EFFECT OF FOLIAR SILICIC ACID AND BORON IN BANGALORE BLUE GRAPES

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UNIVERSITY OF AGRICULTURAL SCIENCES

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Affectionately dedicated to my beloved Parents, Sister and Friend

DEPARTMENT OF HORTICULTURE

UNIVERSITY OF AGRICULTURAL SCIENCES

BANGALORE – 560 065

CERTIFICATE

This is to certify that the thesis entitled **"EFFECT Of FOLIAR SILICIC ACID AND BORON IN BANGALORE BLUE GRAPES"** submitted in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (HORTICULTURE)** in **FRUIT SCIENCE** to the University of Agricultural Sciences, Bangalore, is a record of *bonafide* research work carried out by **Ms. BHAVYA, H.K., ID NO. PHK 811** during the period of his study in this University under my guidance and supervision and the data of this thesis has not previously formed the basis for the award of any other degree, diploma, associate ship, fellowship or other similar titles.

Bangalore
July, 2010

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July, 2010 *(BHAVYA, H. K.)*

EFFECT OF FOLIAR SILICIC ACID AND BORON IN BANGALORE BLUE GRAPES

BHAVYA, H.K.

ABSTRACT

The field experiment was conducted to examine the response of Bangalore Blue grape vines to foliar Silicic acid (SA) and Boron (B) spray. Silicon was given in the form of silicic acid at a concentration of 2, 4, 6 ml L^{-1} foliar SA for 6 sprays at 10 days interval and 3 sprays at 20 days interval, Boron was given in the form of borax at a concentration of 0.01 % and 0.02 % for 3 sprays at 10 and 20 days interval respectively. The highest cane length (110.09 cm), leaf area (179.44 cm^2) and total leaf chlorophyll content (13.73 mg/g) were observed in 4ml L^{-1} foliar SA at 10 days interval (6 sprays). The highest number of bunches per vine (325.53), yield per vine (37.19 kg) and yield per hectare (16.74 t) was recorded in 6ml L^{-1} foliar SA at 10 days interval (6 sprays) followed by 4ml L^{-1} foliar SA at 20 days interval (3 sprays). The maximum total soluble solids (15.33^{o}B) and lowest titratable acidity (0.76%) was recorded with 0.02per cent borax at 20 days interval (3 sprays) which was followed by 4ml L^{-1} foliar SA at 20 days interval (3 sprays). The minimum loss in bunch weight (6.30%) and per cent rotten berries (16.15) was recorded in 4ml L^{-1} foliar SA at 10 days interval (6 sprays) and maximum was recorded in control during storage. Application of 4ml and 6ml L^{-1} foliar SA at 10 days interval (6 sprays) and 6ml L^{-1} foliar SA at 20 days interval (3 sprays) were significantly influenced growth and yield parameters over control.

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INTRODUCTION

I. INTRODUCTION

Grape (*Vitis vinifera* L.) is considered as one of the most important commercial fruit crop of subtropical regions of the world and also grown successfully in the tropical and temperate areas of the world as commercial crop. It is a crop closely associated with history of human civilization. It is said to have originated in Caucasus region between Caspian Sea and Black sea. Grape cultivation first began in Asian minor, from there it spread towards Greece, Germany, United States and Philippines. It seems to have introduced to India from Iran and Afghanisthan invaders in 1300 A.D.

Among the several fruit crops in the world, grape is commercially grown in an area of about 8.92 million hectares with an annual production of 64.87 million tonnes. In India, grape is cultivated in an area of 64.4 thousand hectares with an annual production of 16.77 Lakh tonnes. Grape cultivation in India acquires greater significance due to its higher productivity (26.10 t ha^{-1}) as compared to many other grape growing countries (Anon., 2008). A recorded yield of 100 tonnes per hectare was reported at Hyderabad in grapes cv. Anab-e-Shahi which was termed as biological wonder by Olmo (1970). In India, major grape producing states are Maharastra, Karnataka, Punjab, Andra Pradesh and Tamil Nadu.

Grape is a refreshing fruit, rich in sugars, acids and minerals like nitrogenous compounds, iron, calcium, magnesium and vitamins like B1, B2, C and tannins. It used as table fruit, wine, juice and raisin.

Commonly grown grape varieties in the state are Thompson seedless, Anab-e-Shahi, Dil-Kush, Bangalore Blue and Gulabi. Bangalore Blue is the most popular variety of southern districts of Karnataka. This variety is supposed to be a natural hybrid of *Vitis vinifera* and *Vitis* *labrusca*. It is moderate yielder and vines are medium in vigour. Bunches are medium to small in size and compact. The berries are seeded, bluish or dark purple in color, medium size and spherical in shape, pulp is green and juicy. The juice is purple colored foxy flavored having total soluble solids (TSS) of about 16 to 18^0 brix and about 0.8 to 1.0 per cent acidity (Winkler *et al.*, 1974). The grapes are less preferred for table purpose as the berries are acidic in nature and thick skinned. However, this variety is commonly used for making juice and wine. The variety is resistant to many of the diseases compared to other varieties of grapes and by staggered pruning two crops in a year can be obtained.

Micronutrients play an important role in vine growth and productivity. The role of such nutrient like Boron (B) is well known, while the Silicon's (Si) beneficial as a nutrient role in grape cultivation is not known and research in horticultural crops is limited. They are most commonly applied as foliar spray and are applied to correct the deficiency of specific element rather than complete requirement of that element and they are essential for many enzymatic reactions.

Silicon is the most abundant in soil next to oxygen and comprises 28 per cent of its weight and 3-17 per cent in soil solution (Epstein 1999). It is most commonly found in soils in the form of solution as silicic acid (H_4SiO_4) and plants 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 Si 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. Many plants can accumulate Si concentrations higher than essential macronutrients (Epstein, 1999).

Si is deposited in the walls of epidermal cells after absorption by the plants, contributes considerably to stem strength. SA is not much mobile element in plants (Savant *et al.*, 1999). Therefore a continued supply of this element would be required particularly for healthy and productive development of plant during all growth stages (Yoshida, 1975).

The role of Si in plant biology is subjected to 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). Gong *et al.* (2003) observed improved water economy and dry matter yield with Si application and further it enhance leaf water potential under water stress conditions, reduced incidence of micronutrient and metal toxicity (Matoh *et al.*, 1991).

Mineral nutrition of plants is important for controlling physiological and biochemical processes of plants. Deficiency of mineral nutrient may lead to changes in these processes, disturbed plant growth and yield. Boron is one of such mineral nutrient, required for normal plant growth. It is found mainly in sedimentary rocks. The total content of boron in soils varies from *2 to 200 ppm,* most of which is not taken by the plants. In soil solution it is always found in combination with oxygen, behaving as a borate in all reactions. The borate is highly mobile and hence is easily lost by leaching.

The multiple functions involving B in plant metabolism include the processes of flowering and fruiting, germination of pollen grains, cell divisions, cell wall synthesis, metabolism of nitrogen, carbohydrates and pectic substances. Another critical function of B is in absorption of water by protoplasm and the absorption of mineral salts. The main function of B is reported to facilitate the transport of polar sugar molecules across the cell wall.

B is a constituent of cell membranes. It is immobile in the plant and accumulates in leaves, any boron deficiency is immediately reflected in metabolism of carbohydrates. Grapes require an adequate supply of available B, especially during flowering and fruit set. It is known to be critical in the elongation of the pollen tube, transfer of sugars and nutrients from leaves to fruit, increases pollination, cell wall strength, cell division and seed development (Ahmad *et al.*, 2009).

Therefore, based on the possible benefits of SA and B, this study was to know the effect of foliar application of silicon and boron on yield and quality of Bangalore Blue grapes with the following objectives:

1. Effect of foliar silicic acid and boron spray on vegetative characters of grape vine
2. Effect of foliar silicic acid and boron spray on bunch, berry and yield character
3. Effect of foliar silicic acid and boron spray on berry quality and nutrient uptake.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Grape is one of the important commercial fruit crops, known to receive higher quantity of nutrients than any other fruit crops cultivated in India. Supply of nutrients at critical growth stages of vine efficiently is very important to attain higher growth, yield and quality of grapes.

Among the mineral elements essential for plant growth, Si is reported as non essential element with beneficial effects on several crops. It has been characterized as an 'agronomically essential' for rice in Japan since it is used for obtaining high yield. 'Quasi essential' is another term used to describe Si for its prophylactic role against several stresses observed in a variety of plant species (Epstein and Bloom, 2005). SA can benefit plant growth and development in many ways. Some of these benefits include increased plant growth and crop quality, stimulate photosynthesis, reduced transpiration rate and increased plant resistance to abiotic and biotic stresses (Ma and Takahashi, 2002). Si contributes to greater shoot strength and resistance to lodging by contributing to the structure of cell walls. Si impregnates the walls of epidermal and vascular tissues, where it appears to strengthen the tissues, retard fungal infection and reduce water loss. It increases photosynthesis because of better light interception (Tisdale *et al.*, 1993). Most of the research on the benefits of Si has been conducted on agronomic crops, where as its role in horticulture crops has not been well investigated in comparison to agricultural crops like rice (Iler, 1979).

Boron is considered as an important essential micronutrient used in relatively small quantities for plant metabolism. Grape requires an adequate supply of B, especially during flowering and fruit set. The reviews pertaining to the work done on use of B in grape production is summarized and the research on use of Si on grape production is very much limited. The work done on similar aspects on some of the horticultural crops have been reviewed in this chapter under the following headings.

2.1 Influence of silicon on growth of Horticulture crops

2.2 Influence of silicon on yield and quality parameters of Horticulture crops

2.3 Silicon uptake and its influence on other nutrient uptake in Horticulture crops

2.4 Foliar application of boron on growth and development of grape vine

2.5 Foliar application of boron on berry development and quality of grape vines

2.6 Boron uptake and its influence on other nutrient uptake in Horticulture crop

2.1 Influence of silicon on growth in Horticulture crops

Although, Si is not considered as an essential element, positive growth effect including increased dry mass and yield, enhanced pollination and most commonly increased disease resistance (Gillman *et al.*, 2003). Si is not a much mobile element in plants (Savant *et al.*, 1999), hence a continued supply of this element would be required particularly for healthy and productive development of plant during all growth stages (Yoshida, 1975). The plant height was quadratically related to the rate of SA application, while it was related linearly with crop plant stem diameter (Elawad *et al.*, 1982).

2.1.1 Fruit plants

A study conducted by Cai and Rian (1995b) in apple observed that SA fertilizer applied at a rate of 15kg per tree to soil with concentration of available range from 314 to 404 mg silicon dioxide (SiO_2 Kg^{-1}) enhanced healthy growth and had stronger shoot, thicker and darker green leaves.

Cai and Rian (1995a) reported that Si fertilizer application to pecanut could increase the concentration of chlorophyll in the leaves, strong shoot development, double the nut formation and dry weight of the nut. Plants continuously subjected to 50ppm SiO_2 treatment under hydrophonic culture showed increased root dry weight and top dry weight of the strawberry plant (Miyake and Eiichi, 1986).

2.1.2 Flower plants

The use of sodium silicate ($NaSiO_3$) sprays was beneficial in a study on poinsettia. The severity and occurrence of bract necrosis decreased greatly when sodium silicate sprays were used on the Cv. 'Supjibi'. Postharvest bract damage also decreased in this cultivar (McAvoy and Bible, 1995). The silicates applied at 100ppm effective as calcium chloride sprays at 400ppm for up to five weeks after the cyathia began to open in gerbera and it showed increase in leaf area and peduncle length (McAvoy and Bible, 1995). Potassium silicate increased the basal stem diameter of zinnia plants when applied as a weekly drench weekly at 200mg/L. The flower and apical stem diameter was increased in zinnia with ashed rice hull media incorporated (100 g/m^{-3}), $NaSiO_3$ weekly foliar sprays (50, 100, and 150 mg/L Si), $KSiO_3$ drench (50 and 100 mg/L) and potassium silicate ($KSiO_3$) media incorporation at 140 g m^{-3} (Kamenidou *et al.*, 2009). Basal and apical stem diameters increased in ornamental sunflower treated with rice husk ash substrate incorporation (100 g/m^{-3}), $KSiO_3$ (140 g/m^{-3}), foliar $NaSiO_3$ (50, 100, and 150 mg/L) and $KSiO_3$ drench (50 and 100 mg/L) (Kamenidou and Todd, 2008).

According to Seung *et al.* (2005), Si in the form of Si chelate (500 mg L^{-1}) showed increased plant height, leaf area and number of shoots per plant in miniature rose. Saeed *et al.* (2009) reported that increased peduncle diameter, bud diameter and length, shoot length, leaf area, chlorophyll content, reduced malondialdehyde content and cell wall damage in *Rosa hybrida* cv. 'Hot lady' with the application of 150ppm Si under salt stressed condition. Rose plant cuttings received (50 and 100mg L^{-1}) Si was healthier than control. Leaf and root initiation was more, reduced fungal infection and decreased leaflet loss in plants treated with 50 mg L^{-1} Si (Jeffrey and David, 1999)

Neil and Roland (2010) conducted an experiment to examine whether weekly potassium silicate drenches would affect morphological traits of several floriculture species grown in soilless substrate. Plants treated weekly drenches 100 mg L^{-1} Si as potassium silicate for 10 weeks, showed increased height, diameter, fresh weight, dry weight, flower diameter and leaf thickness in all the 21 species. Tesfagiorgis *et al.* (2008) reported that addition of nutrient solution of Si (50 to 100 mg L^{-1}) enhance the plant growth of Zucchini and Zinnia plant.

2.1.3 Vegetables

Adatia and Besford (1986) reported more leaf thickness, more dry matter per unit leaf area, significant increment in the root fresh and dry weight, leaf fresh and dry weight and increased plant height with the application of Si in cucumber plant. Aziz *et al.* (2001) observed that Si (100 mM) applications to the growth media significantly improved growth of melon plant. Seome *et al.* (2008) reported that application of Si as slag increase in the plant growth, leaf area and increased pollen fertility in potato plants.

Luz *et al.* (2008) stated that application of K_2SiO_3 at 1per cent increased the chlorophyll a, b and total chlorophyll content, increased plant height and leaf area in all parts of the potato plant canopy. Liu (1997) reported that application of Si fertilizers decrease the occurrence of diseases, increased plant height, leaf area and chlorophyll content in the leaves of tomato plants.

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

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

2.2.1 Fruit plants

Cai and Rian (1995b) reported that apple tree receiving Silicon fertilizer at 15kg per tree to soil with a concentration of 300 to 400 mg SiO_2 Kg^{-1}, 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 Si fertilization to pecanut tree could increase the nut yield. Strawberry plants continuously received 50ppm SiO_2 recorded increased top weight, fruit yield and fruit weight and also showed increased pollen fertility (Miyake and Eiichi, 1986). Mathaba *et al.* (2009) revealed that Si at 0.5ppm had greater potential in mitigating chilling injury with less weight loss and membrane damage in citrus fruits.

Reaple and Laane (2008) stated that application of Si as OSAB showed the highest reduction in disease with increase in yield and flavour in papaya. 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 (100 mg L^{-1}) in citrus fruit.

According to Voogt and Sonneveld (1997), supply of Si (1mM L^{-1}) amendment to strawberry recorded upto 10 per cent increase in yield and a clear reduction in the incidence of powdery mildew.

2.2.2 Flower crops

Gerbera plants supplemented with several Si sources ($KSiO_3$ substrate incorporation or weekly substrate drench, $NaSiO_3$ foliar application and rice husk ash substrate) at different combinations, particularly $NaSiO_3$ foliar spray recorded thicker flower peduncle, increased flower diameter, height and early flowering than control (Kamenidou *et al.,* 2010). Kamenidou *et al.* (2009) studied the effect of different source of SA ($KSiO_3$ substrate incorporation or weekly substrate drench, $NaSiO_3$ foliar application & rice husk ash substrate) on the floriculture quality traits in zinnia and ornamental sunflower. The results revealed that, application of $KSiO_3$ as five weekly drenches increased the stem and flower diameter. Similarly, in ornamental sunflower applied $KSiO_3$ substrate drench (200 mg L^{-1}) resulted in larger flower diameter. Application of Si (150 ppm) under salt stressed condition. Saeed *et al.* (2009) observed that increased flower diameter, flower number and improved colour intensity and saturation of petals in *Rosa hybrida* cv. 'Hot lady'. Application of calcium silicate (7.3 g Si) per plot showed increased flower number, height, flower diameter and stem diameter in gerbera (Moyer *et al.*, 2010). Tesfagiorgis *et al.* (2008) reported increased plant yield with the application of 50 to 100 mg L^{-1} of silicate fertilizer by optimal disease in control and maximum growth in Zucchini and Zinnia.

2.2.3 Vegetables

Savvas (2009) reported that application of Si and nutrient induced salinity enhanced the fruit firmness, total soluble solids, β-carotene, lycopene and vitamin C in the tomato fruits and significantly restricted the occurrence of blossom end rot in tomato, when the plants were not exposed to salinity. Adatia and Besford (1986) reported increased number of fruits, average fruit weight with the application of silica solution at 3mM concentration in cucumber plants. The yield increase 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. Liu (1997) showed that application of silicate and calcium fertilizers increased fruit size and subsequently increased yield upto 20 per cent and improved the flavor of the tomato fruits by increasing sugar concentration in the fruit. Liang *et al.* (1993) reported that in a solution culture trail, adding Si (50mg ml^{-1}) to a nutrient solution increased the tomato yield by 42 per cent.

Luz *et al.* (2008) reported an increase in the yield up to 22.4 per cent with the application of 1 per cent K_2SiO_3 in potato plants. Carlor *et al.* (2008) reported that application of Si resulted in lodging and increased tuber weight and tuber yield of potato.

2.3 Foliar application of boron on growth and development of Grape vine

Prabu and Singaram (2001) reported that foliar application of 0.5 per cent $ZnSO_4$ with 0.2 percent Borax combination excelled in increasing the shoot length, number of internodes per shoot and number of leaves per shoot in Muscat grapes.

According to Mustafa *et al.* (2006) foliar application of 0.05 per cent Boric acid recorded increase in shoot length, number of laterals per shoot, number of leaves per shoot, leaf area and leaf fresh and dry weight in Bez El-Anza grape. Mahorkar and Patil (1987) investigated the effect of B on growth of three grape cultivars (Thompson seedless, Gulabi and Bangalore Purple). In Thompson Seedless and Gulabi grapes growth increased up to 0.076 g B per pot, stem girth was highest at 0.03g B per pot in Thompson Seedless. In Bangalore Purple grapes growth increased growth up to 0.07 g per pot.

The effect of B on the growth of Cabernet Sauvignon vines was studied by Downton and Hawker (1980). Results revealed that excessive B concentration showed reduced shoot length, plant dry mass and root mass, while stimulating plant lateral growth.

Dabas and Jindal (1985) studied the effects of B sprays on Thompson seedless. Application of boric acid (0.3 %) showed significantly increased fruitful buds and reduced vegetative buds with increased cane length. Berry set was increased and berry drop was decreased with the applications of 0.1 per cent gave the best results. A reduction in inflorescence dryness and improved quality was also observed. Christensen (1998) examined three different application methods of B on Thompson Seedless. The results showed that foliar sprayed treatments shows increased lateral growth and number of leaves per shoots.

2.4 Foliar application of boron on berry development and quality of Grape vine

Prabu and Singaram (2001) observed that foliar application of 0.5 per cent $ZnSO_4$ with 0.2 per cent Borax increased the yield in Muscat grape. Significant improvement in cluster weight was recorded in Red Roumy grapes by macro and micro nutrient spray (Ahmed *et al.*, 1997)

Ravel and Leela (2000) in Bangalore Blue grapes observed an increase in the TSS, total and reducing sugar and decrease in acidity with the application of B in combination with urea at 0.5 per cent and 0.2 per cent. Mustafa *et al.* (2006) reported foliar application of 0.05 per cent boric acid increased the yield, berry number per cluster, berry size, berry weight and progressively increased the percentage of total soluble solids as well as total sugar and decreased acidity in Bez El-Anza grape variety. Spraying Cabernet Sauvignon vines with Mn, B and Zn at 0.1 per cent, 0.01 per cent and 0.3 per cent in combination resulted in improved TSS, total sugars and maintains the yield (Policarpo and Stefanini, 2006).

According to Usha (2002) foliar application of 0.02 per cent Mg, 0.4 per cent B and 0.4 per cent Zn combination excelled in increasing the number of fruit bunch per plant, fruit weight, number of berries per bunch, fruit yield and also showed reduced number of unripe berries per bunch, acidity and increased TSS in Perlette grape. Spraying the Aliquate and Sapesani vines with Mn, B and Zn resulted in increased berry weight as reported by Sujkovskaja (1964). Musamukhamedor (1976) observed that application of B, Mn, Mo and Zn improved the number of berries per bunch and quality parameters in Taifi Razouyi grapes, the berry weight was improved by combined effect of B, Zn, Mo, Mn and Cu sprays.

Dabas and Jindal (1985) studied the effects of B sprays on Thompson seedless. Application boric acid 0.3 per cent showed significant increased berry set where as berry drop decreased with the applications at 0.1per cent. The author indicated that the application improved pollen germination, viability reduction in inflorescence dryness and improved quality of berries.

2.5 Silicon uptake and its influence on other nutrients uptake in other Horticulture crops

Uptake of Si has been examined, in both accumulating and non accumulating species, by examining the plant absorption of Si over the entire growth period and proposed three modes of Si 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 (Takahashi *et al.*, 1990). They also reported that Si 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. Si content of grapefruit seedlings treated with amorphous silica increased from 0.066 to 0.156 per cent in shoot and from 0.160 to 0.434 per cent in root. (Valdimir and David, 2000). The Si content of leaves increased proportionally to the increased Si concentration in the culture solution, and the incidence of powdery mildew decreased in strawberry (Miyake and Eiichi, 1986).

Mary (2005) showed application of $KSiO_3$ (125, 250 and 500 mg L^{-1}) increased the Si and calcium concentration in the leaf tissue of *Rosa chinensis minima* 'Sonja'. Kamenidou and Todd (2008) reported that application of hydrous $KSiO_3$ substrate (200 mg L^{-1} Si) increased leaf K, Mg, Cu, Mn and Mo concentration in the ornamental sunflower (*Helianthus annus* L. 'Ring of Fire). Foliar sprays of $NaSiO_3$ at a rate of 150 mg Si L^{-1} accumulated higher levels of Si in leaf, peduncle and flower tissues than non-supplemented controls and leaf concentrations of macronutrients (N, K, S and Ca) and micronutrients (B, Cu, Fe, and Mg) were slightly changed in Gerbera plants. Leaf Si concentrations were 1.2 to 3.3 fold higher in Si-supplemented plants, while the macronutrients, N, K, S, Mg, and Ca and micronutrients like Al and B concentration was increased in $KSiO_3$ (280 gm m^{-3}) supplemented Zinnia plants (Kamenidou *et al.*, 2009).

Neil and Roland (2010) conducted an experiment to know the influence of potassium silicate drenches on leaf SA concentration of several floriculture species grown in soilless substrate. SA supplementation increased leaf SA concentration of 11 cultivars, leaf SA concentrations for these supplemented plants was 13 per cent to 145 per cent greater than control plants.

In tomoto plants enhancement of Ca, K, Mg and Si uptake due to the addition of SA (2.25 mM) in the nutrient solution has been reported by Savvas (2009).

2.6 Boron uptake and its influence on other nutrients uptake in other Horticulture crops

The effect of varied concentration of B on mineral composition of Cabernet Sauvignon vines was studied by Downton and Hawker (1980). The B concentration reduced P concentration in the roots and leaf blade. A decrease in K concentration in the roots was also seen but an increased K in leaf blade was observed. Some symptoms of B toxicity were observed in the trial and it was noted that high chloride concentrations decreased the symptoms of B toxicity even with similar leaf blade B levels. Mustafa *et al.*, (2006) reported that foliar spray of B at 0.1 per cent showed progressive increment in the concentration of Fe, Zn, Mn and B in leaves. The B content was about 14ppm and nearly doubled by the B spray to its optimal range (40 to 46ppm).

MATERIAL AND METHODS

III. MATERIAL AND METHODS

The experiment on growth, yield and quality of Bangalore Blue grapes as influenced by application of foliar silicic acid (SA) and boron (B) was carried out in the vine yard of the Horticulture Research Station, Ghandhi Krishi Vignana Kendra, University of Agricultural Sciences, Bengaluru. The experiment was conducted during February to May, 2009. The details of the material and methods carried out during the investigation are described in this chapter.

3.1 Geographical location and climate

The Horticultural Research Station is situated at 12.68^0 north latitude, 77^0 35' longitude at an altitude of about 930 m above the mean sea level. The average annual rainfall of the area is 953 mm. Minimum and maximum temperature ranged from 12^0 C to 27^0 C respectively and relative humidity ranged between 30 and 80 percent. Metiorological data during the period of experimentation from February to May 2009 are presented in Appendix IV. The soil of the experimental plots is red sandy loam with reddish brown colour, deep, well drained with the pH ranged from 5 to 6. The Nitrogen, Phosphorus and Potassium contents of the soil were medium. The physical and chemical properties are presented in Appendices II and III.

3.2 Selection of the vine yard

The experiment was carried out on eighteen years old Bangalore Blue grape vines spaced at 7.5x3.75 m planted in quincunx system and 450 plants per hectare are trained on to bower system of training. Five plants were selected as one replication. Totally one thirty five plants which were having good growing condition were selected.

3.3 Time of Pruning

Vines were pruned during second week of February 2009. Pruning was done at 4th bud level. Treatments were imposed 30 days after pruning.

3.4 Experimental details

The experiment was conducted by using silicic acid and boron. These nutrients were applied as foliar spray at different concentration in addition to normal soil application of recommended fertilizers

Table 1. Treatment details

Treatments	Details	Materials (ha^{-1})
T_1	Soil application of recommended NPK fertilizers as per package of practice	1000:500:1500g NPK/plant/ year
T_2	Foliar application of 2ml Silicic acid per litre per vine as 6 sprays at 10 days interval	6 L ha^{-1}
T_3	Foliar application of 4ml Silicic acid per litre per vine as 6 sprays at 10 days interval	12 L ha^{-1}
T_4	Foliar application of 6ml Silicic acid per litre per vine as 6 sprays at 10 days interval	18 L ha^{-1}
T_5	Foliar application of 2ml Silicic acid per litre per vine as 3 sprays at 20 days interval	3 L ha^{-1}
T_6	Foliar application of 4ml Silicic acid per litre per vine as 3 sprays at 20 days interval	6 L ha^{-1}
T_7	Foliar application of 6ml Silicic acid per litre per vine as 3 sprays at 20 days interval	9 L ha^{-1}
T_8	Foliar application of 0.01 percent Borax per vine as 3 sprays at 10 days interval	50 g ha^{-1}
T_9	Foliar application of 0.02 percent Borax per vine as 3 sprays at 20 days interval	100 g ha^{-1}

Plate 1. General view of the experimental plot

3.4.1 Composition of foliar Silicic acid

Source of Silicon concentrated soluble silicic acid ($OSBA_3$) obtained from Silife Ltd., Leusden, the Netherland was used for conducting field experiment.

- Soluble silicic acid : 2.0 %
- Potassium as KCL : 1.2 %
- Boron as Boric acid : 0.8 %
- PEG_{400} : 48.0 %
- Demi water : 47.0 %

3.4.2 Source of Boron

Borax: $Na_2B_4O_7 . 10H_2O$ (11 % B)

3.4.3 Preparation of soluble silicic acid solution

Dissolve soluble silicic acid in fresh water in 1:5 dilution, leave it for 30 minutes for dissolution. Take required quantity of diluted soluble silicic acid, make up the volume of water based on need per treatment. 500 L of water was used to spray one hectare area. Spray was given to treatment plants along with the wetting agent (APSA-08). The sprays were given in the morning hours using hand sprayer.

3.4.4 Preparation of boron solution

Dissolve calculated amount of borax powder in fresh water, make up the volume of water based on need per treatment. 500 L of water was used to spray one hectare area. Spray was given to treatment plants along with the wetting agent (APSA-08).The sprays were given in morning hours using hand sprayer.

3.4.5 Imposition of treatments

The treatments were imposed third week after pruning at regular intervals. In treatment T_2, T_3 and T_4 foliar SA given as 6 sprays at 10 days interval from 20th March to 9th May 2009. Whereas, in treatment T_5, T_6 and T_7 foliar SA, 3 sprays were given at 20 days interval from 20th March to 29th April 2009. In treatment T_8, Borax given as 3 sprays at 10 from 20th March to 9th April 2009 and in treatment T_9 Borax given as 3 sprays at 20 days interval from 20th March to 29th April 2009.

The treatments were replicated three times by following Randomized Complete Block Design. The recommended fertilizers dosage for Bangalore Blue grapes as per the UAS package of Practice i.e., Nitrogen (1000g), Phosphorus (500g) and potassium (1500g) were applied in the form of Urea, Single Super Phosphate and Sulphate of Potash addition to farm yard manure. The fertilizers were applied as two split doses and continuous irrigation was given through drippers. As the experiment was conducted during summer season, incidence of pest and disease was very less.

3.5 Observations recorded

Following observations on growth parameter and yield attributes were recorded on each treatment vine.

3.5.1 Growth parameter

Growth parameters viz., cane length, number of leaves per cane, internodal length, leaf area, Total leaf chlorophyll content, fresh leaf and dry weight were measured once during 60 days after imposition of treatments.

3.5.1.1 Cane length (cm)

The cane length was recorded with the help of measuring tape from the cane joint to tip of the cane and expressed in centimetre.

3.5.1.2 Number of leaves per cane

The number of leaves per cane was recorded by counting the leaves.

3.5.1.3 Internodal length (cm)

The inter nodal length was measured in between the fifth and sixth internode by using measuring scale before harvest in each treatment and expressed in centimetre.

3.5.2 Leaf characters

3.5.2.1 Leaf area (cm^2)

Ten fully mature index leaves (5^{th} leaf) were collected randomly from each treatment and leaf area was measured using portable leaf area meter. Mean individual leaf area (cm^2) was calculated by dividing the total area by number of leaves.

3.5.2.2 Total Leaf chlorophyll content (mg/g of leaf)

The total leaf chlorophyll was extracted by immersing 100 mg of leaf discs collected randomly from 10 leaves of each treatment using 80 per cent acetone and DMSO (Dimethyl sulphoxide) 10ml each overnight. The extact was used for measuring optical density.

The optical density of the extract was measured at three wave lengths of 645, 652 and 663 nm by using Spectrophotometer. Total leaf Chlorophyll content was calculated by following formula

$$\text{Total Chlorophyll (mg/g of leaf)} = \frac{(A\ 652) \times V}{34.5 \times W}$$

Where: W is weight of leaf sample taken

V is volume made up

3.5.2.3 Leaf fresh weight and dry weight (g)

In each treatment vines, ten index leaves were collected. The fresh weight of the leaves was recorded by using top pan electronic balance and was subjected for drying in an oven at a temperature of 70 ± 5^0 C. After complete drying, dry weight was recorded and expressed in grams.

3.5.3 Yield parameters

The ripened bunches were harvested from each treatment vine separately and number of bunches per vine, weight of harvested bunches per vine were recorded.

3.5.3.1 Yield per vine

Yield per vine was calculated by counting the total number of bunches per vine multiplied with the average weight of the bunches and expressed as yield in kg per vine.

3.5.3.2 Yield per hectare

The weight of total bunches per vine was recorded and expressed in kilograms. The same was computed as yield per hectare and expressed in tonnes per hectare.

3.5.4 Bunch characters

3.5.4.1 Number of bunches per vine

The number of bunches on each vine was recorded by general counting and it is expressed as number of bunches per vine.

Twenty bunches per treatment vine were randomly selected and following bunch characters were taken.

3.5.4.2 Number of bunches per ten canes

The number of bunches on ten randomly selected canes was recorded by general counting and it is expressed as number of bunches per cane.

3.5.4.3 Bunch weight (g)

From labelled twenty canes, bunches were harvested and average bunch weight was recorded by using top pan electronic balance in each treatment and expressed in grams.

3.5.4.4 Bunch volume (ml)

The volume of the bunch was determined by the conventional water displacement method and expressed in millilitres. The average volume of bunch was worked out.

3.5.4.5 Bunch length (cm)

Length of each bunch from stalk end to the bottom end was measured with the help of measuring scale and average length of bunch was worked out and expressed in centimetre.

3.5.4.6 Bunch breadth (cm)

Breadth of each bunch was measured by using measuring scale and average breadth of bunches was worked out and expressed in centimetre.

3.5.5 Berry characters

3.5.5.1 Average berry weight (g)

From the selected bunches, ten berries per bunch were sampled and berry weight was taken by using top loading electronic balance and expressed in grams.

3.5.5.2 Length and breadth of berry (cm)

In each treatment from the labelled bunches five berries were taken and their breadth and length were recorded using a vernier calipers and expressed in centimetres.

3.5.5.3 Volume of berry (ml)

Randomly ten berries were taken from labelled bunches and immersed in the glass- measuring cylinder. The rise in the water level was noted. The difference in water level before and after immersing was calculated as fruit volume. Average fruit volume was recorded for 10 berries and expressed in millilitres.

3.5.5.4 Number of seeds per berry

Treatment wise, seeds were extracted from ten berries from labelled bunches and accounted .The mean value was taken and expressed as number of seeds per berry.

3.5.5.5 Fresh weight of the seeds

Treatment wise, berries from the labelled bunches were cut down and the seeds were taken out. Weight of ten seeds was taken using top loading electronic balance and expressed as fresh weight of seeds.

3.5.5.6 Dry weight of seeds

After taking the fresh weight of seeds, the same seeds were labelled and dried in oven in 65^0C. After drying, the weight of the sampled seeds was taken using electronic top loading balance and expressed as dry weight of seeds.

3.5.5.7 Rachis weight (g)

The berries were separated from the sampled bunches, after separation the weight of individual rachis was recorded by weighing separately on a top loading electronic balance and expressed in grams.

3.5.5.8 Number of berries per bunch

The berries were separated from the bunch and their count was taken and expressed as number of berries per bunch.

3.5.5.9 Pulp content with juice (%)

Treatment wise randomly berries were skin out. 50 berries were taken into account and squeeze out the juice. Then ratio of juice and pulp was calculated and expressed as pulp content with juice.

$$\text{Percent Juice content (v/w)} = \frac{\text{Volume of juice (ml)}}{\text{Weight of berry pulp (g)}} \times 100$$

3.5.6 Quality Parameters

Treatment wise, sampled berries were crushed and 200 grams of the pulp along with the juice was sampled. The juice was treated with sodium benzoate as anti microbial agent to be kept for required duration under refrigeration for chemical analysis.

3.5.6.1 Total soluble solids (^{0}B)

Treatment wise sampled berries were crushed and juice was extracted with the help of muslin cloth .The total soluble solids content of the extracted juice was determined by using an Erma hand refractometer (0-32^0 B) and expressed as degree brix.

3.5.6.2 Titratable acidity (%)

The extracted juice from berries was used for estimation of titratable acidity. 10 ml of the extracted juice was titrated against 0.1 N sodium hydroxide solution using phenolphthalein indicator and was expressed in percentage.

$$\text{Acidity (\%)} = \frac{\text{Titration value x } N_{NaOH} \text{ x vol. made up x Eq. Wt. of acid x 100}}{\text{Aliquot of extract used for titration x wt. of sample x 1000}}$$

3.5.6.3 Reducing sugar (%)

Reducing sugar content of grapes samples was estimated as described by Ranganna (1997) using Fehling's solution. It was estimated through Fehling's method where Fehling's A and B, Methylene blue indicator, 45 per cent neutral lead acetate and 22 per cent potassium oxalate solution were used as regents. 25 g of the blended sample was put in 500 ml beaker, added 200 ml water and the solution was neutralized with 1 N NaOH using phenolphthalein indicator. Then, solution was gently boiled for one hour with occasional stirring over water bath. The solution was cooled and transferred into 250 ml volumetric flask, made up to volume and filtered through whatman No.4 filter paper. From this solution 50 ml was pipette into 250 ml volumetric flask, added 2 ml lead acetate and 100 ml water and left for 10 minutes, then precipitated with the help of potassium oxalate (2 ml) solution, made up to volume and titrated. The filtrate (clarified solution) was used for estimation of reducing sugar.

$$\text{Reducing Sugar (\%)} = \frac{0.05 \times \text{Dilution}}{\text{Titre value} \times \text{Weight of sample}} \times 100$$

3.5.6.4 Total sugar (%)

Total sugar content of grapes samples were estimated as described by Ranganna (1997) using Fehling's solution. 50 ml aliquot of the clarified solution was acidified with the 5 gram of citric acid and kept for 24 hours for inversion. After that, the solution was neutralized with sodium hydroxide using phenolphthalein indicator. Then aliquot was made up to 100 ml and finally this solution was used for estimation of total sugar using Fehling's solution.

$$\text{Total Sugar (\%)} = \frac{0.05 \times \text{Dilution} \times 100}{\text{Titre value} \times \text{Weight of sample}} \times 0.95$$

3.5.6.5 Non Reducing sugar (%)

The non-reducing sugar was estimated by subtracting reducing sugar from total sugar.

Non-reducing sugar (%) = Total sugar (%) – Reducing sugar (%)

3.5.7 Post-harvest life of the grapes

Treatment wise, fully ripened bunches were selected and their weight was taken in the beginning and then kept in room condition. The bunches were kept for 12 days to know the physiological process and loss of weight. At the end, final weight of the sampled bunches was taken and compared with initial weight of the sampled bunches. The loss of bunch weight was counted in percentage. In addition, per cent rotten or fungal infected berries.

3.6 Plant analysis

Petioles are use to determine the nutritional status of grapes. Petioles were collected from the basal 5th leaf of the cane during crop growth stage. Leaves were removed and petioles were collected for further analysis (Nagarajah, 1998).

3.6.1 Estimation of Silicon in leaf petiole of grape cv. Bangalore Blue

3.6.1.1 Plant sample digestion

The grape petiole sample was dried in an oven at 70^0 C for 2 days and made fine powder prior to analysis. The sample (0.1g) was digested in a mixture of 7ml of HNO_3 (70 %), 2ml of H_2O_2 (3%) and 1ml of HF (40 %) [Tri acid mixture] using microwave digesting system (Milestone- start D) at 800 watt for 17min, 800 watt for 10min and venting for 10 min. The digested samples were diluted to 50ml with 4per cent boric acid (Ma *et al.* 2002)

3.6.1.2 Estimation of silicon in plant sample

The silicon concentration in the digested solution was determined by transferring 0.5ml of digested aliquot to a plastic centrifuge tube and added with 1.5ml of 0.2N HCL, 0.5ml of 10per cent ammonium molybdate [$(NH4)6\ Mo_7O_2$] and 0.5ml of 20per cent tartaric acid and 0.5ml of reducing agent (Amino napthol sulphonic acid – ANSA) was added and the volume was made up to 12.5 ml with distilled water. After 1hr, the absorbance was measured at 600nm with a uv-visible spectrophotometer (Ma *et al.,* 2002). Similarly, standards (0, 0.2, 0.4, 0.8 and 1.2ppm) were prepared by following same procedure.

$$Si\ (\%) = \frac{\text{Graph ppm x Vol. made up after digestion x Vol. made up of Aliquot}}{\text{Weight of sample x Aliquot taken}} \times 100$$

3.6.2 Estimation of Boron, phosphorus, potassium and calcium in leaf petiole of grape cv. Bangalore Blue

3.6.2.1 Plant sample digestion

The grape petiole sample was dried in an oven at 70^0 C for 2 days prior to analysis. The sample (0.1g) was digested in a mixture of 7ml of HNO_3 (70 %) and 3ml of H_2O_2 (3%) [Di-acid mixture] using microwave digesting system (Milestone- start D) with the following steps: 800 watt for 17min, 800 watt for 10min and venting for 10 min. The digested samples were diluted to 50ml with distil water.

3.6.2.2 Estimation of Boron in plant sample

The boron concentration in the digested sample was determined by transferring 2 ml of digested aliquot added with 2ml of buffer solution and 2 ml of Azomethine reagent and allowed to stand for 30 minutes. The absorbance was measured at 420nm with a uv - visible spectrophotometer.

$$B\ (ppm) = \frac{\text{Graph ppm x Vol. of digested sample x Vol. made up}}{\text{Weight of sample x Aliquot taken}}$$

3.6.2.3 Estimation of phosphorus in plant sample

The phosphorus concentration in the digested solution was determined by transferring 5ml of digested aliquot to a plastic centrifuge tube, added with 5ml vanadomolybdate reagent and the volume was made up to 50ml. After 30 minutes, the absorbance was measured at 430nm with a uv-visible spectrophotometer. Similarly, standards (0, 0.2, 0.4, 0.8 and 1.2ppm) were prepared by following same procedure.

$$P (\%) = \frac{\text{Graph ppm x Vol. of digested sample x Vol. made up}}{\text{Weight of sample x Aliquot taken}} \times 100$$

3.6.2.4 Estimation of potassium in plant sample

The potassium concentration in the digested samples was determined by preparing the stan dards of 0, 1, 2, 3, 4 and 5ml of 100ppm K and made up the volume to 50ml with distilled water. The readings were recorded by feeding the standards in the flame photometer and prepared the standard curve by plotting flame photometer reading versus concentrations of standards. By feeding the digested samples in flame photometer the readings were recorded and compared the unknown sample readings with standard curve.

$$P (\%) = \frac{\text{Graph ppm x Vol. of digested sample}}{\text{Weight of sample x } 10^6} \times 100$$

3.6.2.5 Estimation of calcium in plant sample

The calcium concentration in the digested sample was determined by transferring 5ml of digested sample in a porcelain basin diluted with 25ml of water, sufficient quantity of 10 per cent NaOH and 0.5g of muroxide indicator. The contents were titrated against standard EDTA with stirring until it becomes violet in colour and the burette readings are noted down. The per cent calcium was calculated by following formula.

$$C (\%) = \frac{\text{B.R. of EDTA x N of EDTA x Vol. of digested sample}}{\text{Weight of sample x Aliquot taken}} \times 100$$

3.7 Statistical Analysis of experimental data

The experimental data collected relating to different parameters were statistically analyzed using fortan computer at the University of Agricultural Sciences, G.K.V.K., Bengaluru, by adopting Randomized complete block design and results were tested at 5 percent level of significance by Fischer method of analysis of variance as suggested by Cochran and Cox (1957). Wherever F- test was significant and for comparison of such treatment means, CD values were worked at the probability level of 0.05.

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

The present investigation entitled "Effect of foliar silicic acid and boron in Bangalore Blue grapes" was carried out to know the effect of SA and B on growth, yield and quality of Bangalore Blue grape. The field experiment was carried out at Department of Horticulture, University of Agricultural Sciences, G.K.V.K, Bengaluru, during February 2009 to Augusts 2009. Results of the experiment are presented in this chapter.

4.1 Growth parameter

4.1.1 Cane length (cm)

The cane length was markedly improved by the use of foliar SA and B. The effect of treatments on cane length is portrayed in Table 2 and Fig. 1. The maximum cane length (110.09 cm) found in the treatment T_3 (4ml L^{-1} foliar SA as 6 sprays at 10 days interval) which was on par with T_4 (6ml L^{-1} foliar SA as 6 sprays at 10 days interval) (107.77 cm). The minimum cane length (89.84 cm) was recorded in T_1 (Control).

4.1.2 Internodal length (cm)

The influence of foliar SA and B on internodal length was found significant and is presented in Table 2. The internodal length between 5^{th} and 6^{th} node was maximum (8.59 cm) in treatment T_3 (4ml L^{-1} foliar SA 6 sprays at 10 days interval) which was on par with T_4 (6ml L^{-1} foliar SA as 6 sprays at 10 days interval) (8.22 cm), T_6 (4ml L^{-1} foliar SA as 3 sprays at 20 days interval) (8.20 cm), T_7 (6ml L^{-1} foliar SA as 3 sprays at 20 days interval) (7.99 cm) and T_9 (0.02% L^{-1} borax 3 sprays at 20 days interval) (7.51 cm) and T_8 (0.01% L^{-1} borax 3 sprays at 10 days interval). However, the minimum intermodal length (7.41 cm) was noticed in treatment T_5 (foliar SA 4ml L^{-1} as 3 sprays at 20 days interval).

Table 2. Effect of foliar silicic acid (SA) and boron (B) on growth characters of Bangalore Blue grapes

Treatments	Cane length (cm)	Internodal length (cm)	Number of leaves per shoot
T_1- Control	89.84	7.61	16.20
T_2- Foliar SA 2ml L^{-1} at 10 days interval (6 sprays)	91.13	7.44	17.53
T_3- Foliar SA 4ml L^{-1} at 10 days interval (6 sprays)	110.09	8.59	21.66
T_4- Foliar SA 6ml L^{-1} at 10 days interval (6 sprays)	107.77	8.22	19.61
T_5- Foliar SA 2ml L^{-1} at 20 days interval (3 sprays)	95.15	7.41	17.88
T_6- Foliar SA 4ml L^{-1} at 20 days interval (3 sprays)	98.15	8.20	19.46
T_7- Foliar SA 6ml L^{-1} at 20 days interval (3 sprays)	92.85	7.99	17.78
T_8- Borax spray 0.01% L^{-1} at 10 days interval (3 sprays)	92.55	7.58	18.77
T_9- Borax spray 0.01% L^{-1} at 20 days interval (3 sprays)	94.79	7.71	19.04
F- test	*	*	*
SEm ±	5.06	0.34	0.88
CD at 5%	11.02	1.05	2.71

*: Significant

NS: non-significant

T_1: Control

T_2: 2ml L^{-1} foliar SA 6 sprays at 10 days interval

T_3: 4ml L^{-1} foliar SA 6 sprays at 10 days interval

T_4: 6ml L^{-1} foliar SA 6 sprays at 10 days interval

T_5: 2ml L^{-1} foliar SA 3 sprays at 20 days interval

T_6: 4ml L^{-1} foliar SA 3 sprays at 20 days interval

T_7: 6ml L^{-1} foliar SA 3 sprays at 10 days interval

T_8: 0.01% borax 3 sprays at 10 days interval

T_9: 0.02% borax 3 sprays at 20 days interval

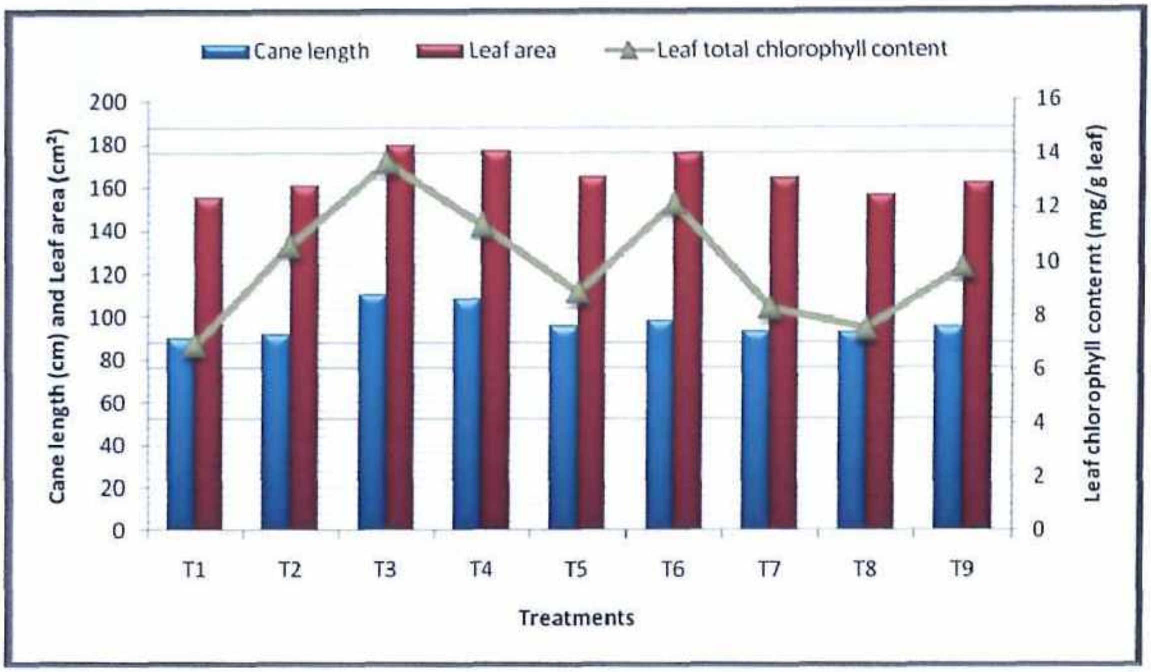

Fig. 1. Effect of foliar silicic acid and boron on cane length (cm), leaf area (cm2) and total leaf chlorophyll content (mg g^{-1} leaf of Bangalore Blue grapes

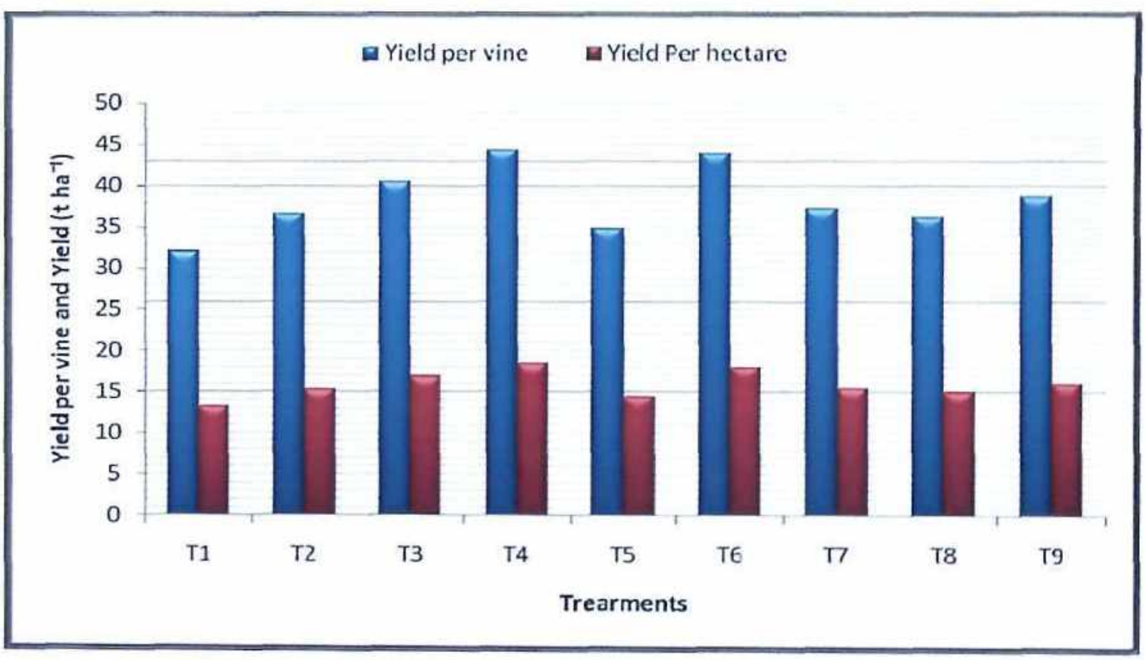

Fig. 2. Effect of foliar silicic acid and boron on yield per vine and Yield (t ha^{-1}) of Bangalore Blue grapes

Plate 2. Bunches of control treatment

Plate 3. Bunches received foliar silicic acid 2ml L^{-1} at 10 days interval as six sprays

4.1.3 Number of leaves per shoot

The number of leaves per shoot differed significantly among the treatments (Table 2). The maximum number of leaves per shoot (21.66) was recorded in treatment T_3 (4ml L^{-1} foliar SA as 6 sprays at 10 days interval) followed by T_4 (6ml L^{-1} foliar SA as 6 sprays at 10 days interval) (19.61), T_6 (4ml L^{-1} foliar SA as 3 sprays at 20 days interval) (19.41) and T_9 (0.02% L^{-1} borax 3 sprays at 20 days interval) (19.04) which were on par with each other. The minimum number of leaves per shoot (16.20) was recorded in the treatment T_1 (control).

4.1.4 Leaf area

The leaf area varied significantly with foliar SA and B application in Bangalore Blue grapes and data is presented in Table 3 and the same is depicted in Fig. 1. The maximum leaf area (179.44 cm^2) was recorded in the treatment T_3 (4ml L^{-1} foliar SA 6 sprays 10 days interval) followed by T_4 (6ml L^{-1} foliar SA as 6 sprays at 10 days interval) (176.81 cm2), T_6 (4ml L^{-1} foliar SA as 3 sprays at 20 days interval) (175.90 cm^2), T_5 (2ml L^{-1} foliar SA 3 sprays at 20 days interval) (164.38 cm^2)and T_7 (6ml L^{-1} foliar SA as 3 sprays at 20 days interval) (164.28 cm^2). However, the minimum leaf area (155.46 cm^2) was recorded in the treatment T_1 (control).

4.1.5 Leaf chlorophyll content

The variation in total leaf chlorophyll content as influenced by different levels of foliar SA and B presented in the Table 3 and Fig. 1.

The leaf total chlorophyll content varied significantly among the treatments. The maximum total leaf chlorophyll content (13.73 mg g^{-1}) was recorded in the treatment T_3 (4ml L^{-1} foliar SA as 6 sprays at 10 days interval) and which was on par with the treatment T_6 (6ml L^{-1} the foliar SA 3 sprays at 20 days interval) (12.21 mg g-^{1}). However, the minimum total leaf chlorophyll (6.93 mg g^{-1}) was recorded in the T_1 (control).

h.

Table 3. Effect of foliar silicic acid (SA) and boron (B) on leaf characters in Bangalore Blue grapes

Treatments	Leaf area (cm^2)	Leaf total chlorophyll content (mg g^{-1} leaf)	Fresh weight of leaf (g)	Dry weight of leaf (g)
T_1- Control	155.46	6.93	23.93	6.82
T_2- Foliar SA 2ml L^{-1} at 10 days interval (6 sprays)	161.01	10.66	27.80	8.34
T_3- Foliar SA 4ml L^{-1} at 10 days interval (6 sprays)	179.44	13.73	31.93	9.76
T_4- Foliar SA 6ml L^{-1} at 10 days interval (6 sprays)	176.81	11.41	26.87	8.95
T_5- Foliar SA 2ml L^{-1} at 20 days interval (3 sprays)	164.38	8.89	26.70	8.48
T_6- Foliar SA 4ml L^{-1} at 20 days interval (3 sprays)	175.90	12.21	30.67	9.23
T_7- Foliar SA 6ml L^{-1} at 20 days interval (3 sprays)	164.28	8.31	22.60	7.38
T_8- Borax spray 0.01% L^{-1} at 10 days interval (3 sprays)	156.94	7.53	29.67	8.24
T_9- Borax spray 0.01% L^{-1} at 20 days interval (3 sprays)	161.94	9.82	30.20	9.68
F- test	*	*	*	*
SEm ±	7.41	0.57	1.74	0.67
CD at 5%	16.15	1.75	5.37	2.09

*: Significant NS: non-significant

4.1.6 Leaf fresh weight (g)

The foliar SA and B had significant influence on the fresh weight of the ten leaves among different treatments in Bangalore blue grapes and is presented in Table 3. The maximum fresh weight (31.93 g) of the leaves was recorded in the treatment T_3 (4ml L^{-1} foliar SA as 6 sprays at 10 days interval) followed by the treatment T_6 (6ml L^{-1} foliar SA as 3 sprays at 20 days interval) (30.67 g), T_9 (0.02% L^{-1} borax 3 sprays at 20 days interval) (30.20 g), T_8 (0.01% L^{-1} borax 3 sprays at 10 days interval) (29.67 g), T_2 (2ml L^{-1} foliar SA 6 sprays at 10 days interval) (27.80 g) and T_4 (6ml L^{-1} foliar SA 6 sprays at 10 days interval) (26.87 g) were on par with each other. The minimum fresh weight (23.93 g) of the leaves was recorded in control treatment.

4.1.7 Leaf dry weight (g)

The dry weight of the ten leaves varied significantly as compare to control and it is presented in Table 3. All the treatments were on par or significantly superior over control. The maximum dry weight of the ten leaves (9.76 g) was recorded in the treatment T_3 (4ml L^{-1} foliar SA as 6 sprays at 10 days interval). The minimum dry weight of ten leaves (6.82 g) was recorded in the treatment T_1 (control).

4.2 Yield parameter

4.2.1 Number of bunches per vine

The foliar SA and B had significant influence on the number of bunches per vine among different treatments in Bangalore Blue grape and is presented in Table 4. The number of bunches per vine was maximum (325.53) in the treatment T_3 (4ml L^{-1} foliar SA as 6 sprays at 10 days interval). The minimum number of bunches per vine (295.20) was recorded in the treatment T_1 (control).

4.2.2 Bunch weight (g)

The bunch weight varied significantly among the treatments and presented in Table 4. The maximum bunch weight (131.19 g) was recorded in the treatment T_4 (6ml L^{-1} foliar SA as 6 sprays at 10 days interval) followed by the treatment T_6 (4ml L^{-1} foliar SA as 3 sprays at 20 days interval) (127.36 g), T_9 (0.02% L^{-1} borax as 3 sprays at 20 days interval) (121.59 g), T_8 (0.01% L^{-1} borax 3 sprays at 10 days interval) (119.44 g) and T_2 (2ml L^{-1} foliar SA 6 sprays at 10 days interval) (117.63 g). The minimum bunch weight (91.53 g) was recorded in the treatment T_1 (control).

4.2.3 Bunch length (cm)

The influence of different treatments of SA and B on length of bunches was significant in Bangalore Blue grapes. The data are presented in Table 4. The maximum bunch length (13.02 cm) was recorded in the treatment T_4 (6ml L^{-1} foliar SA as 6 sprays at 10 days interval) which was on par with the treatments T_6 (4ml L^{-1} foliar SA at 20 days interval) (12.52 cm), T_2 (2ml L^{-1} foliar SA 6 sprays at 10 days interval) (12.35 cm) and T_9 (0.02% L^{-1} borax as 3 sprays at 20 days interval) (12.27 cm). The minimum bunch length (9.84 cm) was recorded in the treatment T_1 (control).

4.2.4 Bunch breadth (cm)

The breadth of the bunch was significantly influenced by foliar SA and boron at different treatment concentrations and is presented in Table 4. The maximum bunch breadth (6.27 cm) was obtained in the treatment T_4 (4ml L^{-1} foliar SA as 6 sprays at 10 days interval) which is followed by the treatment T_6 (4ml L^{-1} foliar SA as 6 sprays at 20 days interval) (5.95 cm), T_9 (0.02% L^{-1} borax as 3 sprays at 20 days interval) (5.83 cm), T_8 (0.01% L^{-1} borax as 3 sprays at 10 days interval) (5.72 cm)

Table 4. Effect of foliar silicic acid and boron on bunch characters in Bangalore blue grapes

Treatments	Number of bunches per vine	Bunch weight (g)	Bunch length (g)	Bunch breadth (g)	Bunch volume (ml)
T_1- Control	295.20	90.38	9.48	4.73	73.40
T_2- Foliar SA 2ml L^{-1} at 10 days interval (6 sprays)	283.27	117.63	12.35	5.69	100.07
T_3- Foliar SA 4ml L^{-1} at 10 days interval (6 sprays)	325.53	104.06	11.26	5.30	83.67
T_4- Foliar SA 6ml L^{-1} at 10 days interval (6 sprays)	301.00	131.19	13.02	6.27	116.40
T_5- Foliar SA 2ml L^{-1} at 20 days interval (3 sprays)	294.00	100.42	11.44	5.13	79.47
T_6- Foliar SA 4ml L^{-1} at 20 days interval (3 sprays)	298.00	127.36	12.52	5.95	115.00
T_7- Foliar SA 6ml L^{-1} at 20 days interval (3 sprays)	296.60	93.92	11.72	5.24	93.53
T_8- Borax spray 0.01% L^{-1} at 10 days interval (3 sprays)	271.33	119.44	11.23	5.72	105.80
T_9- Borax spray 0.01% L^{-1} at 20 days interval (3 sprays)	285.53	121.59	12.27	5.83	106.87
F- test	*	*	*	*	*
SEm ±	1.74	4.83	0.35	0.19	3.29
CD at 5%	5.37	14.89	1.07	0.59	10.12

*: Significant NS: non-significant

and T_2 (2ml L^{-1} foliar SA 6 sprays at 10 days interval) (5.69 cm) which were on par with each other. However, the treatment T_1 (control) recorded minimum bunch breadth (4.73 cm).

4.2.5 Bunch volume (ml)

The volume of the bunch as influenced by foliar SA and B at different concentration was found to be significant (Table 4). The highest bunch volume (116.40 ml) was obtained in the treatment T_4 (4ml L^{-1} foliar SA as 6 sprays at 10 days interval) which is followed by the treatment T_6 (4ml L^{-1} foliar SA as 3 sprays at 20 days interval) (115.00 ml) and T_9 (0.02% L^{-1} borax as 3 sprays at 20 days interval) (106.87 ml) were on par with each other. The lowest bunch volume (73.40 ml) was noticed in the treatment T_1 (control).

4.2.6 Yield per vine (Kg)

Significant difference was noticed in the yield per vine with the application of foliar SA and B in Bangalore Blue grapes and is presented in Table 5 and Fig. 2. The highest yield per vine (37.19 kg) was recorded in the treatment T_4 (6ml L^{-1} foliar SA as 6 sprays at 10 days interval) which was on par with the treatment T_6 (4ml L^{-1} foliar SA as 3 sprays at 20 days interval) (36.14 kg), T_9 (0.02% L^{-1} borax as 3 sprays at 10 days interval) (34.72 kg) and T_3 (4ml L^{-1} foliar SA as 6 sprays at 10 days interval) (33.87 kg). In contrary the lowest yield per vine (31.96 kg) was recorded in T_1 (control).

4.2.7 Yield per hectare (t ha^{-1})

The foliar SA and B had significant influence on yield per hectare among different treatments in Bangalore Blue grapes and it is presented in Table 5 and Fig. 4. The highest estimated yield per hectare (16.74 t) was recorded in the treatment T_4 (6ml L^{-1} foliar SA as 6 sprays at 10 days interval) followed by the treatment T_6 (4ml L^{-1} foliar SA as 3 sprays at 20

Table 5. Effect of foliar silicic acid and boron on yield characters of Bangalore Blue grapes

Treatments	Yield per vine (Kg)	Estimated Yield per hectare (t)
T_1- Control	26.68	12.01
T_2- Foliar SA 2ml L^{-1} at 10 days interval (6 sprays)	31.87	14.34
T_3- Foliar SA 4ml L^{-1} at 10 days interval (6 sprays)	33.87	15.24
T_4- Foliar SA 6ml L^{-1} at 10 days interval (6 sprays)	37.19	16.74
T_5- Foliar SA 2ml L^{-1} at 20 days interval (3 sprays)	29.52	13.29
T_6- Foliar SA 4ml L^{-1} at 20 days interval (3 sprays)	36.14	16.26
T_7- Foliar SA 6ml L^{-1} at 20 days interval (3 sprays)	27.86	12.54
T_8- Borax spray 0.01% L^{-1} at 10 days interval (3 sprays)	31.51	14.18
T_9- Borax spray 0.01% L^{-1} at 20 days interval (3 sprays)	34.72	15.62
F- test	*	*
SEm ±	1.14	0.48
CD at 5%	3.53	1.48

*: Significant

NS: non-significant

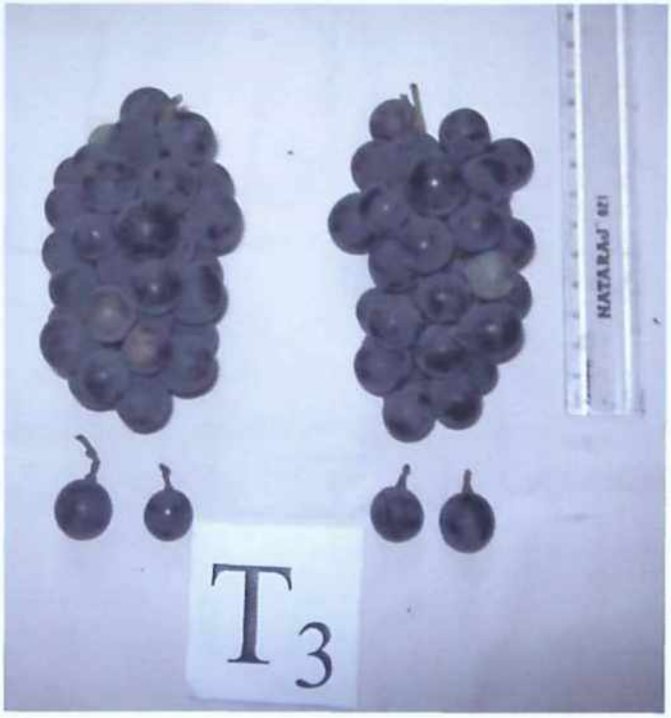

Plate 4. Bunches received foliar silicic acid 4ml L^{-1} at 10 days interval as six sprays

Plate 5. Bunches received foliar silicic acid 6ml L^{-1} at 10 days interval as six sprays

days interval) (16.26 t) and T_9 (0.02% L^{-1} borax 3 sprays at 20 days interval) (15.62 t) which were on par with each other. The lowest yield per hectare (12.01 t) was recorded in treatment T_1 (control).

4.2.8 Number of berries per bunch

The number of berries per bunch was on par and significantly superior over control in Bangalore blue grapes and is presented in Table 6. The maximum number of berries per bunch (38.10) was recorded in the treatment T_4 (6ml L^{-1} foliar SA as 3 sprays at 10 days interval). The minimum number of berries per bunch (32.60) was recorded in the treatment T_1 (control).

4.2.9 Number of Ripe berries per bunch

The influence of foliar SA and B on ripe berries was differed significantly among the treatments and is presented in the Table 6. The maximum number of ripe berries (36.05) was observed in the treatment T_4 (6ml L^{-1} foliar SA as 6 sprays at 10 days interval) which was on par with the treatment T_6 (4ml L^{-1} foliar SA as 3 sprays at 20 days interval) (35.00), T_2 (2ml L^{-1} foliar SA as 6 sprays at 10 days interval) (34.03) and T_9 (0.02% L^{-1} borax 3 sprays at 20 days interval) (34.00). However, the minimum number of ripe berries (27.77) were recorded in the treatment T_7 (6ml L^{-1} foliar SA at 20 days interval) followed by the treatment T_1 (control) (27.27).

4.2.10 Number of Unripe berries per bunch

The unripe berries differed significantly with the application of foliar SA and B at different concentration on Bangalore Blue grapes and presented in Table 6. The minimum number of unripe berries (2.05) was recorded in the treatment T_4 (6ml L^{-1} foliar SA as 6 sprays at 10 days interval) which was on par with the treatment T_2 (2ml L^{-1} foliar SA as 6 sprays at 10 days interval) (2.67), T_6 (4ml L^{-1} foliar SA as 3 sprays at 20 days interval) (3.00) and T_3 (4ml L^{-1} foliar SA 6 sprays at 10 days interval) (3.67). However, the maximum number of unripe berries (5.33) was recorded in the treatment T_1 (control).

4.2.11 Number of seeds per ten berries

The number of seeds per ten berries was statistically significant as compare to control and is presented in Table 6. The maximum number of seeds (18.40) obtained in the treatment T_4 (6ml L^{-1} foliar SA as 6 sprays at 10 days interval) which were on par with the treatments T_6 (4ml L^{-1} foliar SA as 3 sprays at 20 days interval) (18.33), T_3 (4ml L^{-1} foliar SA as 6 sprays at 10 days interval) (18.23), T_9 (0.02% L^{-1} borax 3 sprays at 20 days interval) (17.87), T_2 (2ml L^{-1} foliar SA 6 sprays at 10 days interval) (17.80) and T_8 (0.01% L^{-1} borax 3 sprays at 10 days interval) (17.40). The minimum number of seeds (16.67) was recorded in the treatment T_1 (control).

4.2.12 Fresh weight of ten seeds

The influence of different treatments of SA and B on fresh weight of seeds found statistically non significant in Bangalore Blue grapes. The effect of treatments with foliar SA and B are presented in Table 6. The maximum fresh weight of seeds (1.68 g) was recorded in the treatment T_3 (4ml L^{-1} foliar SA as 6 sprays at 10 days interval) and the minimum fresh weight of seeds (1.42 g) was recorded in the treatment T_1 (control).

4.2.13 Dry weight of ten seeds

The dry weight of seeds was not significantly differed by foliar SA and B at different concentration among the treatments (Table 6). However, the highest dry weight of seeds (1.31 g) was obtained in the treatment T_3 (4ml L^{-1} foliar SA as 6 sprays at 10 days interval). The minimum dry weight of seeds (1.09 g) was noticed in the treatment T_1 (control).

Table 6. Effect of foliar silicic acid and boron on Berry characters of Bangalore Blue grapes

Treatments	Number of berries per bunch	Number of fully ripe berries per bunch	Number of unripe berries per bunch	Number of seed per ten berries	Fresh weight of tee seeds	Dry weight of ten seeds
T_1- Control	32.60	27.27	5.33	16.67	1.42	1.09
T_2- Foliar SA 2ml L^{-1} at 10 days interval (6 sprays)	36.70	34.03	2.67	17.80	1.60	1.16
T_3- Foliar SA 4ml L^{-1} at 10 days interval (6 sprays)	33.00	29.33	3.67	18.23	1.68	1.31
T_4- Foliar SA 6ml L^{-1} at 10 days interval (6 sprays)	38.10	36.05	2.05	18.40	1.66	1.19
T_5- Foliar SA 2ml L^{-1} at 20 days interval (3 sprays)	33.60	28.60	5.00	16.73	1.51	1.11
T_6- Foliar SA 4ml L^{-1} at 20 days interval (3 sprays)	38.00	35.00	3.00	18.33	1.67	1.20
T_7- Foliar SA 6ml L^{-1} at 20 days interval (3 sprays)	33.10	27.77	5.33	16.73	1.56	1.14
T_8- Borax spray 0.01% L^{-1} at 10 days interval (3 sprays)	36.68	32.35	4.33	17.40	1.57	1.13
T_9- Borax spray 0.01% L^{-1} at 20 days interval (3 sprays)	37.67	34.00	3.67	17.87	1.62	1.17
F- test	*	*	*	*	NS	NS
SEm ±	2.05	0.91	0.54	0.34	0.18	0.06
CD at 5%	5.32	2.82	1.65	1.06	0.56	0.20

*: Significant NS: non-significant

Plate 6. Bunches received foliar silicic acid 2ml L^{-1} at 20 days interval as three sprays

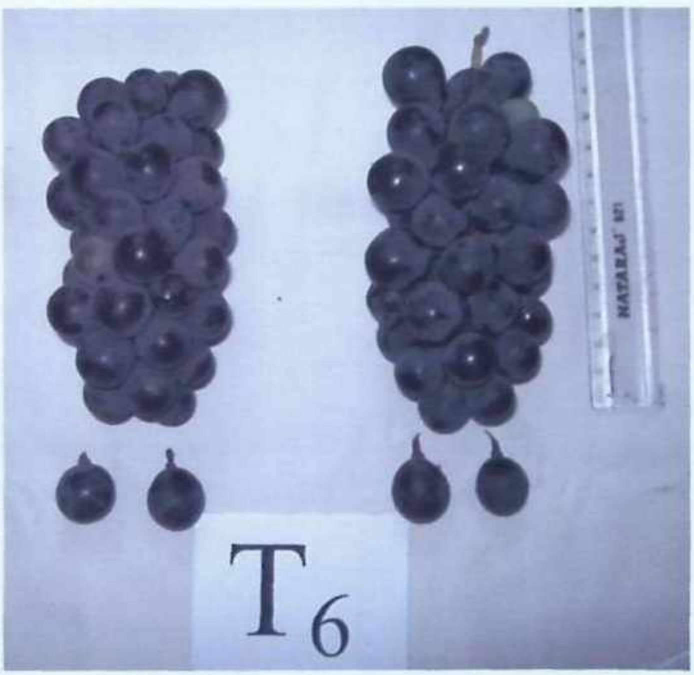

Plate 7. Bunches received foliar silicic acid 4ml L^{-1} at 20 days interval as three sprays

4.2.14 Berry weight (g)

The individual berry weight differed significantly and on par with the application of foliar SA and B at different concentrations on Bangalore Blue grapes as compare to control and is presented in the Table 7. The maximum berry weight (3.07 g) was recorded in the foliar sprayed SA treatment T_4 (6ml L^{-1} f oliar SA as 6 sprays at 10 days interval) which were on par with the treatment T_9 (0.02% L^{-1} borax 3 sprays at 20 days interval) (3.07 g), T_6 (4ml L^{-1} foliar SA as 3 sprays at 20 days interval) (3.02 g), T_8 (0.01% L^{-1} borax 3 sprays at 10 days interval) (3.01 g), T_3 (4ml L^{-1} foliar SA 6 sprays at 10 days interval) (2.97 g) and T_2 (2ml L^{-1} foliar SA 6 sprays at 10 days interval) (2.90 g). The minimum berry weight (2.42 g) was observed in the treatment T_1 (control).

4.2.15 Length of berry (cm)

The different concentrations of foliar SA and B application significantly influenced the length of berry in the Bangalore Blue grapes and are presented in Table 7. The berry length was maximum (1.86 cm) in the treatment T_4 (4ml L^{-1} foliar SA as 6 sprays at 10 days interval) which is on par with the treatment T_6 (4ml L^{-1} foliar SA as 3 sprays at 20 days interval) (1.83 cm), T_9 (0.02% L^{-1} borax as 3 sprays at 20 days interval) (1.80 cm), T_2 (2ml L^{-1} foliar SA 6 sprays at 10 days interval) (1.79 cm), T_7 (6ml L^{-1} foliar SA 3 sprays at 10 days interval). The shortest berry length (1.68 cm) was recorded in the treatment T_1 (control).

4.2.16 Berry breadth (cm)

The berry girth was significantly influenced by foliar SA and B and it is presented in the Table 7. The berry girth was maximum (1.66 cm) in the treatment T_4 (6ml L^{-1} foliar SA as 6 sprays at 10 days interval) which is followed by the treatment T_2 (2ml L^{-1} foliar SA as 6 sprays at 10 days interval) (1.63 cm), T_6 (4ml L^{-1} foliar SA as 3 sprays at 20 days interval)

Table 7. Effect of foliar silicic acid and boron on Berry characters of Bangalore Blue grapes

Treatments	Berry Weight (g)	Berry length (g)	Berry girth (g)	Berry volume (ml)	Rachis Weight (g)	Juice content (g)
T_1- Control	2.62	1.68	1.41	15.47	4.97	60.77
T_2- Foliar SA 2ml L^{-1} at 10 days interval (6 sprays)	2.90	1.79	1.63	23.47	6.06	63.80
T_3- Foliar SA 4ml L^{-1} at 10 days interval (6 sprays)	2.97	1.74	1.59	22.47	6.05	64.06
T_4- Foliar SA 6ml L^{-1} at 10 days interval (6 sprays)	3.09	1.86	1.66	24.67	6.98	66.04
T_5- Foliar SA 2ml L^{-1} at 20 days interval (3 sprays)	2.84	1.76	1.53	20.20	5.00	62.84
T_6- Foliar SA 4ml L^{-1} at 20 days interval (3 sprays)	3.02	1.83	1.62	22.53	6.52	65.89
T_7- Foliar SA 6ml L^{-1} at 20 days interval (3 sprays)	2.70	1.77	1.58	20.80	4.55	61.53
T_8- Borax spray 0.01% L^{-1} at 10 days interval (3 sprays)	3.01	1.73	1.60	21.73	6.73	63.76
T_9- Borax spray 0.01% L^{-1} at 20 days interval (3 sprays)	3.07	1.80	1.61	24.13	6.94	64.06
F- test	*	*	*	*	*	*
SEm ±	0.11	0.04	0.04	1.09	0.23	1.23
CD at 5%	0.34	0.12	0.12	3.35	0.71	3.72

*: Significant   NS: non-significant

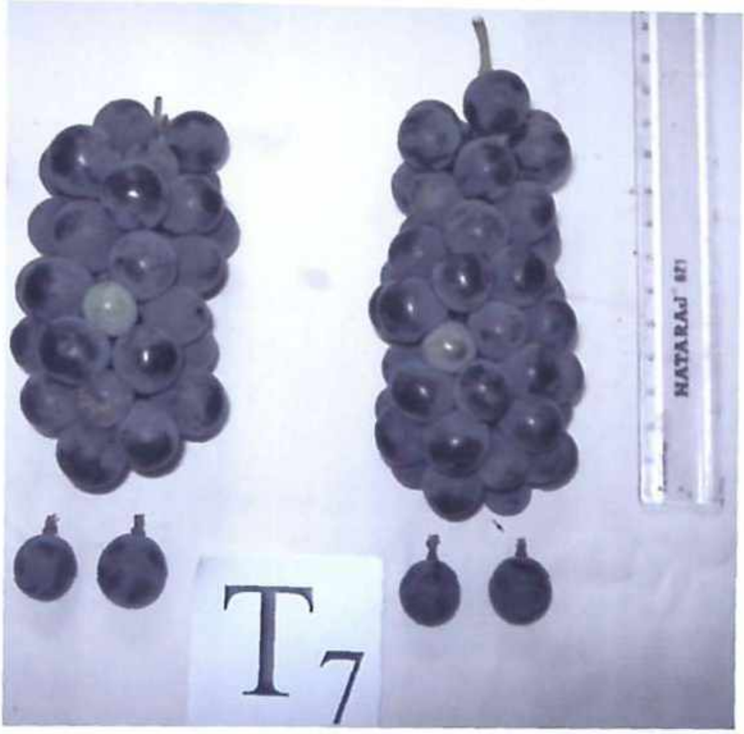

Plate 8. Bunches received foliar silicic acid 6ml L^{-1} at 20 days interval as three sprays

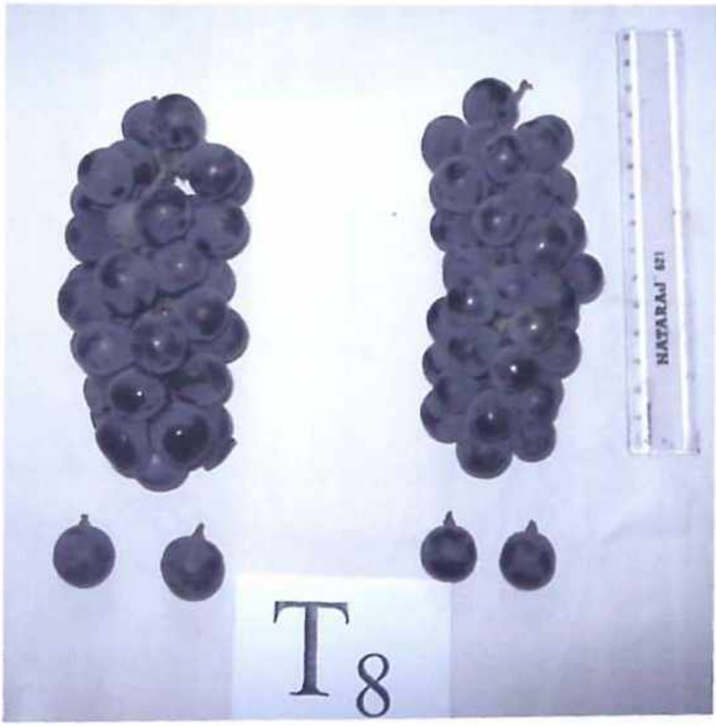

Plate 9. Bunches received Borax 0.01% L^{-1} at 10 days interval as three sprays

(1.62 cm), T_9 (0.02% L^{-1} borax as 3 sprays at 20 days interval) (1.61 cm), T_8 (0.01% L^{-1} borax 3 sprays at 10 days interval) (1.60 cm), T_3 (4ml L^{-1} foliar SA 6 sprays at 10 days interval) (1.59 cm) and T_7 (6ml L^{-1} foliar SA 3 sprays at 10 days interval) (1.58 cm). The minimum berry girth (1.41 cm) was observed in the treatment T_1 (control).

4.2.17 Volume of ten berries (ml)

The influences of different treatments of foliar SA and B on volume of ten berries were significant in Bangalore Blue grapes and are presented in Table 7 and Fig. 6. The maximum berry volume (24.67 ml) was recorded in the treatment T_4 (6ml L^{-1} foliar SA as 6 sprays at 10 days interval) followed by the treatment T_9 (0.02% L^{-1} borax as 3 sprays at 20 days interval) (24.13 ml), T_2 (2 ml L^{-1} foliar SA 6 sprays at 10 days interval) (23.47 ml), T_6 (4ml L^{-1} foliar SA 3 sprays at 20 days interval (22.53 ml)) and T_3 (4ml L^{-1} foliar SA 6 sprays at 10 days interval) (22.47) were on par with each other. The minimum bunch length (15.47 ml) was recorded in the treatment T_1 (control).

4.2.18 Rachis weight (g)

The rachis weight per bunch varied significantly and is presented in Table 7. The maximum rachis weight (6.98 g) was observed in the treatment T_4 (6ml L^{-1} foliar SA as 6 sprays at 10 days interval) which is on par with the treatment T_6 (4ml L^{-1} foliar SA as 3 sprays at 20 days interval) (6.52 g) and T_9 (0.02% L^{-1} borax as 3 sprays at 20 days interval) (6.94 g). The minimum rachis weight (4.97 g) was found in the treatment T_1 (control).

4.2.19 Juice content (%)

The variation in juice content of berries was observer significantly. The data on juice content in relation to SA and B at different concentration is furnished in Table 7. The highest juice content (66.04%)

was recorded in T_4 (6ml L^{-1} foliar SA as 6 sprays at 10 days interval) which were on par with the treatment T_6 (4ml L^{-1} foliar SA as 3 sprays at 20 days interval) (65.89 %), T_9 (0.02% L^{-1} borax as 3 sprays at 20 days interval) (64.60%), T_2 (2ml L^{-1} foliar SA 6 sprays at 10 days interval) (63.80%) and T_8 (0.01% L^{-1} borax 3 sprays at 10 days interval) (63.76%). The minimum juice content (60.77%) was noticed in the treatment T_1 (control).

4.3 Quality parameters

4.3.1 Total soluble solids (^{o} B)

The total soluble solids (TSS) of grape berries were influenced by foliar SA and B treatments (Table 8 and Fig. 3). The highest TSS (15.33^0 B) was recorded in treatment T_9 (0.02% L^{-1} borax as 3 sprays at 20 days interval) which were on par with the treatment T_6 (4ml L^{-1} foliar SA 3 sprays at 20 days interval) (14.87^0 B), T_1 (control) (14.87^0 B), T_2 (2ml L^{-1} foliar SA as 6 sprays at 10 days interval) (14.73^0 B), T_4 (6ml L^{-1} foliar SA 6 sprays at 10 days interval) (14.53^0 B)and T_8 (0.01% L^{-1} borax 3 sprays at 10 days interval) (13.93^0 B). In contrary the lowest TSS (12.96^0 B) was observed in the treatment T_3 (4ml L^{-1} foliar SA as 6 sprays at 10 days interval).

4.3.2 Titratable acidity (%)

Titratable acidity of juice extracted has shown significant difference among the treatments and presented in Table 8 and Fig. 2. The lowest acidity (0.76%) was recorded in the treatment T_9 (0.02% borax as 3 sprays at 20 days interval) which was on par with the treatment T_8 (0.01% borax as 3 sprays at 10 days interval) (0.88%) and T_6 (4ml L^{-1} foliar SA as 3 sprays at 20 days interval) (0.84%). The highest titratable acidity (1.62%) was recorded in the treatment T_3 (4ml L^{-1} foliar SA as 6 sprays at 10 days interval).

Table 8. Effect of foliar silicic acid and boron on quality parameters of Bangalore Blue grapes

Treatments	TSS (° brix)	Titratable acidity (%)	Total sugars (%)	Reducing sugar (%)	Non reducing sugars (%)
T_1- Control	14.87	0.93	11.35	8.93	2.42
T_2- Foliar SA 2ml L^{-1} at 10 days interval (6 sprays)	14.73	0.92	12.07	9.45	2.62
T_3- Foliar SA 4ml L^{-1} at 10 days interval (6 sprays)	12.96	1.62	11.95	9.50	2.45
T_4- Foliar SA 6ml L^{-1} at 10 days interval (6 sprays)	14.53	1.01	12.93	9.68	3.25
T_5- Foliar SA 2ml L^{-1} at 20 days interval (3 sprays)	13.12	1.07	10.75	8.97	1.78
T_6- Foliar SA 4ml L^{-1} at 20 days interval (3 sprays)	14.87	0.84	13.19	9.76	3.43
T_7- Foliar SA 6ml L^{-1} at 20 days interval (3 sprays)	13.13	1.14	10.05	7.75	2.30
T_8- Borax spray 0.01% L^{-1} at 10 days interval (3 sprays)	13.93	0.88	11.65	9.12	2.53
T_9- Borax spray 0.01% L^{-1} at 20 days interval (3 sprays)	15.33	0.76	13.75	10.50	3.68
F- test	*	*	*	*	*
SEm ±	0.71	0.04	0.51	0.29	0.21
CD at 5%	2.19	0.15	1.58	0.89	0.66

*: Significant NS: non-significant

T_1: Control

T_2: 2ml L^{-1} foliar SA 6 sprays at 10 days interval

T_3: 4ml L^{-1} foliar SA 6 sprays at 10 days interval

T_4: 6ml L^{-1} foliar SA 6 sprays at 10 days interval

T_5: 2ml L^{-1} foliar SA 3 sprays at 20 days interval

T_6: 4ml L^{-1} foliar SA 3 sprays at 20 days interval

T_7: 6ml L^{-1} foliar SA 3 sprays at 10 days interval

T_8: 0.01% borax 3 sprays at 10 days interval

T_9: 0.02% borax 3 sprays at 20 days interval

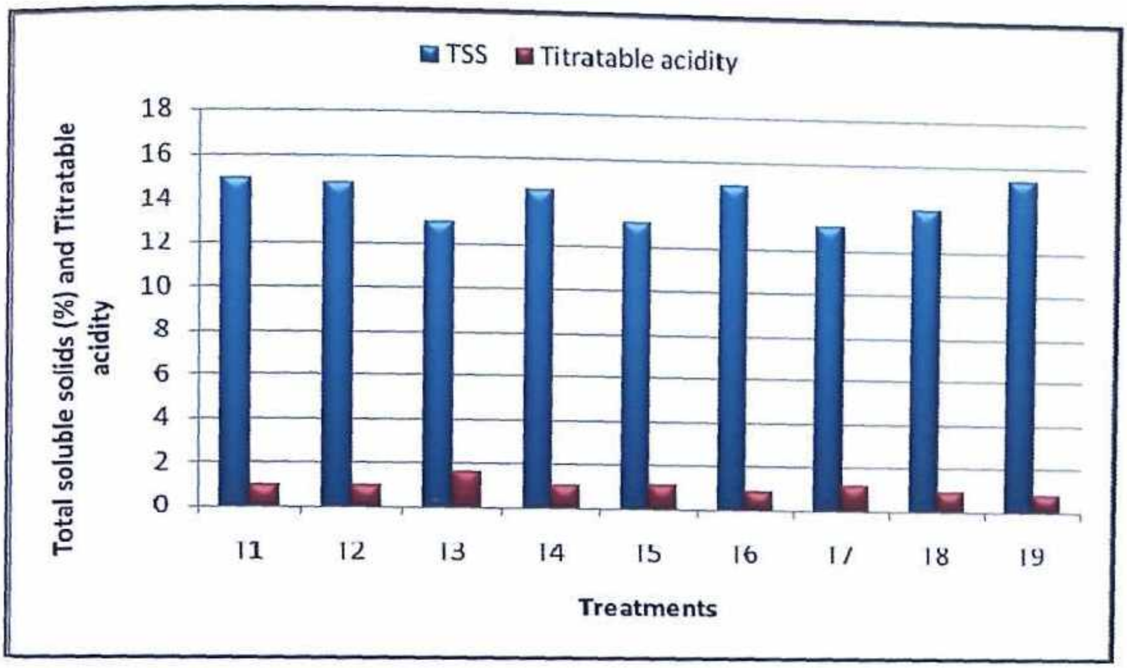

Fig. 3. Effect of foliar silicic acid and boron on Total soluble solids (TSS) and Titratable acidity (%) of Bangalore Blue grapes

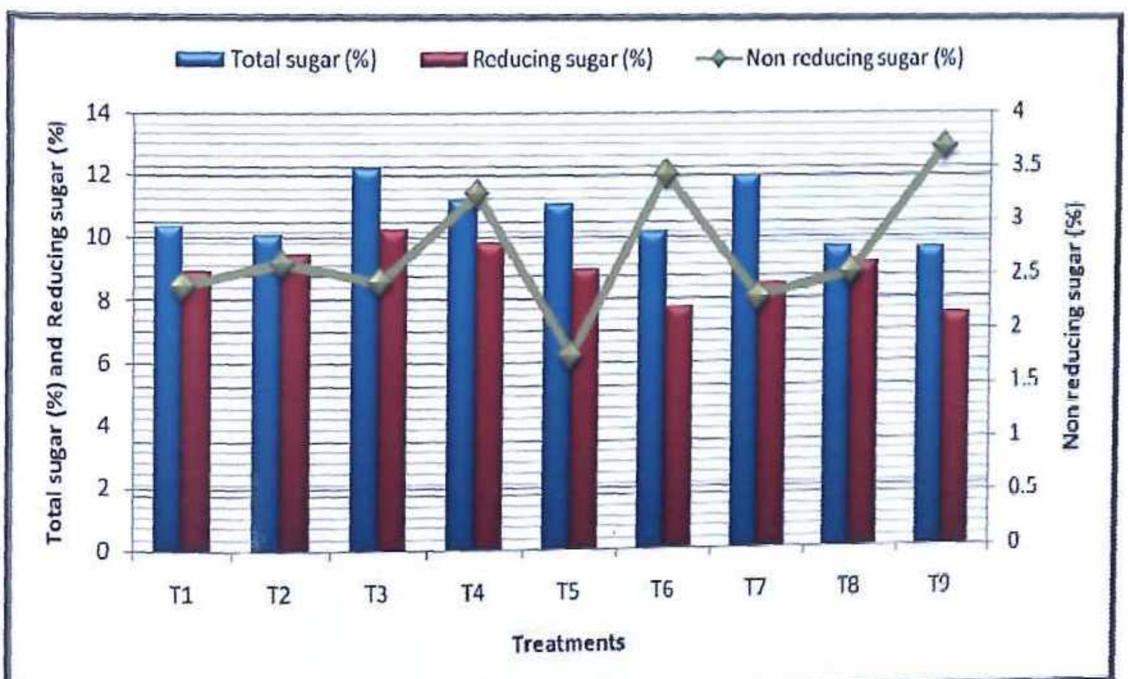

Fig. 4. Effect of foliar silicic acid and boron on Total sugar (%), Reduc ng sugar (%) and Non reducing sugar (%) of Bangalore Blue g apes

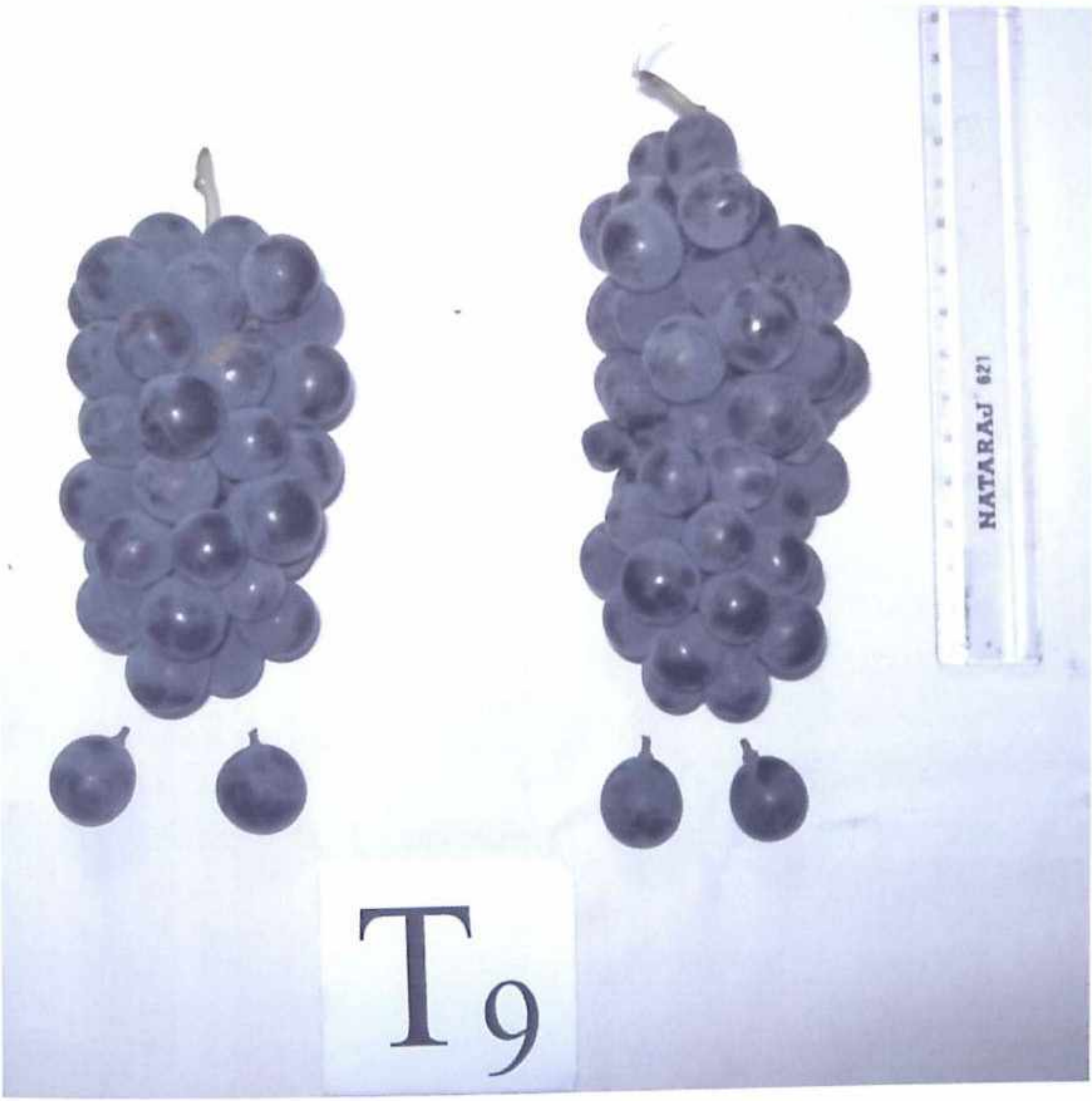

Plate 10. Bunches received Borax 0.02% L^{-1}at 20 days interval as three sprays

4.3.3 Total sugars (%)

Total sugar content of the berries was significantly influenced by the foliar SA and B in Bangalore blue grapes (Table 8 and Fig. 4). The maximum total sugars (13.75%) was recorded in the treatment T_9 (0.02% L^{-1} borax as 3 sprays at 20 days interval) which was on par with the treatments T_6 (4ml L^{-1} foliar SA as 3 sprays at 20 days interval) (13.19%) and T_4 (6ml L^{-1} foliar SA 6 sprays at 10 days interval) (12.93%). The minimum total sugar (10.05%) was recorded in the treatment T_7 (6ml L^{-1} foliar SA as 3 sprays at 20 days interval).

4.3.4 Reducing sugars (%)

The reducing sugar content in berries as influenced by different treatments in Bangalore Blue grapes are presented in Table 8 and Fig. 4. The highest percentage of reducing sugar (10.50%) was recorded in treatment T_9 (0.02% borax spray at 20 days interval) which was on par with T_6 (4ml L^{-1} foliar SA as 3 sprays at 20 days interval) (9.76%) and T_4 (6ml L^{-1} foliar SA as 6 sprays at 10 days interval) (13.68%). The lowest reducing sugar (7.75%) was observed in the treatment T_7 (6ml L^{-1} foliar SA as 3 sprays at 20 days interval).

4.4.5 Non – reducing sugars (%)

The non reducing sugars content in the berries differed significantly among the treatments (Table 8 and Fig. 4). The highest non reducing sugar (3.68%) was found in the treatment T_9 (0.02% L^{-1} borax as 3 sprays at 20 days interval) which was on par with the treatment T_6 (4ml L^{-1} foliar SA as 3 sprays at 20 days interval) (3.43%) and T_4 (6ml L^{-1} foliar SA as 3 sprays at 10 days interval) (3.25%). However, the minimum non reducing sugar (1.78%) was noticed in the treatment T_5 (2ml L^{-1} foliar SA as 6 sprays at 10 interval) and T_7 (6ml L^{-1} foliar SA as 3 sprays at 20 days interval).

Table 9. Effect of foliar silicic acid and boron on quality parameters of Bangalore Blue grapes

Treatments	Physiological loss bunch weight (%)	Rotten berries (%)
T_1- Control	16.20	32.73
T_2- Foliar SA 2ml L^{-1} at 10 days interval (6 sprays)	12.26	19.97
T_3- Foliar SA 4ml L^{-1} at 10 days interval (6 sprays)	6.30	16.15
T_4- Foliar SA 6ml L^{-1} at 10 days interval (6 sprays)	7.42	20.13
T_5- Foliar SA 2ml L^{-1} at 20 days interval (3 sprays)	12.65	28.78
T_6- Foliar SA 4ml L^{-1} at 20 days interval (3 sprays)	7.75	21.05
T_7- Foliar SA 6ml L^{-1} at 20 days interval (3 sprays)	12.37	22.15
T_8- Borax spray 0.01% L^{-1} at 10 days interval (3 sprays)	13.47	32.72
T_9- Borax spray 0.01% L^{-1} at 20 days interval (3 sprays)	12.59	32.73
F- test	*	*
SEm ±	1.50	1.29
CD at 5%	4.63	3.96

*: Significant

NS: non-significant

4.3.6 Post harvest shelf life

The post harvest shelf life results are summarized in the Table 9. The data shows that application of foliar SA and B at different concentration had significant influence on shelf life of Bangalore blue Grapes (Table 9 and Fig. 5). The minimum loss in bunch weight (6.30%) was recorded in the treatment T_3 (4ml L^{-1} foliar SA as 6 sprays at 10 days nterval) which was on par with the treatment T_4 (6ml L^{-1} foliar SA as 3 sprays at 20 days interval) (7.42%) and T_6 (4ml L^{-1} foliar SA 3 sprays at 20 days interval) (7.75%). However, the maximum loss in bunch weight 16.20%) was recorded in the treatment T_1 (control).

The shelf life was also studied in terms of per cent of rotten berries. here was a significant difference among the treatments of different oncentration of foliar SA and B with respect to rotten berries (Table 9 nd Fig. 5). The results shown that the minimum rotten berries (16.15%) as recorded in the treatment T_3 (4ml L^{-1} foliar SA as 6 sprays at 10 days nterval). The maximum number of rotten berries (32.73%) was noticed in ne treatment T_1 (control).

.4 Petiole Silicon content (%)

Si content in the petiole varied significantly in different treatments ith foliar SA and B and is presented in the Table 10 and Fig. 6. The etiole SA content recorded highest (0.93 %) in the treatment T_3 (4ml L^{-1} liar SA as 6 sprays at 10 days interval) and T_6 (4ml L^{-1} foliar SA as 3 rays at 20 days interval) (0.76 %) which were on par with each other. owever, the petiole Si content was minimum (0.27) in treatment T_1 ontrol).

5 Petiole Boron content (ppm)

The influence of foliar SA on B uptake was significantly increased compare to control and is presented in Table 10 and Fig. 6. The maximum boron content (27.88 ppm) was found in the treatment T_3 (4ml L^{-1} foliar SA as 6 sprays at 10 days interval) and it was on par with the treatment T_6 (4ml L^{-1} foliar SA as 3 sprays at 20 days interval) (25.48 ppm) and T_4 (6ml L^{-1} foliar SA as 6 sprays at 10 days interval) (22.17 ppm). The minimum boron content (13.22 ppm) was recorded in the control (T_1).

4.6 Petiole Phosphorus content (%)

The uptake of phosphorus was significantly influenced by foliar sprayed SA compare to the B treatment and control and is presented in the Table 10 and Fig. 6. The maximum phosphorus content in the petiole (0.29%) was found in the treatment T_3 (4ml L^{-1} foliar SA as 6 sprays at 10 days interval) which was on par with the treatment T_4 (6ml L^{-1} foliar SA 6 sprays at 10 days interval) (0.26%), T_6 (4ml L^{-1} foliar SA as 3 sprays at 20 days interval) (0.23%) and T_2 (2ml L^{-1} foliar SA 6 sprays at 10 days interval) (0.22%). The minimum phosphorus content (0.08%) was recorded in T_1 (control).

4.7 Petiole Potassium content (%)

The influence of foliar SA on potassium uptake was significantly increased as compared to control and is presented in (Table 10 and Fig. 6). The maximum potassium content (2.23%) was found in the treatment T_3 (4ml L^{-1} foliar SA as 6 sprays at 10 days interval) which was on par with the treatment T_6 (4ml L^{-1} foliar SA as 3 sprays at 20 days interval) (2.10%). The minimum potassium content (0.90%) was recorded in the control (T_1).

4.8 Petiole calcium content (%)

The foliar sprayed SA had a significant influence on petiole calcium content compared to boron treatment and control and presented in the Table 10 and Fig. 6. The maximum calcium content (4.10%) was found in

Table 10. Effect of foliar silicic acid and boron on petiole nutrient concentration of Bangalore Blue grapes

Treatments	Si (%)	B (ppm)	P (%)	K (%)	Ca (%)
T_1- Control	0.27	13.22	0.08	0.90	1.80
Foliar SA 2ml L^{-1} at 10 days interval (6 sprays)	0.45	19.99	0.22	1.77	3.30
Foliar SA 4ml L^{-1} at 10 days interval (6 sprays)	0.93	27.88	0.29	2.23	4.10
Foliar SA 6ml L^{-1} at 10 days interval (6 sprays)	0.67	24.45	0.26	1.83	3.60
Foliar SA 2ml L^{-1} at 20 days interval (3 sprays)	0.37	16.30	0.20	1.23	2.63
Foliar SA 4ml L^{-1} at 20 days interval (3 sprays)	0.76	25.48	0.23	2.10	4.03
Foliar SA 6ml L^{-1} at 20 days interval (3 sprays)	0.38	16.16	0.13	1.23	2.67
Borax spray 0.01% L^{-1} at 10 days interval (3 sprays)	0.34	22.17	0.10	1.07	2.93
Borax spray 0.01% L^{-1} at 20 days interval (3 sprays)	0.36	20.81	0.10	1.30	2.87
F- test	*	*	*	*	*
SEm ±	0.07	1.98	0.04	0.07	0.34
CD at 5%	0.21	6.11	0.13	0.21	1.03

*: Significant NS: non-significant

T_1: Control

T_2: 2ml L^{-1} foliar SA 6 sprays at 10 days interval

T_3: 4ml L^{-1} foliar SA 6 sprays at 10 days interval

T_4: 6ml L^{-1} foliar SA 6 sprays at 10 days interval

T_5: 2ml L^{-1} foliar SA 3 sprays at 20 days interval

T_6: 4ml L^{-1} foliar SA 3 sprays at 20 days interval

T_7: 6ml L^{-1} foliar SA 3 sprays at 10 days interval

T_8: 0.01% borax 3 sprays at 10 days interval

T_9: 0.02% borax 3 sprays at 20 days interval

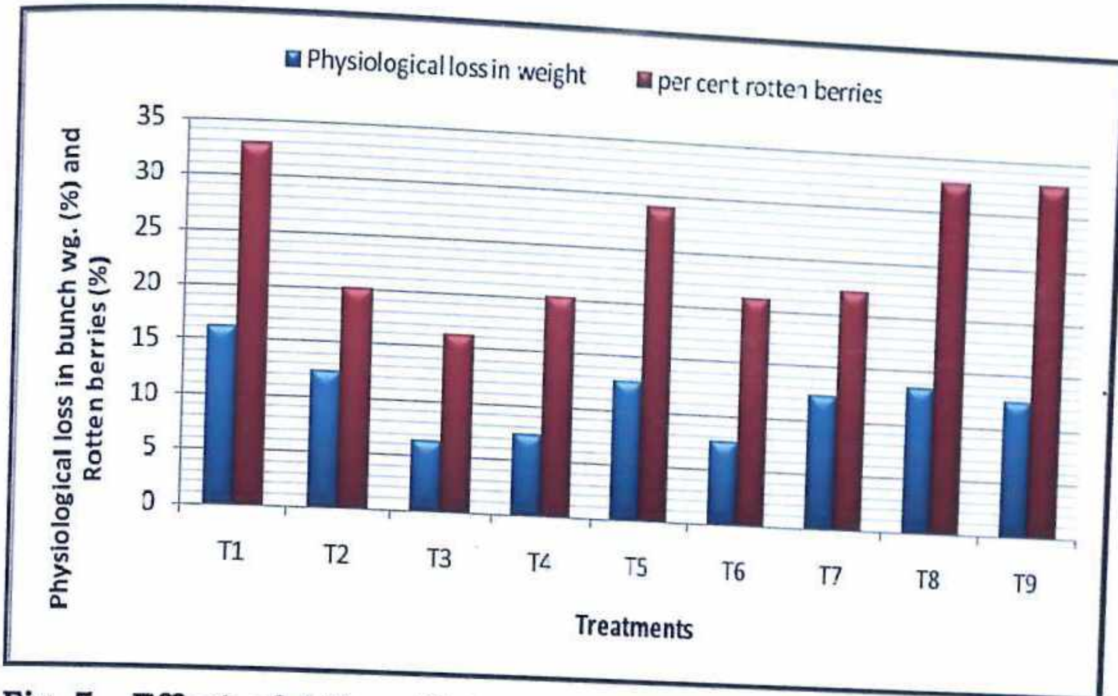

Fig. 5. Effect of foliar silicic acid and boron on physiologaical loss in bunch weight and per cent rotten berries of Bangalore Blue grapes

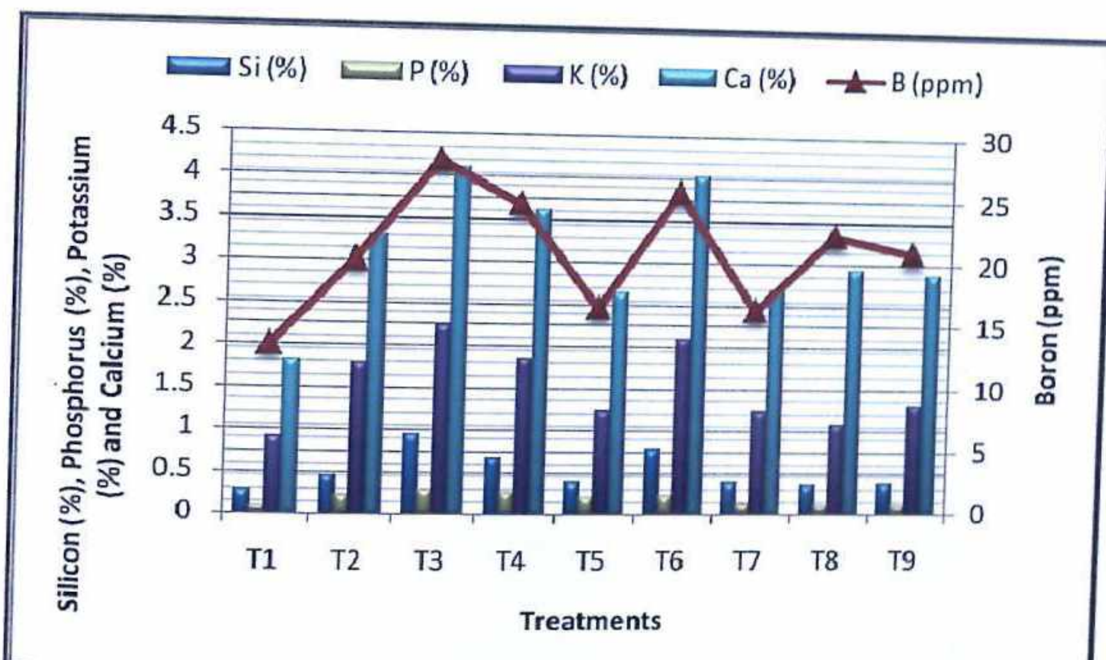

Fig. 6. Effect of foliar silicic acid and boron on Silicon (ppm), Boron (ppm), Phosphorus (%), Potassium (%) and Calcium (%) of Bangalore Blue grapes

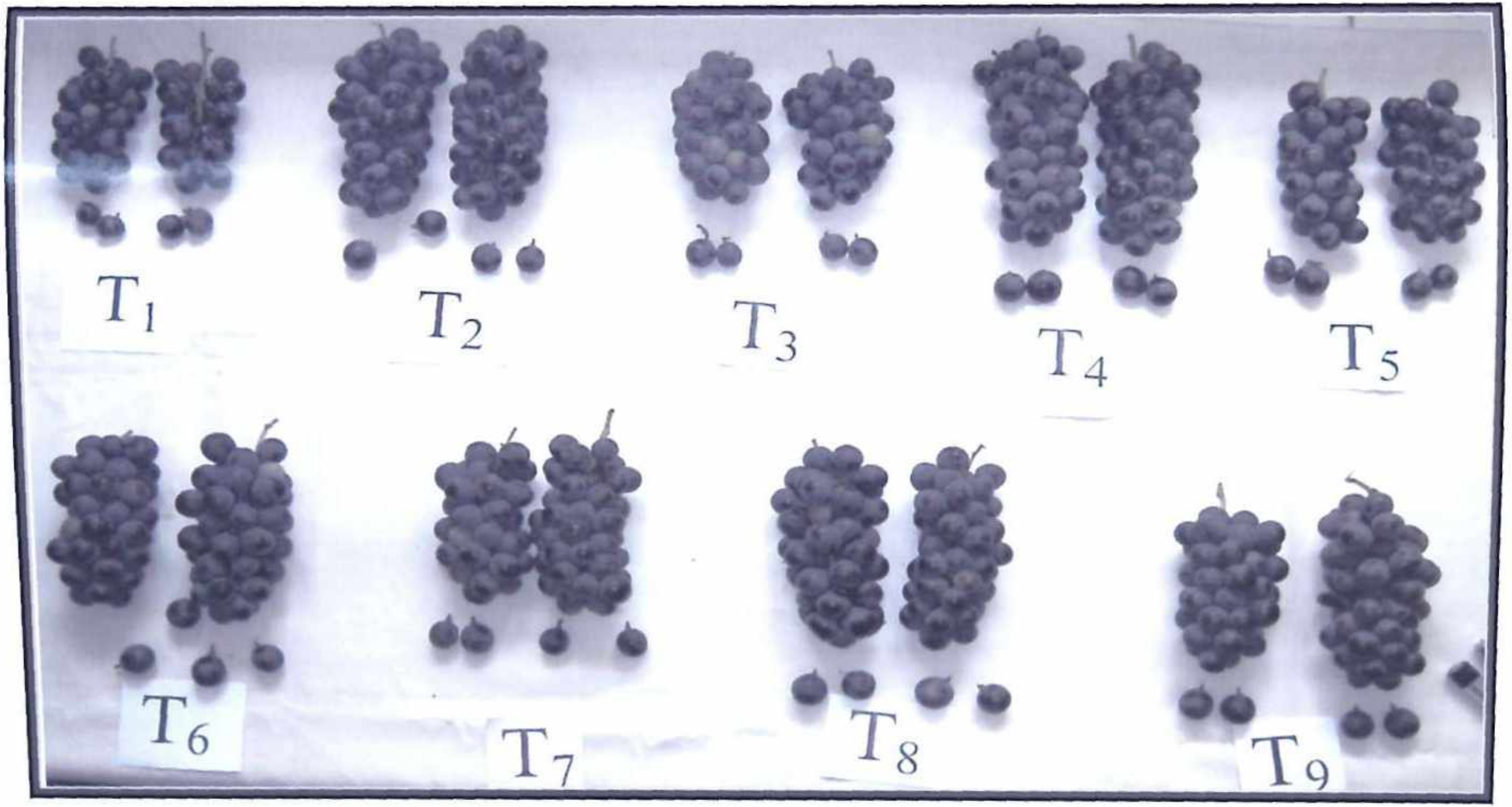

Plate 11. Bunches sprayed with foliar silicic acid and boron at different concentration

the treatment T_3 (4ml L^{-1} foliar SA as 6 sprays at 10 days interval) which was on par with the treatment T_6 (4ml L^{-1} foliar SA as 6 sprays at 20 days interval) (4.03%), T_4 (6ml L^{-1} foliar SA 6 sprays at 10 days interval) (3.60%) and T_2 (2ml L^{-1} foliar SA as 6 sprays at 10 days interval) (3.30%). The minimum calcium content (1.80%) was recorded in the treatment T_1 (control).

DISCUSSION

V. DISCUSSION

The investigation on growth, yield and quality parameters as influenced by foliar SA and B on Bangalore Blue grapes was carried out at the Horticulture research station, Gandhi Krishi Vignana Kendra , University of Agricultural Sciences, Bengaluru. The significant effects of foliar SA and B are discussed here based on the available information and scientific reasoning.

5.1 Growth parameters

Growth of grape vines could be measured in terms of cane length, cane internodal length, leaf area, total leaf chlorophyll content, fresh and dry weight of the leaf. Growth was found to be significantly higher in foliar SA treatment than in B and untreated control. Similar results were observed in Adatia and Besford (1986) in cucumber, Cai and Rian (1995b) in apple, Kamenidou and Todd (2008) in ornamental sunflower, Kamenidou et *al.* (2009) in gerbera and zinnia and Saeed *et al.* (2009) in Rose. This increase in growth parameter is due to the stimulation of growth by Si may be either indirect, owing to the protective effects of Si against pathogens (Belanger *et al.*, 1995) or direct effect originating from implications on both morphological changes and physiological processes in plants. It seems that it is involved directly or indirectly in cell metabolism as well, although in most cases the mode of action is still unclear (Liang *et al.*, 1993; Zhu *et al.*, 2004).

Among the treatments, application of 4ml L^{-1} foliar SA as 6 sprays at 10 days interval (T_3) recorded maximum cane extension growth (110.09 cm) was found to be on par with other treatments and least was in control. In this connection, there are evidences that Si induces the shoot height in crop plants, through its role in both cell division and cell expansion by their effect on RNA and DNA synthesis (Hanafy *et al.*, 2008).

The internodal length of the cane significantly differed among the treatments. The maximum internodal length of cane (8.59 cm) was noticed in the treatment with 4ml L^{-1} foliar SA as 6 sprays at 10 days interval (T_3) followed by the treatment with 6ml L^{-1} foliar SA as 6 sprays at 10 days interval (T_4) and 4ml L^{-1} foliar sprayed SA as 3 sprays at 20 days interval (T_6).

The index leaf area was significantly influenced by the foliar SA spray. The maximum leaf area (179 cm^2) was recorded in treatment with 4ml L^{-1} foliar SA as 6 sprays at 10 days interval (T_3) followed by the treatment with 6ml L^{-1} foliar SA as 6 sprays at 10 days interval (T_4) and 4ml L^{-1} foliar SA as 3 sprays at 20 days interval (T_6). These findings are in line with those of Mary (2005) in miniature rose, Saeed *et al.* (2009) in rose hybrid and Liu (1997) in tomato.

The leaf chlorophyll content was significantly influenced by foliar SA. The maximum total leaf chlorophyll content (13.73 mg/g) was recorded in the application of 4ml L^{-1} foliar SA as 6 sprays at 10 days interval (T_3) and lowest was recorded in control. These observations are in conformity with those of Saeed *et al.* (2009) in *Rosa hybrida* and Liu (1997) in tomato. The increase in the leaf chlorophyll content was due to, the plants supplied with Si resists lodging (drooping, leaning, or becoming prostrate). It can increase mechanical strength of plants, which enables them to achieve and maintain an upright growth habit and allows maximum light interception and increased photosynthetic activity. The enhancing effect was supported by the results of Morgan (1999). Ma and Takahashi (1993) mentioned that in the rice crop, silicate application maintains the erect leaves, increased chlorophyll content, 10 per cent increase in photosynthesis and consequently increase both growth and yield.

The fresh and dry weight of leaf was significantly influenced by the application of foliar SA. The maximum fresh weight of the leaf (31.93 g) was recorded in treatment with 4ml L^{-1} foliar SA as 3 spray at 10 days interval (T_3) followed by the treatment with 4ml L^{-1} foliar SA at 20 days interval (T_6). The maximum dry weight of the leaves (9.76 g) was recorded in the treatment 4ml L^{-1} foliar SA spray at 10 days interval (T_3) followed by the treatment with 6ml L^{-1} foliar sprayed SA spray at 20 days interval (T_6). Dry matter production increased due to increase in chlorophyll formation which ultimately improved photosynthesis. The results are in accordance with Adatia and Besford (1986) in cucumber plants, Singh *et al.* (2006), Rathi and Sharma (1996) and Sheela and Thomas (1995) in rice plants.

5.2 Yield parameters

Yield in case of grapes can be measure in terms of bunch characters, berry characters, yield per vine and yield per hectare. In this experiment growth characters like cane growth, intermodal length, leaf area, fresh and dry weight of leaf, leaf chlorophyll content had their influence on the yield. In relation to this experiment, yield traits given below.

5.2.1 Bunch characters

The yield parameters *viz.*, number of bunches per vine, bunch characters was maximum in foliar SA treatments and B sprays than in control treatments. Pandey and yadav (1999) reported that spraying Si 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 (Pandey and yadav, 1999).

The more number of bunches per vine (325.53) was noticed in the application of 4ml L^{-1} foliar SA at 10 days interval (T_3) and lowest was recorded in control. The average bunch weight was maximum (131.19 g) in application of 6ml L^{-1} foliar SA as 6 sprays at 10 days interval (T_4) followed by the treatment 0.02per cent borax spray at 20 days interval (T_9) and found to be on par with certain other treatments. The increase in bunch weight could be the result of an increase in bunch size and berry size. The increase in berry size can be a major factor contributing to the bunch weight. The bunch weight was also increased with the application of foliar applied borax. Similar observation was recorded by Usha (2002) in Perlette grapes.

Higher bunch volume (116.40 ml) was in bunches which received 6ml L^{-1} foliar SA at 10 days interval (T_4) and lowest was recorded in control (T_1). The increase in bunch volume was largely associated with elongation of rachis and increase in bunch and berry size. The highest bunch length (13.02 cm) was in the application of 6ml L^{-1} foliar SA at 10 days interval (T_4) followed by the treatment 4ml L^{-1} foliar SA spray (T_6) and 0.02 per cent borax (T_9). However the least bunch length (9.84 cm) was recorded in control. The main reason for increase in bunch length could be increase in cell number and length which ultimately resulting in highest rachis length, which consequently could have contribute for increase in bunch length. The highest bunch diameter (6.27 cm) was noticed in bunches received 6ml L^{-1} foliar SA as 6 sprays at 10 days interval (T_4) and lowest was in control. The least bunch diameter was observed in the control. The increase in bunch width could be the result of an increase in berry size and it may be a major factor for contributing to the bunch diameter.

Application of 4ml L^{-1} foliar SA at 10 days interval recorded highest bunches per vine, increased number of bunches, bunch weight, bunch volume, bunch length and breadth of bunch which was on par with certain other treatments.

5.3 Berry characters

The berry characters *viz.*, number of berries, number of ripe berries, number of unripe berries, berry weight, berry length, berry girth, rachis weight, average number of seeds per ten berries, seed fresh weight and dry weight were maximum in foliar SA and B treatments compare to control. The increased berry characters may be due to higher photosynthetic activity, biomass production in the vine might have resulted in more metabolites in the vine. As the growth and development of the berries advances large amount of water and other metabolites move in to the berries, as the berries develop the rachis also developed (Gopalswamy and Rao, 1972 and Musamukhamedor, 1976).

The maximum total number of berries per bunch was recorded in the vines sprayed with foliar SA and B as compare to control. The maximum number of berries per bunch (38.10) was recorded in the vines received 6ml L^{-1} foliar SA as 6 sprays at 10 days interval (T_4) lowest number of berries per bunch (32.60) was recorded in the control. Similar results obtained by Mustafa *et al.* (2006) in grapes. The number of seeds per ten berries was recorded in the vines treated with SA as compare to control. The maximum seeds per 10 berries (18.40) with 6ml L^{-1} foliar SA as 6 sprays at 10 days interval (T_4) followed by spraying 4ml L^{-1} foliar SA as 3 sprays at 20 days interval. There was no significant increase in the dry weight and fresh weight of seeds with the application of foliar sprayed SA and B as compare to control.

The maximum berry weight (3.09 g) was recorded in the treatment 6ml L^{-1} foliar SA as 6 sprays at 10 days interval (T_4) and lowest was recorded in the control (T_1). The increase in berry weight was mainly due to cell division in the initial stages and later due to cell expansion associated with movement of water and other metabolites into the cell causing increase in overall weight of the berry (Ahmed *et al.*, 1997). This increase in berry weight was also reported by Mustafa *et al.* (2006). The highest number of ripe berries (36.05) were in the vines receiving (T_4) 6ml L^{-1} foliar sprayed SA at 10 days interval followed by treatment 4ml L^{-1} foliar sprayed SA at 20 days interval (T_6). However, number of ripe berries (27.27) was less in the control. The unripe berries were also significantly influenced by foliar SA and B. Unripe berries in foliar SA at 6ml L^{-1} at 10 days interval was less followed by the treatment T_6 and T_2 of foliar sprayed SA as compare to other treatments.

The maximum berry length (1.86 cm) was found in the treatment (T_4) 6ml L^{-1} foliar SA as 6 sprays at 10 days interval which is on par with the treatment 0.02 per cent L^{-1} borax as 3 sprays at 20 days interval (T_9) and 0.01 per cent foliar L^{-1} borax as 3 sprays at 10 days interval (T_8). The vines receiving foliar treatment resulted in higher berry girth. The maximum berry girth (1.66 cm) was recorded in the treatment 6ml L^{-1} foliar SA as 6 sprays at 10 days interval (T_4) which is on par with the treatment 2ml L^{-1} foliar SA as 6 sprays at 10 days interval (T_2) and B treated vines. This may be due to beneficial effect of nutrients which leads to cell expansion. The maximum berry volume was recorded in the treatment (24.67 ml) 6ml L^{-1} foliar SA as 6 sprays at 10 days interval. The minimum bunch length was recorded in the treatment T_1 (15.47 ml) control.

A significant increase in rachis weight was observed in foliar sprayed SA and B as compare to control. Thus, the highest rachis weight recorded (6.98 g) in vines received 6ml L^{-1} foliar SA as 6 sprays at 10 days interval (T_4) which was on par with 4ml L^{-1} foliar SA 3 sprays at 20 days interval (T_6). This increase in the rachis weight can be attributed to increase in the cell size. The variation in juice content of berries was observer significantly. The highest juice content (66.04 per cent) was recorded in 4ml L^{-1} foliar SA 6 sprays at 10 days interval (T_3) which is followed by the treatment 4ml L^{-1} foliar SA at 20 days interval (T_6). The minimum juice content (60.77 %) was noticed in the treatment T_1 (control).

Thus the berry characters were found to be influenced more by foliar sprayed SA and B application, which revealed that application of 6ml and 4ml L^{-1} foliar sprayed SA at 10 and 20 days interval and borax application at 0.01per cent and 0.02per cent was ideal in improving the berry characters, which might be due to higher photosynthetic activity, biomass production in the vines which resulted in more metabolites and their translocation into the skins might have contributed to better berry quality.

5.4 Yield per vine (kg)

The yield per vine greatly influenced by foliar SA and B application as compare to control. The maximum yield (37.19 kg) was recorded in the vines receiving 6ml L^{-1} foliar SA as 6 sprays at 10 days interval (T_4) followed by the treatment 4ml L^{-1} fo liar SA as 3 sprays at 20 days interval (T_6). The highest yield per hectare (16.74 t ha^{-1}) was recorded in the treatment 6ml L^{-1} of foliar SA as 6 sprays at 10 days interval (T_4) followed by the treatment T_6 (16.26 t ha^{-1}) 4ml L^{-1} foliar SA as 3 sprays at 20 days interval. SA has many positive effects on the growth and yield as well physiology and metabolism of different crops. Increased yield may attributed to leaf erectness which facilitated better penetration of sunlight leading to higher photosynthetic activity of plant, more formation of carbohydrates and more uptake of other nutrients. Similar results were also noticed by Ma *et al.* (1989), Korndorfer *et al.* (2001), Rodriguesn *et al.* (2003), Rani *et al.* (1997), Singh *et al.* (2006) in rice plant, Mathaba *et al.* (2009) in citrus, Reaple and Laane (2008) in papaya, Voogt and Sonneveld (1997), Kamenidou *et al.* (2009) in zinnia and ornamental sunflower, Saeed *et al.* (2009) in *Rosa hybrida,* Savvas (2009) and Liu (1997) in tomato, Adatia and Besford (1986) in cucumber and Luz *et al.* (2008) in potato.

Application of 6ml L^{-1} foliar sprayed SA at 10 days interval (T_4) followed by 4ml L^{-1} foliar sprayed SA at 20 days interval (T_6) and 4ml L^{-1} foliar sprayed SA at 10 days interval (T_4) resulted in better growth, bunch and berry characters, which has lead to overall increase in the yield of Bangalore blue grapes.

5.4 Quality parameters

The quality parameters *viz.*, total soluble solids, acidity, total sugar, reducing sugar, non reducing sugars, physiological loss in bunch weight, per cent rotten berries were significantly influenced by foliar applied B and Si. The total soluble solids, titratable acidity, total sugar, reducing sugar and non reducing sugar significantly influenced by foliar applied B spray than SA application and control. However, physiological loss in bunch weight and per cent rotten berries were reduced significantly with the application of foliar SA compared to B and control. Because of reduced total soluble solids and increased in fruit firmness, the shelf life of bunches was increased while stored in room temperature. Similar observation was made by Savvas (2009) in tomato.

The maximum total soluble solid (15.33° B) content was recorded in foliar application of borax 0.02 per cent L^{-1} as 6 sprays at 20 days interval (T_9) and it was followed by the application of 4ml L^{-1} foliar SA as 6 sprays at 20 days interval (T_6) and control (T_1). The lowest total soluble solid (12.96 °B) content was recorded in 4ml L^{-1} foliar SA as 3 sprays at 10 days interval (T_3). Application of borax helps to increased total soluble solids in the grape vines and the similar results was made by Ravel and Leela (2000) in Bangalore Blue grapes, Bez El-Anza grape, Policarpo and Stefanini (2006) in cabernet Sauvignon grape, Usha (2002) in Perlette grape.

The titratable acidity was less (0.76%) in foliar application of 0.02 per cent L^{-1} borax as 3 sprays at 20 days interval (T_9) which was followed by 0.01 per cent L^{-1} foliar borax at 10 days interval (T_8). The decrease in acidity may be due to increase in the total soluble solids and it is also because of B which might have either involved in fast conversion of metabolites into sugar and their derivatives. Similar, observations were made by Ravel and Leela (2000) in Bangalore Blue grape, Mustafa *et al.* (2006) in Bez El-Anza grape, Policarpo and Stefanini (2006) in cabernet Sauvignon grape and Usha (2002) in perlette grape. The increased in total soluble solids in the berries leads to decrease in acidity content.

The highest total sugar (13.25%) was recorded in the 0.02 per cent L^{-1} borax as 3 sprays at 20 days interval (T_9) followed by the treatment 4ml L^{-1} foliar SA as 6 sprays at 20 days interval (T_6). The reducing sugar content (10.50%) was more in foliar application 0.02 per cent L^{-1} borax as 3 sprays at 20 days interval (T_9) and it is followed by 4ml L^{-1} foliar SA as 3 sprays at 20 days interval (T_6). This progressive increase could be related to increase in total soluble solids. Since, the reducing sugars constitute a major part of solids percent in the grapes. Maximum non - reducing sugars (3.68%) was noticed in 0.02 per cent L^{-1} borax as 3 sprays at 20 days interval (T_9) followed by the treatment 4ml L^{-1} foliar SA as 6 sprays at 20 days interval (T_6). Similar results was made by Ravel and Leela (2000) in Bangalore Blue grapes, Bez El-Anza grape, Policarpo and Stefanini (2006) in cabernet Sauvignon grape and Usha (2002) in Perlette grape.

The post harvest shelf life of grape was influenced by application of foliar SA as compare to B treatment and the control. The maximum loss (16.20%) in bunch weight was observed in control (T_1), where as the minimum loss (6.30%) in bunch weight was recorded in 4ml L^{-1} foliar SA as 6 sprays at 10 days (T_3) interval followed by the treatment with 6ml L^{-1} foliar SA as 3 sprays at 20 days interval (T_4). Shelf life in terms of per cent rotted berries was also influenced significantly by foliar sprayed SA treatments. The maximum per cent rotten berries (32.73%) were recorded in 0.02 per cent foliar sprayed borax at 20 days interval (T_9) which is on par with the treatment control (T_1) and 0.01per cent foliar sprayed borax at 10 days interval (T_8). The lowest rotten berries were recorded in 4ml L^{-1} foliar SA 6 sprays at 10 days interval (T_3). It seems that B treated and control bunches were found to be less effective with respect to maintaining quality during storage life, where as SA treated bunches were more effective to maintain the quality of bunches over a period of 15 days storage at room condition.

Thus, the quality parameters were found to be increased with the foliar application of B compare to foliar sprayed SA and control. The positive action of B on yield and quality might be attributed to vine nutritional status, biosynthesis and translocation of carbohydrates (Ali, 2000). This revealed that application of foliar applied borax 0.02 per cent proved to be better in improving the quality parameters. However, the post harvest shelf life was influenced by foliar sprayed SA at 4ml L^{-1} at 10 days interval.

5.5 Petiole Si content

The uptake and accumulation of Si in petiole was found to be more in foliar SA treatment compare to B treatment and control. However, the Si content in the petiole was maximum (0.93%) in 4ml L^{-1} foliar SA as 6 sprays at 10 days interval (T_3) followed by the treatment with 4ml L^{-1} foliar SA 3 sprays at 20 days interval (T_6). The results are in conformity with those of Kamenidou *et al.* (2009) in gerbera and zinnia, Savvas (2009) in tomato and Mary (2005) in rose.

5.6 Petiole B content

The influence of foliar SA on B uptake was significantly increased as compare to control. The maximum B content (27.88 ppm) was found in the treatment with 4ml L^{-1} foliar SA as 6 sparys at 10 days interval (T_3) followed by 4ml L^{-1} foliar SA 3 sprays at 20 days interval (T_6). These results are in conformity with those of Kamenidou and Todd (2008) in sunflower and Kamenidou *et al.* (2009) in zinnia.

5.7 Petiole phosphorus content

The uptake of phosphorus was significantly influenced by foliar sprayed SA compare to the B treatment and control. The maximum phosphorus content (0.29) in the petiole was found in 4ml L^{-1} foliar SA as 6 sprays at 10 days interval (T_3) followed by the treatment with 4ml L^{-1} foliar SA 3 sprays at 20 days interval (T_6). The results are in conformity with Takahashi *et al.* (1990) and Kamenidou *et al.* (2009) in zinnia and ornamental sunflower.

5.8 Petiole potassium content

The influence of foliar SA on potassium uptake was significantly increased as compare to control. The maximum potassium content (2.23%) was found in 4ml L^{-1} foliar SA as 6 sprays at 10 days interval (T_3)

followed by the treatment T_6 (4ml L^{-1} foliar SA as 3 sprays at 20 days interval). The minimum potassium content (0.90%) was recorded in the control (T_1). The results are in conformity with Takahashi *et al.* (1990), Kamenidou *et al.* (2009) in zinnia and ornamental sunflower and Kamenidou *et al.* (2010) in gerbera

5.9 Petiole calcium content

The application of foliar SA had a significant influence on petiole calcium content compared to B treatment and control. The maximum calcium content (4.10%) was found in the treatment 4ml L^{-1} foliar SA as 6 sprays at 10 days interval (T_3) which was followed by the treatment 4ml L^{-1} foliar SA 3 sprays at 20 days interval (T_6). Similar observations were made by Kamenidou *et al.* (2009) in ornamental sulflower and zinnia, Savvas (2009) in tomato, Mary (2005) in rose and Mahorkar and Patil (1987) in grape were also noted that there was a slight decrease in the Ca content of the petioles as B levels increased.

FUTURE LINE OF WORK

The study also indicates the necessity of more research on

1. Mechanism involved in increased in growth, yield, uptake of SA and other nutrients and quality improvement to be studied in detail.
2. Similar type of work can be carried out on other leading varieties of grapes.
3. Silicon in combination with other nutrients may be studied.
4. Role of silicon in controlling pest and disease control need to be studied.

SUMMARY

VII. SUMMARY

The field experiment was carried out at Horticulture Research Station, Department of Horticulture, GKVK, The University of Agricultural Sciences, Bengaluru to study the effect of foliar SA and B on growth, yield and quality of Bangalore Blue grapes during February 2009 to April 2009.

The application of foliar SA at different concentrations had a significant influence on the growth, yield characters and nutrient uptake. Whereas, application of B at different concentration had a significant influence on quality parameters.

The silent findings of the investigations are summarised as below.

6.1 Growth parameters

The highest cane length (110.09 cm), internodal length (8.59), number of leaves per shoot (21.66), leaf area index (179.44), leaf fresh weight (31.93 g) and dry weight (9.76 g) and leaf total chlorophyll (13.73 mg/g) content were observed in treatment with 4ml L^{-1} foliar SA at 10 days interval (6 sprays) (T_3) followed by 6ml L^{-1} foliar SA at 10 days interval (6 sprays) (T_6).

6.2 Bunch characters

The highest number of bunches per vine (325.53) was recorded in 6ml L^{-1} foliar SA at 10 days interval (6 sprays) (T_4).

The total bunch weight (131.19 g), bunch length (13.02 cm), bunch volume (116.40 ml) and bunch breadth (6.27 cm) were recorded in 6ml L^{-1} foliar SA at 10 days interval (6 sprays) (T_4) which was followed by the application of 4ml L^{-1} foliar SA at 20 days interval (3 sprays) (T_6) and 0.02 per cent L^{-1} borax at 20 days interval (3 sprays) (T_9).

6.3 Berry characters

The highest number of berries per bunch (38.10), number of fully ripe berries (36.05), berry weight (3.09 g), berry length (1.86 cm), berry breadth (1.66 cm), berry volume (24.67 ml), rachis weight (6.98 g), number of seeds per ten berries (18.40), fresh weight (1.68 g) and dry weight (1.31 g) of ten berries seeds were recorded in application of 6ml L^{-1} foliar SA at 10 days interval (6 sprays) (T_4) which was followed by 4ml L^{-1} foliar SA at 20 days interval (3 sprays) (T_6).

The maximum number of unripe berries (5.33) per bunch was recorded and minimum unripe berries (2.05) was recorded in application of 6ml L^{-1} foliar SA at 10 days interval (6 sprays) (T_4) followed by 4ml L^{-1} foliar SA at 20 days interval (3 sprays) (T_6).

6.4 Yield

The highest yield per vine (37.19 kg) and yield per hectare (16.74 t) was recorded with 6ml L^{-1} foliar SA at 10 days interval (6 sprays) (T_4) followed by the treatment with 4ml L^{-1} foliar SA at 20 days interval (3 sprays) (T_6).

6.5 Quality parameters

The maximum total soluble solids (15.33° B), total sugar (13.75%), reducing sugar (10.50%), non reducing sugar (3.68%) and lowest titratable acidity (0.76%) were recorded with 0.02per cent borax spray at 20 days interval (3 sprays) (T_9)which was followed by 4ml L^{-1} foliar SA at 20 days interval (3 sprays) (T_6).

The minimum loss in bunch weight (6.30%) and per cent rotten berries (16.15) was recorded in 4ml L^{-1} foliar SA at 10 days interval (6 sprays) (T_3) and the maximum loss in bunch weight and per cent rotten berries (16.20% and 32.73, respectively) was recorded in control and 0.02% L^{-1} borax spray. Application of SA was found to be effective to maintain the quality of grapes during storage life.

6.6 Nutrient uptake

The maximum petiole Si (0.93 %), B (27.88ppm), phosphorus (0.29 %), potassium (2.23%) and calcium (4.10%) content was recorded in 4ml L^{-1} foliar SA at 10 days interval (6 sprays) (T_3) followed by 4ml L^{-1} foliar SA at 20 days interval (3 sprays) (T_6) and the minimum nutrient concentration was recorded in the control (T_1).

PRACTICAL APPLICATION

In the nutrient management of Bangalore Blue grapes the foliar spray of 4ml and 6ml L^{-1} foliar SA at 10 days interval (6 sprays) and 4ml L^{-1} foliar SA at 20 days interval (3 sprays) were on par with each other and found to be better as revealed by the results so obtained thus indicating that the above treatments was optimum for all benefits in its applicability. However, application of 4ml L^{-1} foliar SA at 20 days interval (3 sprays) can be recommended to increase the growth, yield, shelf life and nutrient uptake as it is beneficial as compare to other treatments. Foliar spray of borax 0.02 per cent at 20 days interval (3 sprays) can be recommended to increase the quality of Bangalore Blue grapes.

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APPENDICES

APPENDIX I

A. Physical properties of soil at the experimental site, UAS, GKVK, Bangalore

Physical properties	Value
Coarse sand (%)	37.82
Fine sand (%)	30.20
Silt (%)	16.75
Clay (%)	15.38

APPENDIX II

B. Chemical properties of the soil

p^H	EC(dsm^{-1})	Organic carbon (%)	N Kg/ha	P_2O_5 Kg/ha	K_2O Kg/ha
5.78	0.04	0.43	80.0	35.0	95

APPENDIX III

The monthly mean meteorological data for the year 2009-10 (during crop growth period) recorded at senior farm superintendent office, University of Agricultural Sciences, GKVK, Bangalore

Month	Temperature (^{0}c)		Relative Humidity (%)		Rain fall (mm)	Bright sun shine (hrs)
	Maximum	Minimum	Maximum	Minimum		
January	27.6	12.2	92	38	0.00	9.00
February	30.8	14.2	88	32	0.00	9.9
March	32.7	17.4	89	31	10.2	8.2
April	34.2	20.0	88	31	106.0	7.9
May	32.1	19.9	90	37	153.0	7.2
June	29.4	19.4	93	46	58.8	7.0
July	28.7	19.5	93	49	55.8	4.1