among the different treatments with respect to silicon content of fruit. The maximum silicon content (0.85 ppm) was observed in T_6 (Half of RDF + 900 kg/ha of DE), which was followed by T_5 (0.68 ppm), T_1 (0.56 ppm) and T_3 (0.41 ppm). While minimum silicon content (0.26 ppm) was observed in T_8.

4.8 Nutrient status of soil after harvest of the crop

Effect of different treatments on nutrient status of soil after harvest *viz.*, pH, nitrogen, phosphorus, potassium, calcium, magnesium, zinc, iron and silica is presented in Table 14.

4.8.1 pH

There was significant difference among the different treatments with respect to pH of soil. The maximum pH (8.22) was observed in T_1 (absolute control), which was on par with T_3 (8.15), T_6 (8.12), T_2 (8.07), T_5 (8.04) and T_7 (8.03). While minimum pH (7.08) was observed in T_8 (RDF + 600 kg/ha of DE).

4.8.2 Electrical conductivity (dS/m)

There was significant difference among the different treatments with respect to electrical conductivity of soil. The maximum electrical conductivity (0.17 dS/m) was observed in T_9 (RDF + 900 kg/ha of DE), which was on par with T_2 (0.14 dS/m). Which was followed by treatment T_7 (0.13 dS/m), T_3 (0.12 dS/m) and T_6 (0.12 dS/m), while minimum electrical conductivity (0.22 %) was observed in T_1.

4.8.3 Organic carbon (%)

There was significant difference among the different treatments. The highest organic carbon (1.55 %) was noticed in T_8 (RDF + 600 kg/ha of DE), which was on par with the treatment T_2 (1.37 %) and T_9 (1.32 %). These results were followed by the treatment T_4 (1.21 %), T_1 (1.14 %) and T_7 (1.09 %), while lowest organic carbon (0.56 %) was observed in T_6 (Half of RDF + 900 kg/ha of DE).

4.8.4 Phosphorous (kg/ha)

Phosphorus content of soil varied significantly among the different treatments. Highest phosphorus content (7.29 kg/ha) was observed in T_1 (absolute), which was followed by treatment T_2 (6.93 kg/ha), T_3 (6.43 kg/ha) and T_5 (6.14 kg/ha), while minimum phosphorous content (3.91 kg/ha) was observed in T_9 (RDF + 900 kg/ha of DE).

4.8.5 Potassium (kg/ha)

There was significant difference among the different treatments with respect to potassium content of soil. The maximum potassium content (94.49 kg/ha) was observed in T_9 (RDF + 900 kg/ha of DE), which was on par with T_5 (94.03 kg/ha). These results were followed by treatment T_4 (85.98 kg/ha), T_1 (85.60 kg/ha) and T_6 (84.71 kg/ha). While minimum potassium content (55.42 kg/ha) was observed in T_2 (RDF).

4.8.6 Calcium (%)

There was significant difference among the different treatments with respect to calcium content of the soil. The maximum calcium content (0.39 %) was observed in T_8 (RDF + 600 kg/ha of DE), which was on par with T_9 (0.35 %) and T_7 (0.34 %) and followed by treatment T_3 (0.31 %), T_4 (0.31 %) and T_6 (0.30 %). While minimum calcium content (0.21 %) was observed in T_1.

4.8.7 Magnesium (%)

It was observed that there was significance difference between the treatments with respect to magnesium content of soil. The maximum magnesium content (0.08 %) was observed in T_5 (Half of RDF + 600 kg/ha of DE), which was on par with the treatment T_9 (0.07 %), T_4 (0.07 %), T_8 (0.05 %) and T_6 (0.05 %). These results were followed by treatment T_1 (0.04 %), T_3 (0.04 %) and T_2 (0.03 %). While minimum magnesium content (0.02 %) was observed in T_7 (RDF + 300 kg/ha of DE).

4.8.8 Copper (ppm)

There was significant difference among the different treatments with respect to copper content of soil. The maximum copper content (9.40 ppm) was observed in T_5 (Half of RDF + 600 kg/ha of DE), which was on par with T_9 (7.83 ppm). These results were followed by T_1 (7.19 ppm), T_6 (6.97 ppm) and T_7 (6.86 ppm). While minimum copper content (3.89 ppm) was observed in T_8 (RDF + 600 kg/ha of DE).

4.8.9 Zinc (ppm)

There was significant difference among the treatments with respect to zinc content of soil. The maximum zinc content (2.52 ppm) was observed in T_8 (RDF + 600 kg/ha of DE), which was on par with T_9 (2.11 ppm) and T_7 (2.08 ppm). These results were followed by treatment T_5 (1.97 ppm), T_6 (1.94 ppm) and T_1 (1.85 ppm). While minimum zinc content (1.37 ppm) was observed in T_3.

4.8.10 Iron (ppm)

There was significant difference among the different treatments with respect to iron content of soil. The maximum iron content (7.75 ppm) was observed in T_8 (RDF + 600 kg/ha of DE), which was on par with T_7 (6.89 ppm) and T_9 (6.66 ppm). These results were followed by T_5 (5.75 ppm), T_6 (5.66 ppm) and T_3 (5.33 ppm). While minimum iron content (4.33 ppm) was observed in T_2.

4.8.11 Silicon (ppm)

There was significant difference among the different treatments with respect to silicon content of soil. The maximum silicon content (91.96 ppm) was observed in T_3 (Half of RDF), which was on par with T_6 (79.56 ppm). And These results were followed by T_4 (77.56 ppm), T_5

(76.14 ppm) and T_2 (74.02 ppm). While minimum silicon content (57.10 ppm) was observed in T_7 (RDF + 600 kg/ha of DE).

4.9 Disease incidence

The data on disease incidence with respect to per cent disease coverage on fruits, number of fruits infested on pomegranate are influenced by treatments are presented in Table 15 and 16.

4.9.1 Per cent disease coverage on fruits (Anthracnose)

It was observed that there was a significance difference between the treatments with respect to occurrence of anthracnose disease. Among the treatments, T_9 (RDF + 900 kg/ha of DE) recorded lowest (19.06) per cent disease coverage, which was on par with T_7 (20.63), T_8 (21.30), T_6 (22.50), T_5 (23.10) and T_4 (25.10), followed by the treatment T_2 (27.73) and T_3 (29.86) while highest per cent disease coverage on fruits (31.16) was observed in T_1.

4.9.2 Number of fruits infected by anthracnose disease

The results indicate that there was a significant difference among the treatments with respect to number of fruits infected by anthracnose disease. Among the treatments, T_9 (RDF + 900 kg/ha of DE) recorded lowest (10.20) number of fruits infected, which was on par with T_7 (10.93), T_8 (10.93), T_4 (11.46), T_5 (12.00) and T_2 (12.06), followed by the treatment T_6 (12.26) and T_3 (12.86) while highest number of fruits infected (14.86) was observed in T_1.

4.9.3 Per cent disease coverage on fruits (Bacterial blight)

It was observed that there was a significance difference between the treatments with respect to occurrence of bacterial blight disease and presented in Table 13. Among the treatments, T_9 (RDF + 900 kg/ha of DE) recorded lowest (11.33) per cent disease coverage, which was on par with T_4 (12.00) and T_3 (17.03) followed by T_8 (21.13), T_6 (21.40), T_2 (23.40), T_5 (24.33) and T_7 (24.70) while highest per cent disease coverage on fruits (26.50) was observed in T_1.

4.9.4 Number of fruits infected by bacterial blight disease

The results indicate that there was a significant difference among the treatments with respect to number of fruits infested by bacterial blight disease. Among the treatments, T_9 (RDF + 900 kg/ha of DE) recorded lowest (12.30) number of fruits infected, which was on par with T_5 (12.83), T_3 (12.86), T_6 (12.96), T_4 (13.06), T_2 (13.10), T_8 (13.16) and T_7 (13.83), while highest number of fruits infected (14.40) was observed in T_1.

4.9.5 Number of lesions per leaf

The data on the number of lesions per leaf is presented in Table 16. The significant difference was observed among the treatments. The least lesions per leaf (3.70) recorded in T_9 (RDF + 900 kg/ha of DE), which was on par with T_8 (3.73), T_5 (3.83), T_6 (4.03), T_3 (4.16), T_2 (4.20) and T_7 (4.26), followed by T_4 (4.30) whereas maximum number of lesions per leaf (4.76) was recorded in T_1.

The plants which were applied with T_9 (RDF + 900 kg/ha DE), T_8 (RDF + 600 kg/ha DE) and T_7 (RDF + 300 kg/ha DE) has recorded lowest disease incidence compared to control.

4.10 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 17.

Among the different treatments, T_9 (RDF + 900 kg/ha DE) has recorded highest benefit: cost ratio (9.57) and net profit (1575500 Rs./ ha). This was followed by T_5. Which was applied with half of RDF + 600 kg/ha DE. While the lowest Benefit: Cost ratio was noticed in T_1 (6.24 and 456896 Rs./ ha) in which no fertilizers were added.

Table 17: Economics of Diatomaceous earth on pomegranate cv. Kesar

Treatments	Total cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	Benefit : Cost ratio
T_1 - Absolute control	73104	530000	456896	6.24
T_2 - Recommended dose of fertilizer (RDF)	160000	1230000	1070000	6.68
T_3 - Half of Recommended dose of fertilizer	106552	870000	763448	7.16
T_4 - Half of RDF + 300 kg/ha of DE	108052	1080000	971948	8.99
T_5 - Half of RDF + 600 kg/ha of DE	109552	1150000	1040448	9.49
T_6 - Half of RDF + 900 kg/ha of DE	111052	1140000	1028948	9.26
T_7 - RDF + 300 kg/ha of DE	161500	1180000	1018500	6.30
T_8 - RDF + 600 kg/ha of DE	163000	1270000	1107000	6.79
T_9 - RDF + 900 kg/ha of DE	164500	1740000	1575500	9.57

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. Pomegranate grows well in low fertility soils, even though application of manures and fertilizers will increase the growth, 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 imbalance, 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 1999).

Research work on beneficial effect of silicon application and evidences of such effect are essentially lacking in pomegranate. Therefore investigation on growth, yield and quality parameters as influenced by soil application of Diatomaceous Earth on pomegranate cv. Kesar was carried out in the farmer's field at Lokapur village of Mudhol taluk. The significant effects of soil application of silicon are discussed in this chapter.

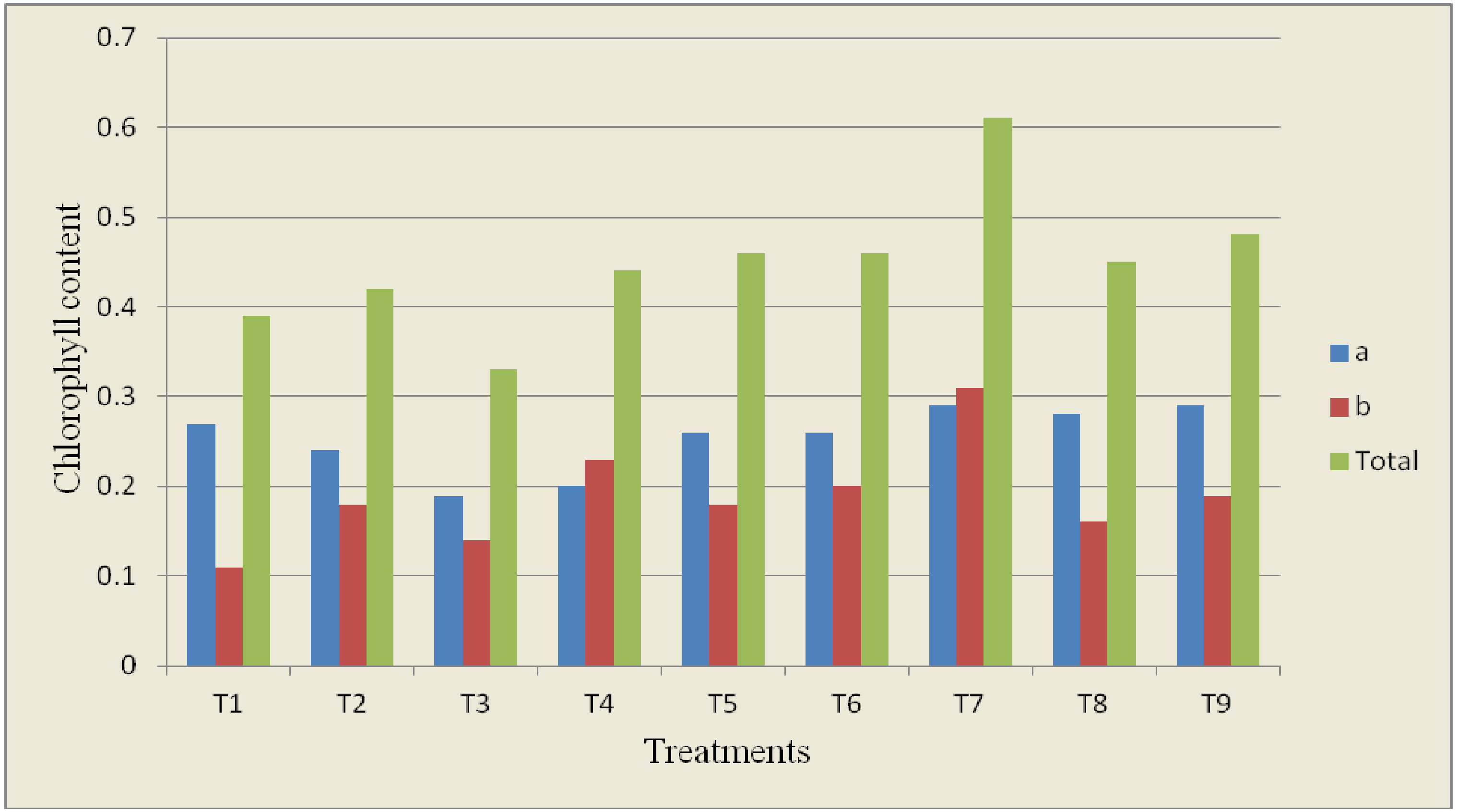
5.1 Effect of Diatomaceous Earth on growth parameters of pomegranate

When the plants were applied with T_9 (RDF + 900 kg/ha DE), the result for plant height was significantly higher with values like 228.00, 242.53, 255.73, 268.30 and 279.86 cm at 1, 2, 3, 4 and 5 months after treatment imposition respectively (Table 1). Among the treatments, T_9 (RDF + 900 kg/ha DE) recorded the highest values for plant spread in North-South and East-West direction (Table 2 and 3). Whereas, the lowest plant height (235.20 after 5 months of treatment imposition) and spread (246.33 for North-South and 244.00 for East-West after 5 months of treatment imposition) was noticed in the treatment T_1 in entire growth stages. The increase in plant height and spread might be due to the fact 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 or due to altered levels of plant growth regulators. Similar results were observed by Pilon *et al.* (2013) in potato, Kidane and Liang (2010) in banana, Bhavya (2010) in Bangalore Blue grapes, Henriet *et al.* (2006), Wang and Galleta (1998) in strawberry and Adatia and Besford (1986) in cucumber.

The leaf chlorophyll content was significantly influenced by soil application of silicon. The maximum chlorophyll 'a' content (0.29 mg/g) was recorded in T_9 (RDF + 900 kg/ha of DE) and T_7 (RDF + 300 kg/ha of DE), which were on par with the treatment T_8 (0.28 mg/g), T_6 (0.26 mg/g), T_5 (0.26 mg/g) and T_1 (0.27 mg/g). While least value was recorded in T_3 (0.19 mg/g). Chlorophyll 'b' content was non-significant due to treatments, However, maximum value was recorded in T_7 (RDF + 300 kg/ha of DE) and least value recorded in T_1 (Table 4).

Maximum total chlorophyll content (0.61 mg/g) was recorded in T_7 (RDF + 300 kg/ha of DE), while the minimum value (0.33 mg/g) was recorded in T_3 (Fig 1). The increase in the leaf chlorophyll content was due to Diatomaceous Earth supplied as a source of silicon has lead to the reduced degradation of chlorophyll. These observations are in conformity with those of Ghasemi *et al.* (2013) in Broad bean, Bhavya (2010) in Bangalore Blue grapes and Wang and Galleta (1998) in strawberry.

5.2 Effect of Diatomaceous Earth on nutrient status of pomegranate leaf



T_1-Absolute control

T_2-Recommended dose of fertilizer;

T_3-Half of Recommended dose of fertilizer

T_4-Half of RDF + 300 kg/ha of DE

T_5- Half of RDF + 600 kg/ha of DE

T_6- Half of RDF + 900 kg/ha of DE

T_7- RDF + 300 kg/ha of DE

T_8- RDF + 600 kg/ha of DE

T_9- RDF + 900 kg/ha of DE

Fig. 1: Influence of Diatomaceous Earth on chlorophyll content of pomegranate

The higher nitrogen (2.25 %), phosphorous (0.58 %), potassium (0.64 %), calcium (3.30 %), magnesium (0.58 %), zinc (15.43 ppm) and iron (226.40 ppm) content of leaf was observed in T_9 (RDF + 900 kg/ha of DE) and lower content 1.32 %, 0.22 %, 1.91 %, 0.31 %, 6.03 ppm, 164.63 ppm was observed in T_1 respectively except potassium (0.36 % in T_4). Higher silicon content (0.27 ppm) of leaf was observed in T_5 (Half of RDF + 600 kg/ha of DE) and lower content (0.13 ppm) was in T_2 (Table 5). Silicon application will avoid the leaching of nutrients from the soil and thus helped in more uptake. Similar results were observed by Lalithya *et al.* (2014) in sapota, Milne *et al.* (2012) in lettuce.

5.3 Effect of Diatomaceous Earth on flowering parameters of pomegranate

The soil application of Diatomaceous Earth treatments had significant influence on number of days taken for first flowering and harvesting. Among the different treatments, early flowering (9.60 days) was found in the plants receiving treatment T_9 (RDF + 900 kg/ha of DE), while delayed flowering (13.06 days) was observed in T_1 (Absolute control). Regarding the total number of flowers, maximum (708.20) was recorded in T_9 (RDF + 900 kg/ha of DE), while less number of flowers (266.00) was recorded in T_1 (Table 6 and 7, Fig 2 and 3).

The days taken for harvesting was minimum (129.93 days) in the treatment T_9 (RDF + 900 kg/ha of DE). With respect to total crop duration, treatment T_9 (RDF + 900 kg/ha of DE) recorded the early crop duration (139.53 days), while delayed harvesting (133.40 days) was noticed in the treatment T_1. As silicon influenced the plants to capture more light and increases chlorophyll content in leaf, led to more production of photosynthates and early growth, thus helps in early flowering and harvesting. These results are in similar with Ghasemi *et al.* (2013) in broad bean, Gang and Jiashu (2005) in melon and Cai and Rian (1995a) in pecan nut.

5.4 Effect of Diatomaceous Earth on yield of pomegranate

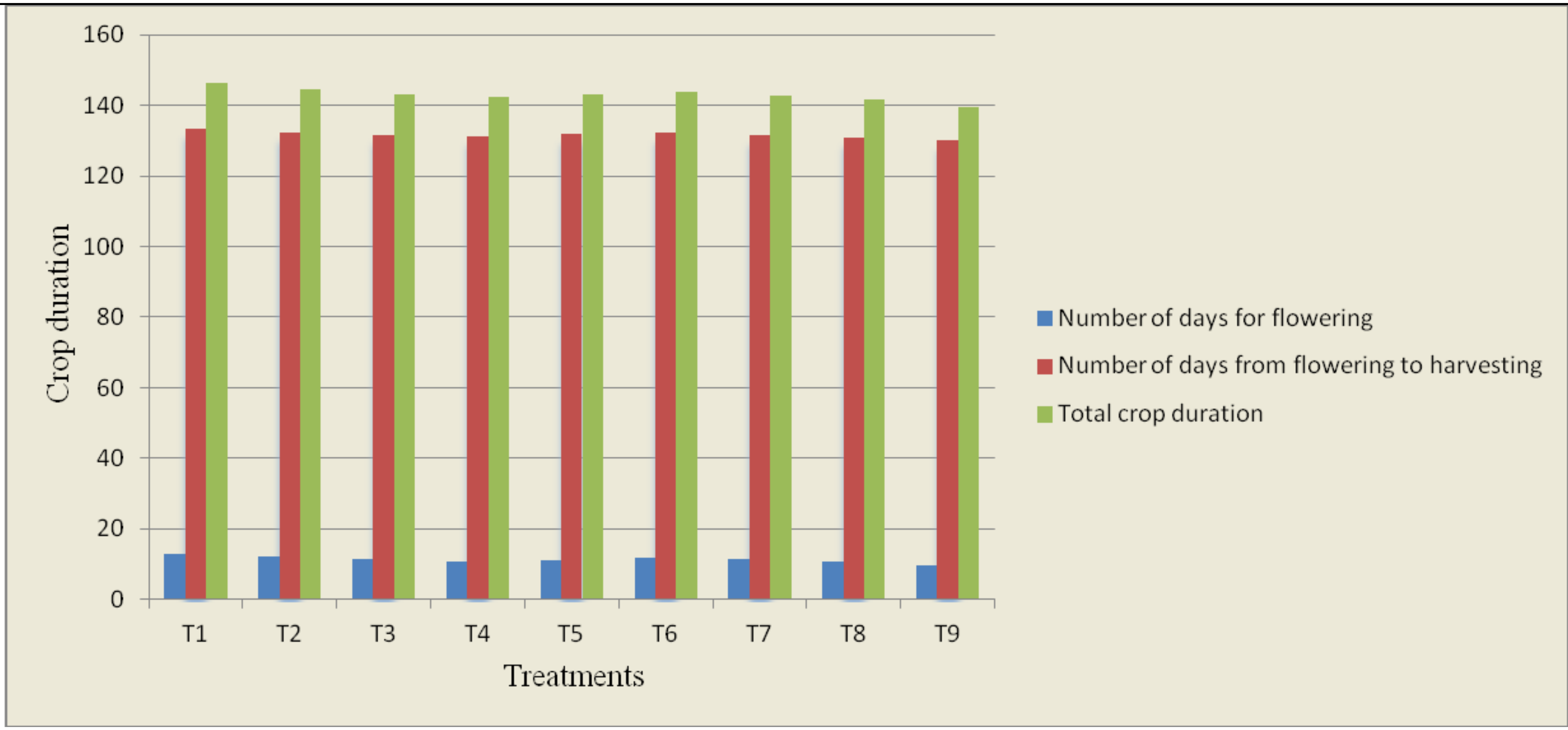
The yield in pomegranate can be measured in terms of number of fruits per plant, yield (Kg/plant) and yield per hectare. Results revealed the highest values for number of fruits per plant (71.36), yield kg per plant (21.33) and yield per hectare in tones (17.40) were found in the plants which were supplied with T_9 (RDF + 900 kg/ha DE), which was on par with T_8 (RDF + 600 kg/ha DE), whereas the lowest values were observed in the treatment T_1 34.33, 6.60 and 5.36 respectively (Table 8, Fig 4).

The yield parameters *viz.* number of fruits per plant, yield (Kg/plant) and yield per hectare were maximum in soil applied with Diatomaceous Earth when compared to control treatment. Pandey and Yadav (1999) reported that spraying silicon increased the 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.

Silicon had many positive effects on the growth and yield as well physiology and metabolism of different crops. Increased yield might be attributed to leaf erectness which facilitated better penetration of sunlight leading to higher photosynthetic activity of plant, more formation of carbohydrates and more uptakes of other nutrients. Similar results were also noticed by Ghasemi *et al.* (2013) in broad bean, Bhavya (2010) in Bangalore Blue grapes, Reaple and Laane (2008) in papaya, Miyake and Eiichi (1986) in strawberry and Adatia and Besford (1986) in cucumber.

5.5 Effect of Diatomaceous Earth on fruit characters of pomegranate

Maximum values for fruit characters like weight (298.66 g), volume (315.00 ml), girth (82.69 mm), length (83.68 mm), 100 aril weight (35.66 g), total aril weight (203.66 g), seed weight (15.00 g) and rind weight (107.00 g) were recorded in T_9 (RDF + 900 kg/ha DE). The



T_1-Absolute control

T_2-Recommended dose of fertilizer;

T_3-Half of Recommended dose of fertilizer

T_4-Half of RDF + 300 kg/ha of DE

T_5- Half of RDF + 600 kg/ha of DE

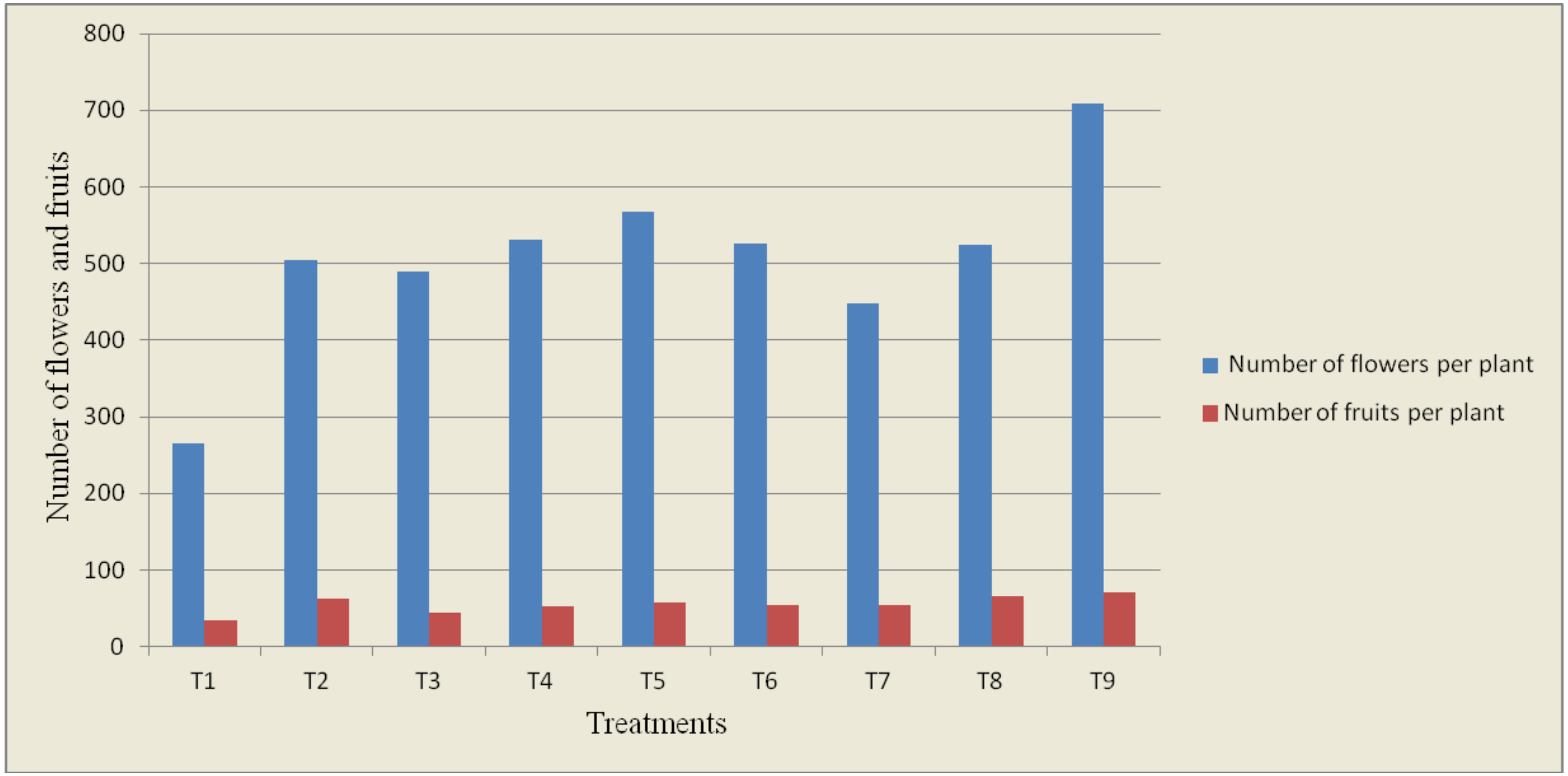
T_6- Half of RDF + 900 kg/ha of DE

T_7- RDF + 300 kg/ha of DE

T_8- RDF + 600 kg/ha of DE

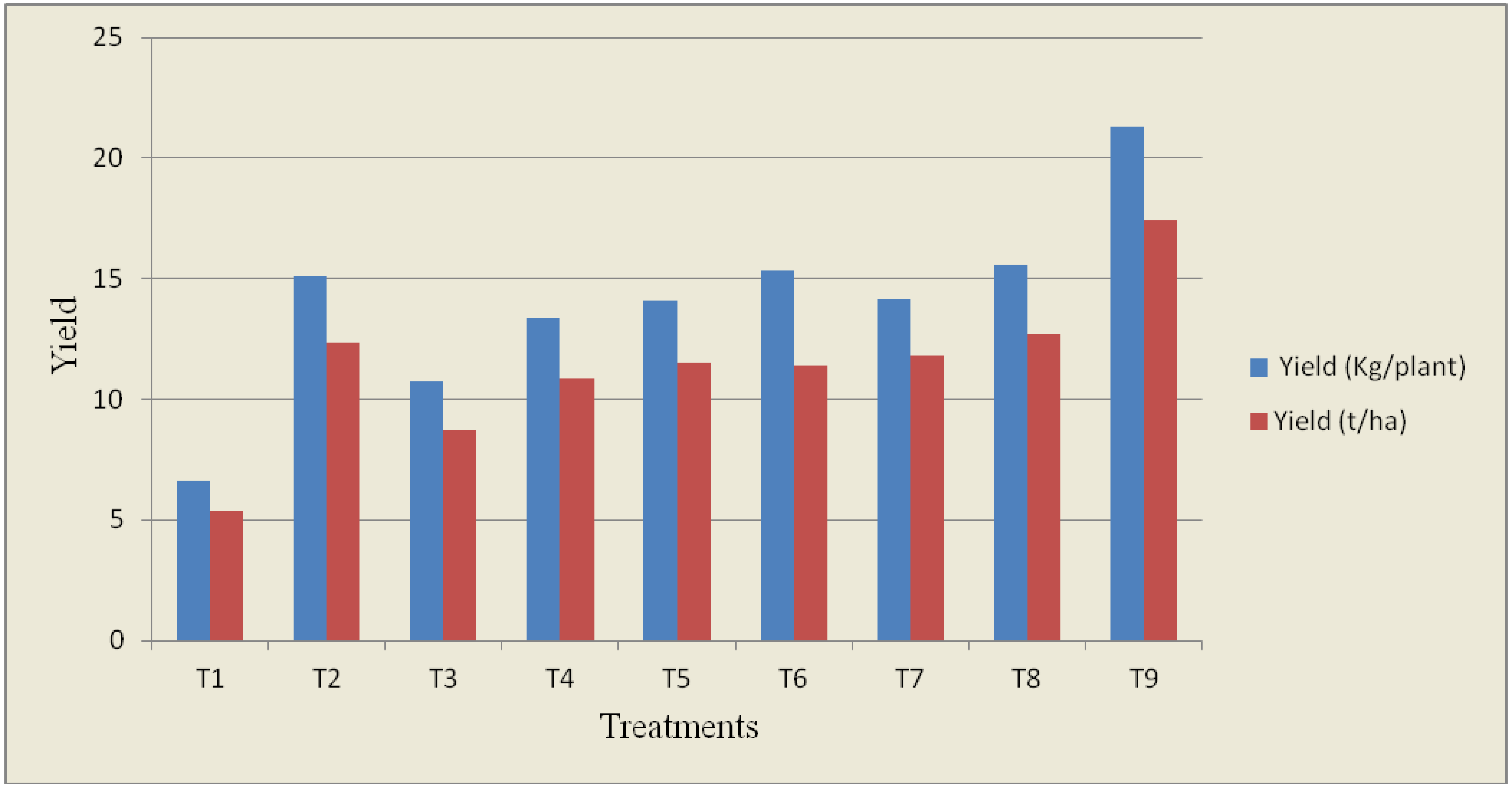
T_9- RDF + 900 kg/ha of DE

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



T_1-Absolute control
T_2-Recommended dose of fertilizer;
T_3-Half of Recommended dose of fertilizer
T_4-Half of RDF + 300 kg/ha of DE
T_5- Half of RDF + 600 kg/ha of DE
T_6- Half of RDF + 900 kg/ha of DE
T_7- RDF + 300 kg/ha of DE
T_8- RDF + 600 kg/ha of DE
T_9- RDF + 900 kg/ha of DE

Fig. 3: Influence of Diatomaceous Earth on number of flowers and fruits per plant of pomegranate



T_1-Absolute control

T_2-Recommended dose of fertilizer;

T_3-Half of Recommended dose of fertilizer

T_4-Half of RDF + 300 kg/ha of DE

T_5- Half of RDF + 600 kg/ha of DE

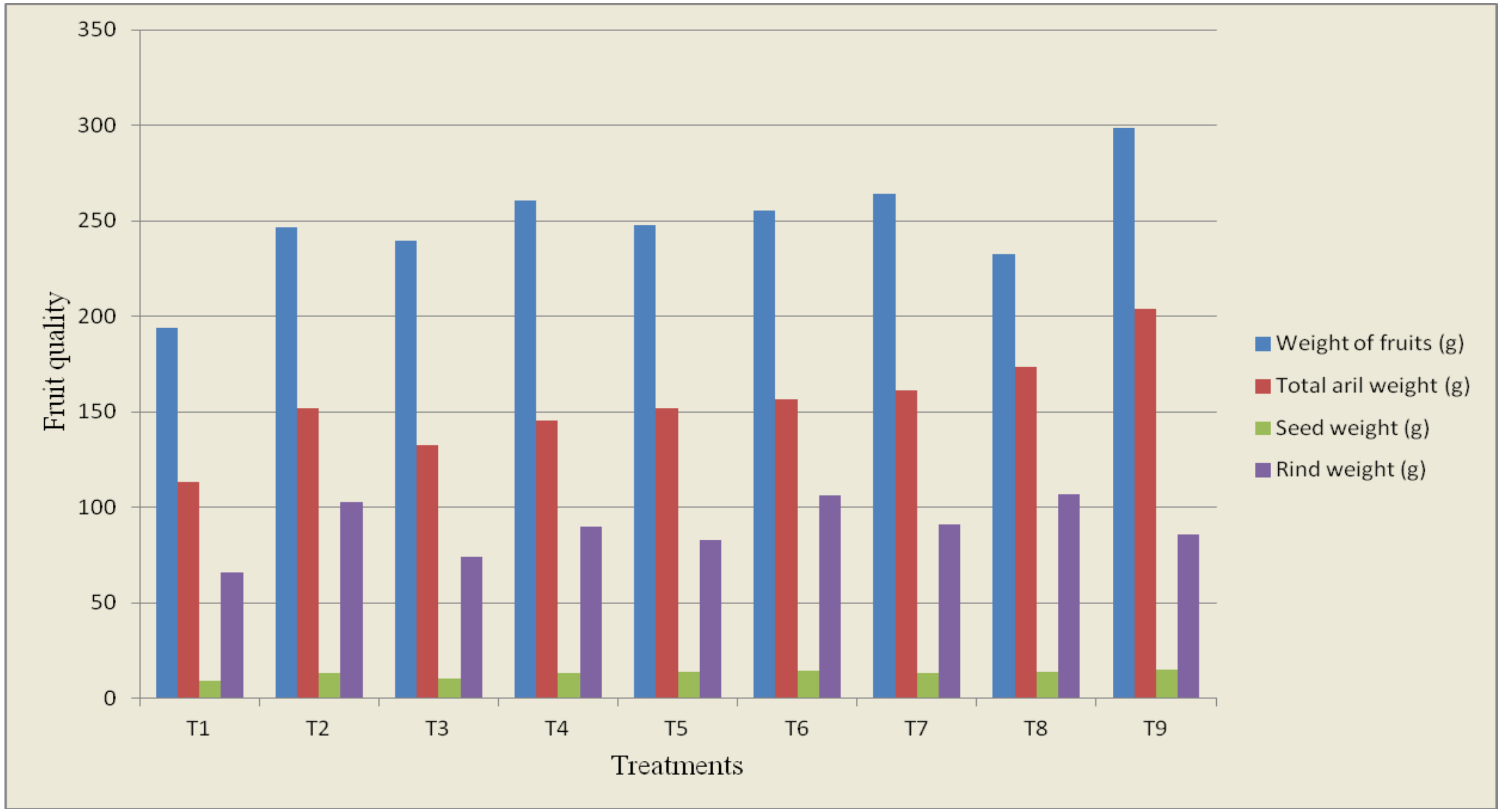
T_6- Half of RDF + 900 kg/ha of DE

T_7- RDF + 300 kg/ha of DE

T_8- RDF + 600 kg/ha of DE

T_9- RDF + 900 kg/ha of DE

Fig. 4: Influence of Diatomaceous Earth on yield of pomegranate



T_1-Absolute control T_4-Half of RDF + 300 kg/ha of DE T_7- RDF + 300 kg/ha of DE

T_2-Recommended dose of fertilizer; T_5- Half of RDF + 600 kg/ha of DE T_8- RDF + 600 kg/ha of DE

T_3-Half of Recommended dose of fertilizer T_6- Half of RDF + 900 kg/ha of DE T_9- RDF + 900 kg/ha of DE

Fig. 5: Influence of Diatomaceous Earth on fruit quality of pomegranate

lowest values were recorded in treatment T_1 193.99 g, 197.43 ml, 70.90 mm, 70.13 mm, 26.00 g, 113.33 g, 9.00 g and 65.66 g respectively (Table 9 and 10). This might be 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, volume, length, girth, total aril weight, 100 aril weight, seed weight and rind weight of the fruit. Similar results were noticed by Ghasemi *et al.* (2013) in broad bean, Nesreen *et al.* (2011) in beans, Bhavya (2010) in grapes, Ahmed *et al.* (1997) in grape and Namsang *et al.* (1996) in grape.

5.6 Effect of Diatomaceous Earth on quality parameters of pomegranate

The significant difference was noticed in total soluble solids due to soil application of silicon in pomegranate. The maximum TSS (16.23 ^oB) was found in T_9 (RDF + 900 kg/ha DE) which was on par with the treatment T_8 (RDF + 600 kg/ha DE), T_7 (RDF + 300 kg/ha DE), T_6 (half of RDF + 900 kg/ha DE) and T_5 (half of RDF + 600 kg/ha DE), while the lowest TSS (13.56 ^oB) was observed in the treatment T_1. The maximum sugars to acid ratio (21.03) was recorded in the treatment T_9 (RDF + 900 kg/ha DE), while the minimum value (5.86) was observed in the treatment T_1 (Table 11). Silicon helped in synthesis of more sugars in the fruit and thus helped in increasing total soluble solids. The results are in accordance with Stamatakis *et al.* (2003), Bhavya (2010) in Bangalore Blue grapes, Rodrigues *et al.* (2010) in beans and Savvas (2009) in tomato.

Significant difference was noticed with respect to titrable acidity of the fruit. Minimum acidity (0.85 %) was found in T_9 (RDF + 900 kg/ha DE) which was on par with the treatment T_6 (half of RDF + 900 kg/ha DE), T_5 (half of RDF + 600 kg/ha DE) and T_8 (RDF + 600 kg/ha DE), while the maximum acidity (2.34 %) was noticed in the treatment T_1 (Table 11). The decrease in acidity might be due to increase in the total soluble solids and it was also because of silicon which might have either involved in fast conversion of metabolites into sugar and their derivatives. Similar, observations were made by Su *et al.* (2011) in apple, Bhavya (2010) in Bangalore Blue grapes, and Stamatakis *et al.* (2003) in tomato.

Maximum reducing sugar (11.13 %) and total sugar (11.76 %) content was found in the fruits T_9 (RDF + 900 kg/ha DE), while the minimum reducing sugar (9.36 %) and total sugar (9.50 %) content was noticed in the treatment T_1 (Table 11). With respect to non reducing sugar, maximum content (0.66 %) was found in the fruits of T_6 (Half of RDF + 900 kg/ha DE), while the minimum content of non reducing sugar (0.20 %) was noticed in the treatment T_1.

This progressive increase could be related to increase in total soluble solids. The similar result was obtained by Bhavya (2010) in Bangalore Blue grapes, Su *et al.* (2011) in apple and Stamatakis *et al.* (2003) in tomato.

The highest juice percentage (71.36) was observed in T_9 (RDF + 900 kg/ha DE) which was on par with the treatment T_8 (RDF + 600 kg/ha DE) and T_7 (RDF + 300 kg/ha DE), while the minimum juice percentage (53.28) was noticed in the treatment T_1 (Table 11). Silicon application had led to the increased fruit size, fruit weight and aril weight so that has given the highest result for juice per cent. Similar result was obtained by Bhavya (2010) in Bangalore Blue grapes.

5.7 Effect of Diatomaceous Earth on organoleptic evaluation of pomegranate

The results indicate that there was a significant difference among the treatments with respect to rind colour, aril colour, taste and overall acceptability. View of organoleptic evaluation by judges was presented in Plate 6.

Significantly maximum score was recorded in T_9 (RDF + 900 kg/ha of DE) with respect to rind colour (4.56), aril colour (4.60) and overall acceptability (4.40), whereas

Plate 6: Organoleptic evaluation of pomegranate fruits by judges

minimum score with respect to rind colour (2.16), aril colour (2.66) and overall acceptability (2.83) was noticed in T_1. Regarding taste, the treatment T_8 (RDF + 600 kg/ha of DE) recorded the maximum score (4.36) and minimum score (2.83) was noticed in T_1 (Table 12). This was due to increased antioxidant capacity under stress condition for colour, silicon helped in synthesis of more sugars in the fruit and thus helped in increasing total soluble solids has given the good taste and overall acceptability. Similar results were observed by Anastasia *et al.* (2013) in tomato, Tesfay *et al.* (2011) in avocado, Bhavya (2010) in Bangalore Blue grapes, Savvas (2009) and Rodrigues *et al.* (2010) in beans.

5.8 Effect of Diatomaceous Earth on nutrient status of pomegranate fruit

Higher nitrogen (1.57 %), phosphorous (0.41 %), potassium (0.67 %), copper (7.18 %), calcium (2.92 %), magnesium (0.50 %), zinc (8.58 ppm) and iron (16.23 ppm) content of fruit was observed in T_9 (RDF + 900 kg/ha of DE) and lower content 0.61 %, 0.26 %, 0.35 %, 2.38 %, 1.60 ppm was observed in T_1 respectively except magnesium in T_2 (0.24 %), zinc in T_3 (4.22 ppm) and iron in T_1 (8.86 ppm). Higher silicon content (0.85 ppm) of fruit was observed in T_6 (Half of RDF + 900 kg/ha of DE) and lower content (0.26 ppm) was in T_8 (Table 13). Silicon application will avoid the leaching of nutrients from the soil and thus helped in more uptake. Similar results were observed by Lalithya *et al.* (2014) in sapota, Milne *et al.* (2012) in lettuce.

5.9 Effect of Diatomaceous Earth on nutrient status of soil after harvesting of pomegranate

The maximum pH (8.22) was observed in T_1 (absolute control) and minimum pH (7.08) was observed in T_8 (RDF + 600 kg/ha of DE), maximum electrical conductivity (0.17 dS/m) was observed in T_9 (RDF + 900 kg/ha of DE) and minimum electrical conductivity (0.22 %) was observed in T_1, highest organic carbon (1.55 %) was noticed in T_8 (RDF + 600 kg/ha of DE) and lowest organic carbon (0.56 %) was observed in T_6 (Half of RDF + 900 kg/ha of DE), highest phosphorus content (7.29 kg/ha) was observed in T_1 (absolute) and minimum phosphorous content (3.91 kg/ha) was observed in T_9 (RDF + 900 kg/ha of DE), maximum potassium content (94.49 kg/ha) was observed in T_9 (RDF + 900 kg/ha of DE) and minimum potassium content (55.42 kg/ha) was observed in T_2 (RDF), maximum calcium content (0.39 %) was observed in T_8 (RDF + 600 kg/ha of DE) and minimum calcium content (0.21 %) was observed in T_1, maximum magnesium content (0.08 %) was observed in T_5 (Half of RDF + 600 kg/ha of DE) and minimum magnesium content (0.02 %) was observed in T_7 (RDF + 300 kg/ha of DE), maximum zinc content (2.52 ppm) was observed in T_8 (RDF + 600 kg/ha of DE) and minimum zinc content (1.37 ppm) was observed in T_3, maximum iron content (7.75 ppm) was observed in T_8 (RDF + 600 kg/ha of DE) and minimum iron content (4.33 ppm) was observed in T_2, maximum copper content (9.40 ppm) was observed in T_5 (Half of RDF + 600 kg/ha of DE) and minimum copper content (3.89 ppm) was observed in T_8 (RDF + 600 kg/ha of DE), maximum silicon content (91.96 ppm) was observed in T_3 (Half of RDF) and minimum silicon content (57.10 ppm) was observed in T_7 (Table 14). These results indicate the soil application of silicon will fix the nutrients in plant available form and help the plant for better absorption. Similar results were observed by Milne *et al.* (2012) in lettuce.

5.10 Effect of Diatomaceous Earth on disease occurrence in pomegranate

The minimum percentage of anthracnose (19.06) and bacterial blight (11.33) coverage on fruits, minimum number of fruits infected by anthracnose (10.20) and bacterial blight (12.30) and minimum number of lesions of bacterial blight (3.70) on leaf was recorded in T_9 (RDF + 900 kg/ha of DE) and the maximum infction of anthracnose and bacterial blight was recorded in T_1 (Table 15 and 16).

Two hypotheses for the Si enhanced resistance to disease have been proposed. One is that Si deposited on the tissue surface acts as a physical barrier and another one is Si prevents physical penetration and / or makes the plant cells less susceptible to enzymatic degradation by fungal pathogens. This mechanism was supported by the positive correlation between the Si content and the degree of suppression of diseases. The other one is that Si functions as a signal to induce the production of phytoalexin (Feng, 2004). Similar results were noticed by Kablan *et al.* (2012), Vermeire *et al.* (2011) in banana, Bosse *et al.* (2011) in avocado, Kidane and Laing (2010), Kaluwa *et al.* (2010), Bertling *et al.* (2009) in avocado, Bekker *et al.* (2007), Kaiser *et al.* (2005), Anderson *et al.* (2005), and Cherif *et al.* (1993) in cucumber.

5.11 Effect of Diatomaceous Earth on Benefit: Cost ratio of pomegranate

Among the different treatments, T_9 (RDF + 900 kg/ha DE) has recorded highest benefit: cost ratio (9.57). This was followed by T_5 which was applied with half of RDF + 600 kg/ha DE. While the lowest Benefit: Cost ratio was noticed in T_1 (Table 17). The higher benefit: cost ratio was due to the higher yield and yield attributes. Similar results were obtained by Bhavya (2010) in Bangalore Blue grapes, Reaple and Laane (2008) in papaya and Miyake and Eiichi (1986) in strawberry.

5.12 Future line of work

1. Diatomaceous Earth in combination with micronutrients may be studied.
2. Similar type of work can be carried out on other commercial varieties of pomegranate.
3. Role of Diatomaceous Earth in controlling pest and disease needs to be studied.
4. Studies on residual accumulation of Diatomaceous Earth in soil and fruits to be carried on next season crop may be carried.
5. Split application of Diatomaceous Earth needs to be studied.

6. SUMMARY AND CONCLUSIONS

An investigation on “Effect of Diatomaceous Earth on growth, yield and quality of pomegranate cv. Kesar” was carried out in the department of fruit science, Kittur Rani Channamma college of Horticulture, Arabhavi with experiment in the farmer’s field at village Lokapur (Mudhol) during 2013-2014. The salient features of the investigation are summarised here under.

In the present experiment, all the vegetative growth parameters *viz.*, plant height and plant spread (both North-South and East-West) were recorded. The values for plant height was significantly higher (279.86 cm after 5 months of treatment imposition), in the plants applied with T_9 (RDF + 900 kg/ha DE. Among the treatments, T_9 (RDF + 900 kg/ha DE) recorded the highest values for plant spread in north-south direction (298.13 cm after 5 months of treatment imposition). Similarly, T_6 (half of RDF + 900 kg of DE), T_7 (RDF + 300 kg of DE), T_8 (RDF + 600 kg of DE) were on par with T_9. With respect to plant spread in east-west direction, significant difference was observed during the treatment. Among the all treatments, T_9 (RDF + 900 kg of DE) recorded the higher value (295.63 MAT) and which was on par with the treatments T_6 (half of RDF + 900 kg of DE), T_7 (RDF + 300 kg of DE) and T_8 (RDF + 600 kg of DE). Whereas, the lowest plant height and spread were noticed in the treatment T_1 (Absolute control) durind the entire growth stages.

The significant difference was recorded regarding chlorophyll a and total chlorophyll content of leaf, but non-significant results were observed with respect to chlorophyll b. The highest value for chlorophyll ‘a’ content (0.29 mg/g) was recorded in T_9 (RDF + 900 kg/ha of DE) and T_7 (RDF + 300 kg/ha of DE) which were on par with the treatment T_8 (RDF + 600 kg/ha of DE), T_6 (Half of RDF + 900 kg/ha of DE), T_5 (Half of RDF + 600 kg/ha of DE) and T_1 (Absolute control), while the least value was recorded in T_3 (Half of RDF). The highest total chlorophyll content was recorded in T_7 (RDF + 300 kg/ha of DE), while the lowest value (0.33 mg/g) was recorded in T_3 (half of RDF).

The higher nitrogen (2.25 %), phosphorous (0.58 %), potassium (0.64 %), calcium (3.30 %), magnesium (0.58 %), zinc (15.43 ppm) and iron (226.40 ppm) content of leaf was observed in T_9 (RDF + 900 kg/ha of DE) and lower content 1.32 %, 0.22 %, 1.91 %, 0.31 %, 6.03 ppm, 164.63 ppm was observed in T_1 respectively except potassium (0.36 % in T_4). Higher silicon content (0.27 ppm) of leaf was observed in T_5 (Half of RDF + 600 kg/ha of DE) and lower content was in T_2 (0.13 ppm).

Early flowering (9.60 days) was recorded in the plants receiving T_9 (RDF + 900 kg/ha of DE) which was on par with the treatment T_8 (RDF + 600 kg/ha of DE), while delayed flowering was observed in T_1 (Absolute control). With respect to total number of flowers, maximum number of flowers (708.20) was recorded in T_9 (RDF + 900 kg/ha of DE), followed by T_5 (half of RDF + 600 kg/ha of DE), T_4 (half of RDF + 300 kg/ha of DE), T_6 (half of RDF + 900 kg/ha of DE), T_8 (RDF + 600 kg/ha of DE), T_2 (RDF), T_3 (half of RDF) and T_7 (RDF + 300 kg/ha of DE), while minimum number of flowers was recorded in T_1 (Absolute control).

The days taken for harvesting was minimum (129.93 days) in the treatment T_9 (RDF + 900 kg/ha of DE) and maximum days were taken by the T_1 (133.40 days). With respect to total crop duration, treatment T_9 (RDF + 900 kg/ha of DE) recorded the early crop duration (139.53 days), while delayed harvesting (Absolute control) was noticed in the treatment T_1 (146.46).

The highest values for number of fruits per plant, yield (Kg/plant) and yield per hectare (tonnes) was found in the plants which were supplied with T_9 (RDF + 900 kg/ha DE), T_8 (RDF + 600 kg/ha DE) and T_2 (RDF). Whereas, the lowest values were observed in the treatment T_1 (Absolute control).

Maximum value for fruit characters like weight (298.66 g), volume (315.00 ml), length (83.68 mm), girth (82.69 mm), total aril weight (203.66 g), 100 aril weight (35.66 g), seed weight (15.00) and rind weight (107.00 g) was recorded in T_9 (RDF + 900 kg/ha DE), followed by T_8 (RDF + 600 kg/ha DE) and the lowest values was recorded in treatment T_1 (Absolute control).

The maximum TSS (16.23 ºB) was found in T_9 (RDF + 900 kg/ha DE) which was on par with the treatment T_8 (RDF + 600 kg/ha DE), T_7 (RDF + 300 kg/ha DE), T_6 (half of RDF + 900 kg/ha DE) and T_5 (half of RDF + 600 kg/ha DE), while the lowest TSS (13.56 ºB) was observed in the treatment T_1. The maximum sugars to acid ratio (21.03) was recorded in the treatment T_9 (RDF + 900 kg/ha DE), while the minimum value (5.86) was observed in the treatment T_1.

Minimum acidity (0.85 %) was found in T_9 (RDF + 900 kg/ha DE) which was on par with the treatment T_6 (half of RDF + 900 kg/ha DE), T_5 (half of RDF + 600 kg/ha DE) and T_8 (RDF + 600 kg/ha DE), while the maximum acidity (2.34 %) was noticed in the treatment T_1.

Maximum reducing sugar (11.13 %) content was found in the fruits of T_9 (RDF + 900 kg/ha DE), while the minimum reducing sugar (9.36 %) content was noticed in the treatment T_1. With respect to non reducing sugar, maximum content (0.66 %) was found in the fruits of T_6 (Half of RDF + 900 kg/ha DE), while the minimum content of non reducing sugar (0.20 %) was noticed in the treatment T_1. Maximum total sugar (11.76 %) content was found in T_9 (RDF + 900 kg/ha DE), while the minimum total sugar (9.50 %) content was noticed in the treatment T_1.

The highest juice percentage (71.36) was observed in T_9 (RDF + 900 kg/ha DE) which was on par with the treatment T_8 (RDF + 600 kg/ha DE) and T_7 (RDF + 300 kg/ha DE), while the minimum juice percentage (53.28) was noticed in the treatment T_1.

Significantly maximum score was recorded in T_9 (RDF + 900 kg/ha of DE) with respect to rind colour (4.56), aril colour (4.60) and overall acceptability (4.40), whereas minimum score with respect to rind colour (2.16), aril colour (2.66) and overall acceptability (2.83) was noticed in T_1. Regarding taste, T_8 (RDF + 600 kg/ha of DE) recorded the maximum score (4.36), while minimum score (2.83) was noticed in T_1.

higher nitrogen (1.57 %), phosphorous (0.41 %), potassium (0.67 %), copper (7.18 %), calcium (2.92 %), magnesium (0.50 %), zinc (8.58 ppm) and iron (16.23 ppm) content of fruit was observed in T_9 (RDF + 900 kg/ha of DE) and lower content 0.61 %, 0.26 %, 0.35 %, 2.38 %, 1.60 ppm was observed in T_1 respectively except magnesium in T_2 (0.24 %), zinc in T_3 (4.22 ppm) and iron in T_1 (8.86 ppm). Higher silicon content (0.85 ppm) of fruit was observed in T_6 (Half of RDF + 900 kg/ha of DE) and lower content was in T_8 (0.26 ppm).

The maximum pH (8.22) was observed in T_1 (absolute control) and minimum pH (7.08) was observed in T_8 (RDF + 600 kg/ha of DE), maximum electrical conductivity (0.17 dS/m) was observed in T_9 (RDF + 900 kg/ha of DE) and minimum electrical conductivity (0.22 %) was observed in T_1, highest organic carbon (1.55 %) was noticed in T_8 (RDF + 600 kg/ha of DE) and lowest organic carbon (0.56 %) was observed in T_6 (Half of RDF + 900 kg/ha of DE), highest phosphorus content (7.29 kg/ha) was observed in T_1 (absolute) and minimum phosphorous content (3.91 kg/ha) was observed in T_9 (RDF + 900 kg/ha of DE), maximum potassium content (94.49 kg/ha) was observed in T_9 (RDF + 900 kg/ha of DE) and minimum potassium content (55.42 kg/ha) was observed in T_2 (RDF), maximum calcium content (0.39 %) was observed in T_8 (RDF + 600 kg/ha of DE) and minimum calcium content (0.21 %) was observed in T_1, maximum magnesium content (0.08 %) was observed in T_5 (Half of RDF + 600 kg/ha of DE) and minimum magnesium content (0.02 %) was observed in T_7 (RDF + 300 kg/ha of DE), maximum zinc content (2.52 ppm) was observed in T_8 (RDF + 600 kg/ha of DE) and minimum zinc content (1.37 ppm) was observed in T_3, maximum iron content (7.75 ppm) was observed in T_8 (RDF + 600 kg/ha of DE) and minimum iron content (4.33 ppm) was observed in T_2, maximum copper content (9.40 ppm) was observed in T_5 (Half of RDF + 600 kg/ha of DE) and minimum copper content (3.89 ppm) was observed in T_8 (RDF + 600 kg/ha of DE), maximum silicon content (91.96 ppm) was observed in T_3 (Half of RDF) and minimum silicon content (57.10 ppm) was observed in T_7 (RDF + 600 kg/ha of DE).

The minimum percentage of anthracnose (19.06) and bacterial blight (11.33) coverage on fruits, minimum number of fruits infected by anthracnose (10.20) and bacterial blight (12.30) and minimum number of lesions of bacterial blight (3.70) on leaf was recorded in T_9 (RDF + 900 kg/ha of DE) and the maximum infction of anthracnose and bacterial blight was recorded in T_1 (Table 15 and 16).

Among the different treatments, T_9 (RDF + 900 kg/ha DE) recorded the highest benefit: cost ratio (9.57). This was followed by T_5 (half of RDF + 600 kg/ha DE). While the lowest Benefit: Cost ratio was noticed in T_1 (Absolute control).

Conclusion

Among the different treatments, T_9 (RDF + 900 kg/ha DE) recorded higher values for plant height, spread, number of flowers, yield, quality parameters, Benefit:Cost ratio and lower disease incidence, which was followed by the treatment T_8 (RDF + 600 kg/ha DE). So application of silicon with RDF will help the plants.

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Appendix I: Meteorological data recorded for the experimental period during 2013-2014

Months	Temperature (°C)		Mean Relative Humidity (%)	Rainfall (mm)
	Maximum	Minimum		
September	30.50	18.90	73.00	76.00
October	30.90	18.60	76.50	93.20
November	28.90	17.60	56.00	6.00
December	28.40	15.20	47.50	0.00
January	29.60	17.50	49.00	3.00
February	31.60	18.40	36.50	21.40

Appendix II: Initial soil analysis data of experimental site

Sl. No.	Soil properties	Characterization	Method employed
I Physical properties (oven dry basis)			
1	Sand (%)	56.50	Hydrometer method (Piper, 1950)
2	Silt (%)	18.50	-do-
3	Clay (%)	25.00	-do-
4	Texture	Sandy clay loam	-do-
II Chemical properties			
1	Soil pH	7.66	Potentiometric method (Jackson, 1967)
2	EC (Mmhos/cm^2)	0.13	Titration method (Yuan, 1959)
3	Available phosphorus (kg/ha)	5.37	Olsen's method (Jackson, 1967)
4	Available potassium (kg ha^{-1})	64.36	Flame photometer method (Jackson, 1967)
5	Calcium (ppm)	0.25	Titration with EDTA
6	Magnesium (ppm)	0.45	-do-
7	Zinc (ppm)	0.96	DTPA method (Lindasay and Norwell, 1978)
8	Cu (ppm)	3.51	-do-
9	Fe (ppm)	8.85	-do-

Appendix III: Prevailing input costs

Particulars	Cost (Rs.)
Inorganic inputs	
Urea	6.00/kg
DAP	8.00/kg
MOP	10.00/kg
Silicon	5.00/kg
Organic inputs	
FYM	5.00 /kg
Pomegranate	100.00/kg

EFFECT OF DIATOMACEOUS EARTH (SOURCE OF SILICON) ON GROWTH, YIELD AND QUALITY OF POMEGRANATE Cv. Kesar

ANAND S. KALATIPPI 2014 Dr. G. S. K. SWAMY
Major Advisor

ABSTRACT

Experiment was carried out in the farmers field at Lokapur (Mudhol) during 2013-2014 to study the effect of soil application of Diatomaceous earth (DE) on pomegranate cv. Kesar with 9 treatments. DE was applied after bahar treatment as whole basal application and recommended dose of fertilizer at the interval of 0, 45 and 90 days after bahar treatment. The experiment was laid out in RBD with three replications on six years old pomegranate plants planted at 3.5 X 3.5 m spacing.

Among the different treatments, maximum plant height, plant spread in north-south direction and plant spread in east-west direction were noticed in the treatment T_9 (RDF + 900 kg/ha DE) and the lowest were noticed in the treatment T_1 (Absolute control) at different stages of plant growth. Maximum total chlorophyll content was recorded by the treatment T_7 (RDF + 300 kg/ha of DE), whereas minimum value was recorded in T_3 (half of RDF). With respect to total crop duration, treatment T_9 (RDF + 900 kg/ha of DE) has taken less number of days, while delayed harvesting was noticed in the treatment control T_1. Maximum total number of flowers and yield per hectare was recorded in T_9 (RDF + 900 kg/ha of DE), while minimum total number of flowers and yield per hectare was recorded in T_1 (Absolute control).

Maximum fruit weight, volume, length, girth, total aril weight, 100 aril weight, seed weight, rind weight, TSS, sugars to acid ratio, minimum acidity, total sugar, juice percentage, rind colour, aril colour, overall acceptability, nutrient content in leaf and fruit except soil, minimum infection of anthracnose, bacterial blight and highest benefit:cost ratio was recorded in T_9 (RDF + 900 kg/ha DE) and the minimum values were recorded in treatment T_1 (Absolute control).