Response of Foliar Spray of Iron, Zinc and Boron in Strawberry (*Fragaria × ananassa*Duch.) cv. Winter Dawn

स्ट्रॉबेरी (*फ्रैगरिया ×अनासा* डच.) सी.वी. विंटरडॉन में लौह, जस्ता और बोरोन के पर्णीय छिड़काव की प्रतिक्रिया

LOKESH KUMAR

THESIS

Master of Science in Agriculture

(Horticulture)

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DEPARTMENT OF HORTICULTURE

RAJASTHAN COLLEGE OF AGRICULTURE

MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND TECHNOLOGY, UDAIPUR- 313001 (RAJ.)

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Thesis

Submitted to the

MaharanaPratap University of Agriculture & Technology, Udaipur

in partial fulfillment of the requirements for the degree of

Master of Science in Agriculture

(Horticulture)

BY

LOKESH KUMAR

2021

CERTIFICATE – I

CERTIFICATE OF ORIGINALITY

The research work embodied in this thesis titled **"Response of Foliar Spray of Iron, Zinc and Boron in Strawberry (*Fragaria* × *ananassa*Duch.) cv. Winter Dawn"**submitted for the award of degree of **Master of Science in Agriculture** in the subject of Horticulture**,** to MaharanaPratap University of Agriculture and Technology, Udaipur (Raj.) is original and bona fide record of research work carried out by me under the supervision of **Dr. H.L. Bairwa,**Assistant Professor, Department of Horticulture, Rajasthan College of Agriculture, MPUAT, Udaipur. The content of the thesis, either partially or fully, have not been submitted or will not be submitted to any other institute or University for the award of any degree or diploma.

The work embodied in the thesis represents my ideas in my words and where others' ideas have been included; I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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CERTIFICATE - II

Dated: /   /2021

This is to certify that the thesis entitled **"Response of Foliar Spray of Iron, Zinc and Boron in Strawberry (*Fragaria* × *ananassa*Duch.) cv. Winter Dawn"**submitted for the degree of **Master of Science** in Agriculturein the subject of Horticulture**,** embodies bona fide research work carried out by**Mr. Lokesh Kumar** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of this thesis was also approved by the advisory committee on 03.08.2021.

The manuscript has been subjected to plagiarism check by software Urkund. It is certified that as per the check, the similarity index of the content is 9% and is within permissible limit as per the MPUAT guideline on checking Plagiarism.

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Dated: / /2021

This is to certify that the thesis entitled **"Response of Foliar Spray of Iron, Zinc and Boron in Strawberry (*Fragaria* × *ananassa*Duch.) cv. Winter Dawn"**submitted by **Mr. Lokesh Kumar**to the MaharanaPratap University of Agriculture and Technology, Udaipur in partial fulfillment of the requirements for the degree of**Master of Science** in Agriculture in the subject of **Horticulture** after recommendation by the external examiner was defended by the candidate before the following members of the examination committee. The performance of the candidate in the oral examination held on …/…/2021 was found satisfactory; we therefore, recommend that the thesis be approved.

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This is to certify that**Mr. Lokesh Kumar** student of **Master of Science in Agriculture, Department of Horticulture,** Rajasthan College of Agriculture, Udaipur has made all corrections/ modifications in the thesis entitled **"Response of Foliar Spray of Iron, Zinc and Boron in Strawberry (*Fragaria* × *ananassa*Duch.) cv. Winter Dawn"**which were suggested by the external examiner and the advisory committee in the oral examination held on / /2021. The final copies of the thesis duly bound and corrected were submitted on / /2021 are enclosed here with for approval.

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Date:

Place: Udaipur **(Lokesh Kumar)**

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ACRONYMS

%	:	Per cent
&	:	and
/	:	per
@	:	At the rate of
N	:	Normality
CD	:	Critical difference
Cm	:	Centimeter
cm^2	:	Centimeter square
Cv	:	Cultivar
d.f.	:	Degree of freedom
et al.	:	(et-alai) and other
etc.	:	Etcetera
Fig.	:	Figure
G	:	Gram
Ha	:	Hectare
i.e.	:	that is
K	:	Potassium
kg	:	Kilogram
m	:	Metre
M.S.	:	Mean Square
mg	:	Milligram
N	:	Nitrogen
NAA	:	Naphthalene Acetic Acid
NaOH	:	Sodium Hydroxide
NS	:	Non-significant
°C	:	Degree Celsius
P	:	Phosphorus
RH	:	Relative Humidity
SEm	:	Standard error of mean
TSS	:	Total Soluble Solids
viz.	:	Namely (Videlicet)

1. INTRODUCTION

Strawberry (*Fragaria* × *ananassa*) is one of the most delicious fruit of the world which attained a prime position in the world fruit market as fresh fruit with in the processing industries. All the cultivated varieties of strawberry are octaploid (2n=8×=56) in nature and belongs to the family Rosaceae, sub-family Rosoideae. It is short day plant, native from France in 17^{th} century and the two American diploids *Fragaria* × *chiloensis* and *Fragaria* × *virginiana* are considered as its progenitors. Strawberry is perennial, stoliniferous herbs which spread via stolons or runners. The strawberry have a type of aggregate fruit botanically. The true fruit that contain the seed of the strawberry are achene and the edible portion of the fruit is fleshy thalamus. Its progenitors are native to the new world. *F. chiloensis* is found to occur in Chile and coastal areas of South America. *F. virginiana* is present in Canada, United States of America and introduced in Europe in 1624. In India, many strawberry cultivars were introduced in early 1960.

Primarily strawberry was growing in temperate zone of the country. However, it can also be cultivated under sub-tropical climate, even at higher altitudes of tropical climate. Presently, strawberry is being cultivated in about 75 countries. The major strawberry growing countries are China, United States, Canada, France, Italy, United Kingdom, Bulgaria, Poland, Southern and Eastern Africa, New Zealand, Australia and Japan. In India its main centers of cultivation are Nainital (district) and Dehradun in Uttrakhand, Mahabaleshwer (Maharashtra), Kashmir Valley, Bangalore and Kalimpong (West Bengal). In recent years, strawberry is being cultivated successfully in plains of Maharashtra around Pune, Nashik and Sangli towns. In Rajasthan strawberry is getting popularity for the cultivation in Jhadol and Mavali (Udaipur), Nimbaheda (Chittorgarh), Mandalgarh (Bhilwara) and Jhalawar.

Strawberry is one of the most widely distributed fruit crop due to its genotypic diversity, highly heterozygous nature and broad range of environmental adaptations. The fruit of strawberry different from other fruits as their seeds are produced on the outside of the fruit. Strawberry is quick growing plant, propagated through one year old runners and used in home gardens and commercial cultivation for its beautiful, nutritious and bright red colored fruits. The fruit is highly perishable and yet grown on a small scale in India. It has tremendous scope for its cultivation near the towns, cities and processing units where the fruit can be utilized immediately after harvest.

The strawberry plants are strongly affected by the environmental factors like temperature, photoperiod and light intensity. It requires optimum day temperature of 22°C to 25°C and night temperature of 7°C to 13°C. In cold climate, frost as well as winter injury seriously reduce yield of strawberry. Frost may damage centre of the open flowers, causing the characteristics black eye. The frost injury may be reduced using mulch, covering row with plastic and by creating good air drainage. Photoperiod has a marked effect on strawberry vegetative growth, plant morphology and yield. Stolon formation, petiole length, leaf area and yield increases with the increase in photoperiod.

It is a short day plant which requires exposure to about 10 days of less than 8 hours sunshine for initiation of flowering. In winter, the plants do not make any growth and remain dormant. The exposure to low temperature during this period helps in breaking dormancy of the plant. In spring season when the days become longer (more than 12 hours photoperiod) and the temperature raises the plants resume growth and begin flowering. The varieties grown in milder sub-tropical climate do not require chilling and continue to make some growth during winter.

From the point of view of response to length of the light period, strawberries are placed in two groups: (1) varieties which develop flower buds during both long and short light periods and (2) other hand, varieties which develop flower buds during the short light periods only, it is most commercial varieties. In cold climate the soil is covered with mulch in winter to protect the root from chilling injury. The mulch keep the fruits free from soil, reduces decay of fruits, conserves the soil moisture, lowers soil temperature in hot weather, protects flower from frost in mild climates and protect plants from freezing injury in cold climates. Several kinds of mulches are used but the commonest one is straw mulch. The name strawberry has been derived from this fact. Black alkathene mulch (40 micron) is also used to cover the soil it saves irrigation water, prevents the growth of weed and keeps the soil temperature high.

Strawberry plant grows best in sandy loam soil but in case of light soil frequent irrigation needed for establishment of runners. The heavier soil with adequate soil moisture is better than lighter soil. Strawberry prefers soil reasonably rich in humus because of 70-90 % of its roots were found in the top 15 cm soil. It grows well in soil with pH 5.0- 7.5. However the plant thrives best in slightly acidic soil (pH 5.5-6.5). The availability of micronutrient like iron, zinc and boron to the plant at less than pH 6.5. The plants should be set in the soil with their roots going straight-down. The soil around the plant should be firmly packed to exclude air. The growing point of the plant should be just above the soil surface. During planting, the plants should not be allowed to dry out and should be irrigated immediately after planting.

Boron is absorbed in H_3BO_4 form. Next to zinc, boron is widely deficient nutrient. It is a micronutrient mobile in soil and immobile in the plant. Availability of boron in soil is reduced on account of calcareousness, salinity or sodicity, over liming. Very little is known about mineral of B in soils. Boron plays many important roles in plant metabolism.

Zn absorbed by the plant in Zn^{2+} form. Zn is very most important micro-nutrient of global concern, and highly deficient micro-nutrient of equal magnitude on both acid as well as alkaline soils. zinc is an immobile micro-nutrient in the plants. The availability of zinc in soil is adversely affected by soil calcareousness, high phosphorus content, salinity or sodicity, over liming *etc.*

Iron absorbed by plant in Fe^{2+} form. It is one of the micronutrients becomes extremely mobile under waterlogged conditions and it is highly immobile in the plant. In acid soils, soluble iron could fix phosphates which are aggravated further by high water table and water logging. Whereas on alkaline calcareous soils, lime induced Fe chlorosis is perhaps the most researched nutritional disorder in citrus. Availability of iron becomes less available in soils having beyond pH 7.8. High available iron could induce manganese-deficiency.

Chandrakar*et al.*, 2019 studies on nutritionally, strawberry contains low calorie carbohydrate and a potential source of vitamin-C and fibers. It contains more vitamin-C than oranges. The chemical composition of strawberry is ascorbic acid (64.0 mg), water (91.75 g), protein (0.61 g), fat (0.37 g), carbohydrate (7.02 g), fiber (2.3 g), calcium (14.0 mg), potassium (166 mg/100 g) and vitamin-A (27 IU). Ellagic acid is a naturally occurring plant phenol. It has been found to inhibit the cancer disease and asthma by the regular consumption of the fruit. It used for preparation of ice cream and Jam on account of its rich aroma. It is a soft and a highly perishable fruit, often shipped in frozen condition in Western countries.

Currently, the production of strawberry in more than 63 countries, the global production of strawberry in 2012 about 4516810 tons and planted area of 2.41 Mha and the United States ranks first in the list of producing countries with a total of 1.36 MT, more than a quarter of the world production (FAO, 2014).

In India the total area of strawberry is 1000 ha with production of 5000 MT (Anonymous, 2018). In India, Maharashtra is the leading state in production of strawberry fruits. The nutrition status of strawberry plant plays a vital role in determining the yield and yield attributing parameters since, it is a very sensitive plant to nutritional balance (Mohamed *et al*., 2011). An optimal fertilization is contributive in obtaining high yield of good quality and high biological value. Both calcium and micro-nutrients are well known to ameliorate yield and yield attributing parameters.

Therefore, keeping the above facts in view, the present investigation entitled “Response of foliar spray of iron, zinc and boron in strawberry (*Fragaria* × *ananassa*Duch.) cv. Winter Dawn” was taken during 2020-21 with the following objectives.

1. To study the effect of iron, zinc and boron on growth, yield and quality of strawberry.
2. To find out economic feasibility of the treatments.

2. REVIEW OF LITERATURE

A complete review on this topic has been collected from published sources and utilized for planting of present work. The literature pertaining to the "Response of foliar spray of iron, zinc and boron in strawberry (*Fragaria* × *ananassa*Duch.) cv. Winter Dawn" is reviewed under suitable headings.

Response of foliar spray of boron

Kavitha*et al.* (2000) reported that an experiment on foliar spray of Zn (0.5%) + B (0.1%) at 4^{th}, 8^{th}, 12^{th} and 16^{th} month after planting improved total number of fruits per plant, fruit characters, and latex yield per plant in papaya.

Sdoodee and Chiarawipa (2005) reported that plant treated with 1percent $CaCl_2$, 0.8 percent boric acid and its combination reduced the percentage of fruit splitting to 5.56, 8.89 and 6.67 respectively in Shogun mandarin (*Citrus reticulate* Blanco).

Wojcik (2005) conducted that application of Boron has increased yield and fruit quality, in raspberry decreased acidity in fruit of prune.

Singh *et al.* (2007) concluded that pre-harvest foliar spray of combination of Ca and B is quite useful in Chandler strawberry for reducing the incidence of physiological disorders which helps in getting higher marketable fruit yield with better firmness and other quality parameter of the fruit.

Kumar and Shukla (2010) reported that the physico-chemical composition of fruit was significantly influenced for the combined foliar spray of 0.3 to 0.6 per cent Boron and 0.2 to 0.4 per cent zinc sulphate showing maximum fruit set, minimum fruit drop and maximum fruit yield in old orchard of ber cv. Gola.

Rahman (2010) reported that foliar application of calcium nitrate (2%) + boric acid at 1g/L reduces the fruit cracking and increase the yield as well as quality parameters in Navel orange.

Sajid*et al.* (2010) recorded that highest fruit yield (kg/plant) and reduce the physiological disorder in sweet orange by the foliar application of 1.0 percent zinc and 0.2 per cent boron.

Ahmad *et al.* (2012) reported that when plant sprayed with the exogenous application of zinc improves the growth parameters, fruit yield and chemical composition of the fruits i.e. zinc plays major role in plant metabolism: which includes, the processes of cell division, cell wall synthesis, metabolism of nitrogen, carbohydrates and pectic substances *etc.*

Bhatt *et al.* (2012) concluded that plant of mango sprayed with 0.5 per cent borax, 1 per cent $Ca(NO_3)_2$ and1.2 per cent $CaCl_2$ increased fruit yield, fruit weight and fruit volume of mango cv. Dashehari.

Cakici and Arslan (2012) concluded that three time foliar application of potassium (1.5%), boron (150 ppm) and zinc (400 ppm) increased the yield parameters and quality parameters like TSS, acidity and ascorbic acid content in strawberry cv. Camarosa.

Singh *et al.* (2012) conducted that anola plant sprayed with the application of boron and zinc being highly helpful in the process of photosynthesis which laid to accumulation of carbohydrate which ultimately improved the fruits quality of the anola fruit cv. Baranasi.

Ullah*et al.* (2012) observed that Kinnow mandarin sprayed with foliar application of boron as boric acid viz. (0.2%) increased flush length, tree height & spread and tree trunk diameter, while leaf length and leaf age showed non-significant results in *Citrus reticulata*.

Aboutalebi and Hassanzadeh (2013) studied on increased yield and quality parameters in sweet lime through foliar spray of 10 mg L^{-1} iron and zinc sulphate during June in calcareous soil.

Bakshi*et al.* (2013) Studies in strawberry by foliar application of zinc sulphate (0.4%) resulted maximum (158.9 g) fruit yield per plant with maximum fruit weight and fruit diameter (10.56 g and 3.56.cm respectively.

Jarande*et al.* (2013) reported that integrated effect of sucrose 10 per cent + boric acid 0.5 per cent gave higher fruit setting at pea and marble stage as well as higher value of fruit set and fruit retention at harvest and significantly increased number of fruit and yield in mango cv. Kesar.

Yadav*et al.* (2013) obtained significantly maximum number (492) of fruits per plant and fruit of yield (25.39 kg/ tree) by combined foliar application of 0.5 (%) $FeSO_4.7H_2O$ + 0.1 (%) H_3BO_3 + 0.5 (%) $ZnSO_4.7H_2O$ in low chill peach cv. Sharbati.

Ahsan *et al.* (2014) studied on repeated foliar application of boron-zinc might helped to increase the plant height, from this study it was observed that three times spraying of 100 ppm boron- and zinc obtained more yield.

Etehadnejad and Aboutalebi (2014) recorded that foliar application of zinc increased the fruit yield and TSS improved of apple cv. GolabKohanz.

Khehra and Bal (2014) observed reduction in fruit cracking by spraying Borax 1 per cent (24.70%) and minimum reduction in fruit cracking in control (34.12%) in lemon.

Kazemi (2014) reported that an increase the leaves per plant, number of flower, number of flower per plant, ultimately increase the yield per plant in strawberry by the foliar application of zinc and iron.

Gurjar*et al.* (2015) observed that combined foliar application of boric acid (0.2%) + zinc sulphate (0.5%) at fruit set and peach size stage of fruit through foliar spray exerted great influence on plant height, plant spread and shoot length in kinnow mandarin.

Response of foliar spray of zinc

Haque*et al.* (2000) conducted an experiment and reported that spraying of micronutrients (Cu, Zn and B) alone and their combination significantly increased the number of fruits per plant, total fruit weight per plant, fruit diameter and yield of mandarin orange.

Lal*et al.* (2000) conducted an experiment and concluded that the foliar spray of Zn @ 4 g/plant per year and Mn at same rate per plant per year, significantly increased fruit yield in guava.

Ziauddin (2000) conducted an experiment and recorded maximum length of finger (15.69 cm) under the treatment combination of 100 per cent RDF + Fe (9.0 g/plant) + Zn (4.5 g/plant) and minimum length of finger (11.63 cm) was obtained under the treatment combination of 75 per cent RDF + Fe (9.0 g/plant) + Zn (4.5 g/plant) in banana cv. Ardhapuri.

Yadlod and Kadam (2003) conducted an experiment and recorded maximum percentage of reducing sugar (12.97%), non- reducing sugar (3.58%) and highest amount of ascorbic acid (120.70 mg $100g^{-1}$) with two foliar sprays of micronutrient mixture (1%), while minimum percentage of reducing sugar (12.65%) and ascorbic acid (0.63 mg/100 g) was noted under control on banana cv. Grand Naine.

Dutta and Banik (2007) reported that the increase in size of fruit as a result of foliar application of micronutrients in present investigation might be because it improved the internal physiology of developing fruit in terms of better water supply, nutrients and other compounds vital for their proper growth and development of Sardar guava.

Shivanandam*et al.* (2007) studied on zinc has been recognized as component of almost 60 enzymes and it has a role in synthesis of growth promoting hormone i.e. auxin which is directly connected with improvement of fresh weight of the fruits.

Mahnaz*et al.* (2010) claimed that zinc sulphate as a source of zinc had a positive impact on increasing leaf area, length and diameter ratio of petiole, fresh and dry shoot ratio, yield of fruit, TSS, acidity and vitamin-C of strawberry plant.

Yadav*et al.* (2010) conducted that experiment shows the minimum number of days for inflorescence emergence to harvesting (77.50 days) and total crop duration (366.00 days) with the application of RDF + Zn (40 g) + Mn (20 g) + Cu (5 g) + B (10 g) in banana cv. Grand Naine.

Pathak *et al.* (2011) studied the effect of zinc and iron found that combined spray of Fe (0.5%) + Zn (0.5%) showed the best response on plant growth in terms of plant height, basal girth of pseudo stem and number of leaves produced per plant and minimum duration between the emergence of two successive leaves in banana.

Abdollahi*et al.* (2012) showed that application of zinc sulphate increased inflorescence and fruit size because of its important role in pollination and more fruit set. Boron increased crown number and fresh weight root, but decreased yield of strawberry cv. Selva.

Ahmad *et al.* (2012) observed that foliar application of $ZnSO_4$ (0.5%) and boric acid (0.3%) at fruit set stage showed the significant increase of plant height and also increase the plant spread and stem girth in *Citrus reticulata*.

Hasani*et al.* (2012) reported that foliar application of 0.6 per cent $MnSO_4$ and 0.3 per cent $ZnSO_4$ significantly increased quality parameters like the aril peel ratio, TSS, TAA TA ratio, weight of 100 arils, juice content of arils, anthocyanin index, fruit diameter and juice content of arils in the pomegranate cv. Malas e Torsh e Saveh.

Saadati and Moallemi (2012) conducted an experiment found that number of leaf, leaf area, fresh and dry weight of leaf and of root, yield characteristics, chlorophyll index and leaf relative water content were reduced in the conditions of salinity, while foliar application of Zinc could increase them, significantly in strawberry.

Ashoori*et al.* (2013) concluded that impact of zinc commenced flowering promptly and induced fruit setting earlier, similar results about days to fruit setting were also observed in grapes.

Razzaq*et al.* (2013) studied that foliar application of zinc influence on leaf mineral status, vegetative and reproductive growth, yield and fruit quality of kinnow mandarin. The result recorded that the application of boric acid at 0.4 per cent increase the peel thickness compare to control.

Kazemi (2014) reported that an increase the leaves per plant, number of flower, number of flower per plant, ultimately increase the yield per plant in strawberry by the foliar application of zinc and iron.

Etehadnejad and Aboutalebi (2014) reported that foliar application of zinc increase the fruit set percent, fruit length, fruit diameter, Zn amount in shoot and root and chlorophyll index significantly ($p<0.05$) was observed in foliar application of 6 gL^{-1} Zn in apple cv. GulabKohanaz.

Mehraj*et al.* (2015) reported that an experiment to evaluate the response of repeated foliar application of boron and zinc (100 ppm each) on strawberry. The tallest plant (21.1 cm) and maximum number of leaves (21.9) were found from the foliar application of boron-zinc three times spraying at 30, 45 and 60 DAP in strawberry.

Rahman *et al.* (2016) conducted a field experiment consisting of three levels of micronutrients as M_0- Control, M_B- Boron and M_{Zn}- Zinc. Maximum number of fruits (26.3/plant), fruit weight (369.9 g/plant), brix (7.3%) and yield (10.6 t/ha) was found for M_{Zn} while the minimum in M_0. The number of runners also increased with the Zinc sulphate. So, it can be concluded that zinc showed the best performance for growth and yield of strawberry.

Yadav*et al.* (2017) conducted an experiment found that maximum fresh weight (28.09 g) as well as dry weight (2.05 g) and quality parameter like TSS, acidity and ascorbic acid was found significantly influenced by foliar application of micronutrient in strawberry.

Bhanukar*et al.*(2018) reported that foliar application of micronutrient on sweet orange cv. Blood Red gave highest number of fruits (256.99/ tree) along with biggest fruit (195.55 g) with highest yield of 50.25 kg/tree, when sprayed with one per cent $ZnSO_4$.

Thorat*et al.* (2018) found that increase in yield attribute number of fruit per tree, weight of fruit per tree and weight of one fruit has been reported in sweet orange by with soil application of $ZnSO_4$ @ 150 g + foliar spray of $ZnSO_4$ @ 0.5 per cent.

Chandrakar*et al.* (2019) conducted to study the response of foliar spray of micro-nutrients on number of flowers, fruits and yield per plant of strawberry cv. Nabila under net tunnel with different concentration of micro-nutrient spray as treatments. Result revealed that the maximum number of flowers per plant and maximum number of fruits per plant were recorded under the treatment RDF + $ZnSO_4$ @ 0.6% whereas the minimum was recorded under the treatment RDF + water spray.

Bhanukar*et al.* (2021) assessed the performance of sweet orange cv. Blood Red to foliar application of micronutrients. The plants were sprayed with micronutrients on first week of April and first week of July. All the micronutrients treated plants produced higher magnitude of growth and fruit yield over control. However, foliar application of $ZnSO_4$ 1.00% produced significantly higher number of fruits, fruit weight, yield and increased the plant height by 9.62%and spread EW (10.78%) and NS (10.32%).

Response of foliar spray of iron

Meena*et al.*(2008) concluded that there are several reports where iron has improved the yield and related attributes in fruit crops and in one such study in ber and found improvement fruit weight, fruit length, fruit breadth, pulp weight, stone weight and pulp stone ratio through foliar application of $FeSO_4$ and borax at 0.6 per cent.

Kumar *et al.* (2010) observed that the foliar application of ferrous sulphate at 0.2 and 0.6 per cent alone or with zinc sulphate at 0.4 per cent in strawberry gave best result in increased ascorbic acid content, decreased acidity, increased TSS content, total sugar, reducing sugar and also enhanced shelf life of fruits and Patel *et al.* (2010) also found that in banana cv. Basrai.

Kotur and Satisha (2011) reported that aqueous solutions of zinc sulphate of 0.5 per cent concentration used for foliar sprays tend to be acidic enough to scorch and harm the foliage. Among horticultural crops, most fruit and vegetable crops have shown positive response to Zinc application in terms of growth, yield, and quality and storage behavior of the produce.

Bakshi*et al.* (2013); Singh *et al.* (2015); Mehraj*et al.* (2015); Mishra *et al.* (2016) and Chandrakar*et al.* (2018) reported that foliar application of ferrous sulphate alone @ 0.4 and 0.6 per cent or in combination with zinc sulphate @ 0.4 per cent on strawberry gave best result regarding growth parameters *i.e.* increased number of leaves plant^{-1}, leaf area, runners plant^{-1}, plant height and plant spread in strawberry.

Kazemi (2014) reported that foliar spray of zinc sulphate on strawberry plant at 150 mg, iron at 1000 mg and calcium at 10 mg improved number of flowers, weight of primary and secondary fruit and quality parameters of strawberry cv. Pajero.

Ilyas*et al.* (2015) found that effect of micro-nutrient like zinc, copper and boron on plant height, plant spread and increase the fruit yield per plant and quality like TSS and ascorbic acid content of *Citrus reticulata* Blanco.

Vijaya*et al.* (2017) reported that significantly higher annual increase in plant height (39.1 cm), stem girth (5.71 cm) and plant spread (34.3 cm) upon foliar spray of 0.5 per cent each of $FeSO_4$, $MnSO_4$ and $ZnSO_4$ + 1 per cent urea, which was found statistically as par with soil application of $FeSO_4$ (126 g) + $MnSO_4$ (43 g) + $ZnSO_4$ (42 g).

Panwar*et al.* (2019) reported that foliar application of micronutrient in kinnow that significantly improved the TSS (10.93^{0}B), reducing sugar (2.96%), total sugar (6.59%), ascorbic acid content (27.08 mg/100 ml) and reduced the acidity and rind thickness to a considerable extent.

Chandrakar*et al.* (2018) conducted an experiment to find out the effect of Calcium and micro-nutrients on growth parameters, flowering, fruiting and fruit maturity of strawberry cultivar Nabila under net tunnel condition. As per the growth parameters are concerned the treatment (RDF + $FeSO_4$ @ 0.6% showed maximum vegetative growth i.e. plant height, number of leaves, plant spread and number of runners per plant, while the minimum was recorded under the treatment RDF + water spray. Earliest flowering, fruiting and fruit maturity was exhibited under the treatment RDF + $FeSO_4$ @ 0.6%, whereas the treatment RDF + water spray had too late in flowering, fruiting and maturity of the fruits.

Pawar*et al.* (2019) obtained highest fruit yield (78.23 kg/ plant) from 69.74 per cent fruit retention with maximum number of fruits (477.50/ plant), having maximum (170.13 g) fruit weight and fruit volume (198 cc) in kinnow mandarin by foliar application of 1.0 per cent $MnSO_4$ + 0.5 per cent $FeSO_4$.

Response of combine application of zinc, iron and boron

Monga and Josan (2000) reported thatfoliar application of Zn, alone and in combination with Fe and Mn as $ZnSO_2$, $FeSO_4$ and $MnSO_4$ respectively significantly affected quality of kinnow mandarin. Juice content and total soluble solids were found maximum under $ZnSO_4$ (0.3%) treatment. Acidity decreased in all treatments compared to control.

Chaturvedi*et al.* (2005) revealed that application of zinc sulphate at 0.4 per cent and ferrous sulphate at 0.2 per cent in strawberry increased the number of leaves (29.93 and 23.24), flowers (2.22 and 3.33), fruit set (2.6 and 2.8), fruits (16.10 and 16.88) and fruit yield (133.82 and 140.47g) per plant; plant height (18.85 and 18.28 cm) and ascorbic acid content (66.1 and 65.94 mg). Increase in fruit weight (8.12 and 7.98g) and acidity (0.97 and 0.96%), TSS content (9.42 and 9.33° Brix) of fruits were also found with 0.2 per cent of ferrous sulphate and 0.4 per cent of zinc sulphate. The number of runners also increased with the 0.4 per cent zinc sulphate. Higher concentration of zinc sulphate resulted in enhanced shelf life of fruits (2.95 days) at ambient temperature. On the other hand, higher concentration of ferrous sulphate had toxic effect on the plant and retarded the growth, yield and quality attributes.

Meenaet al. (2014) reported that combined foliar application of calcium nitrate (0.6%) + borax (0.4%) + zinc sulphate (0.8%) in Aonla cv. N-7 (Neelam) resulted, maximum fruit weight (45.2 g) fruit length (4.2 cm) and diameter (4.46 cm) respectively along with highest fruit yield (42.7 kg/ plant).

Ilyas*et al.* (2015) reported that foliar application of Zn (0.3%) Cu (0.1%) and B (0.2%) resulted, improved photosynthetic activity and fruit yield contributing parameters along with fruit yield and quality in *Citrus reticulate* Blanco Var. Kinnow.

Meena*et al.* (2017) concluded that foliar application of calcium nitrate (3.0%) + boric acid (0.6%) + zinc sulphate (0.6%) increase in yield and quality attributing characteristics in Nagpur mandarin.

Kumar *et al.* (2018) reported that foliar application of combined nutrient of $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) + H_3BO_3 (0.2%) + (0.4%) $CuSO_4$ + (0.3%) $MnSO_4$ in mandarin orange resulted in better performance regarding yield and other yield contributing characters and also gross return and B: C ratio.

Mahida*et al.* (2018) concluded that maximum fruit set, fruit retention and highest yield, TSS, Vitamin-A, and other quality parameters in Kesar mango influenced by the foliar application of 0.50 per cent $FeSO_4$ + 0.50 per cent $ZnSO_4$.

Response of micro-nutrient on benefit cost ratio

Patel *et al.* (2010) conducted an experiment and reported that higher benefit cost ratio (1.94:1) with the foliar application of $ZnSO_4$ (0.5%) + $FeSO_4$ (0.5%) treated plots in banana cv. Basrai.

GeethaShetty *et al.* (2014) conducted an experiment and reported that bunch sprayed with combination of SOP (2%) and urea (1%) increased benefit cost ratio in banana whereas the minimum benefit cost ratio was observed under the control treatment.

3. MATERIAL AND METHODS

The present investigation entitled "Response of foliar spray of iron, zinc and boron in strawberry (*Fragaria* × *ananassa*Duch.) cv. Winter Dawn" was conducted from October, 2020 to March, 2021 at Horticulture Farm, Department of Horticulture, Rajasthan College of Agriculture, Udaipur. The details of experimental techniques, materials used and criteria adopted for evaluation of treatments during the whole course of investigation are described in that chapter.

3.1 EXPERIMENTAL SITE

The experiment was conducted from October, 2020 to March, 2021 at Horticulture Farm, Department of Horticulture, Rajasthan College of Agriculture, Udaipur. This is situated at 24^{o} 34′ N latitude and 73^{o} 42′ E longitude at an elevation of 582.17 meter above mean sea level. Udaipur region falls under agro climatic zone IV a (Sub-Humid Southern plain and Aravalli Hills) of Rajasthan.

3.2 CLIMATE AND WEATHER CONDITION

Climate of Udaipur has a typical sub-tropical and characterized by winters and summers. The average rainfall of this region ranges from 760 to 900 mm per year, most of which is contributed by south western monsoon from June to September. About 90 percent rainfall is received during the mid-June to September with scarce showers during the winter months. The analyzed data reveal that maximum and minimum temperature ranged between 24.6 to 10.3^{o}C during growing period. Data recorded for mean weekly weather parameters during the period of field experimentation have been presented in Table 3.1 & Fig. 3.1

Table 3.1 Mean weekly meteorological parameters during crop growing season (*Rabi*, 2020)

Location: RCA

Latitute 24'35

Longitude 73'42 Oct - March (2020-21)

Week No.	Temperature (°C)		R.H. (%)		Wind velocity (kn/hr)	Sunshine (hrs)	Rainfall (mm)	Evap. (mm)
	Max.	Min.	Max.	Min.				
44	30.1	10.3	67.0	21.4	2.6	8.6	0.0	4.6
45	30.2	9.6	68.9	24.4	2.2	8.7	0.0	3.1
46	28.9	11.6	79.7	42.9	2.3	6.8	0.0	3.8
47	26.2	9.4	73.1	34.3	2.4	7.1	0.0	3.4
48	27.1	9.7	83.0	34.0	2.9	8.0	0.0	3.1
49	30.4	10.2	76.1	27.3	1.8	8.8	0.0	3.7
50	24.5	12.1	85.4	52.1	2.9	4.1	0.0	2.8
51	23.3	4.3	80.9	26.7	2.0	7.9	0.0	3.1
52	22.5	3.8	81.9	27.8	2.4	8.3	0.0	3.1
1	24.0	8.7	85.7	46.7	2.3	3.4	12.6	4.0
2	22.8	9.7	90.6	51.4	2.4	4.3	0.0	2.6
3	27.3	7.5	87.9	32.9	1.8	8.3	0.0	4.0
4	24.5	4.1	83.1	28.1	2.3	8.8	0.0	3.9
5	26.1	4.4	76.1	23.1	2.2	8.6	0.0	4.1
6	26.6	5.9	75.6	22.3	2.6	8.7	0.0	4.0
7	29.0	8.0	74.4	23.1	2.6	8.3	0.0	4.4
8	28.7	8.3	63.8	20.9	2.2	9.2	0.0	3.7
9	32.3	11.4	64.9	23.1	3.2	9.6	0.0	6.8
10	33.1	13.1	54.4	26.5	4.4	9.5	0.0	6.8
11	33.3	14.7	57.4	27.1	2.7	8.5	0.0	7.9
12	33.2	15.3	61.7	20.7	3.5	7.3	0.0	6.4

Source: Agro Met Observatory, Department of Agronomy, Rajasthan College of Agriculture, MPUAT, Udaipur

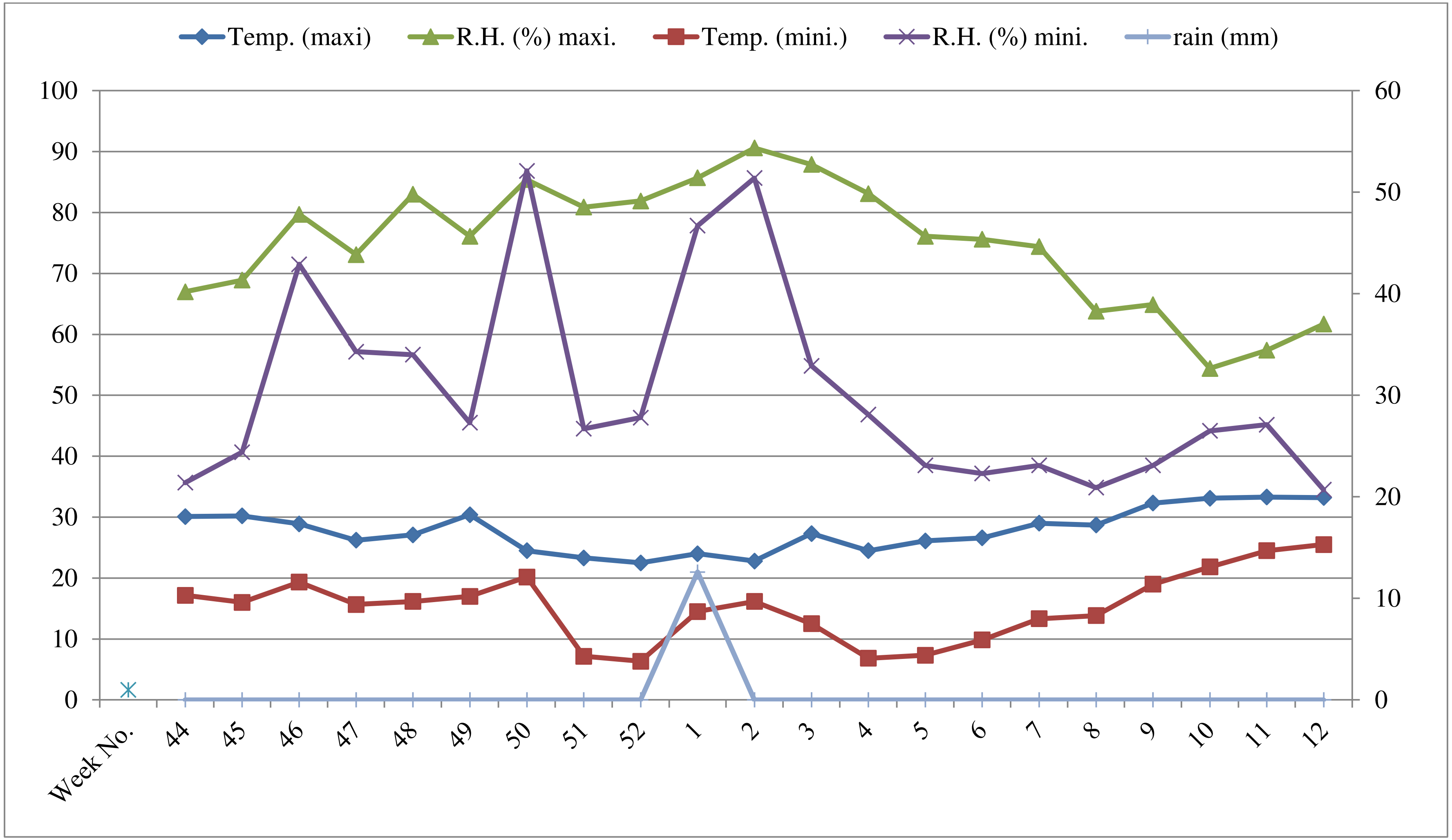


Fig. 3.1 Mean weekly meteorological parameters during crop growing season (*Rabi*, 2020)

3.3 PHYSICO AND CHEMICAL PROPERTY OF SOIL

Physical property			Chemical property	
A	Sand (%)	32.40	Organic carbon (%)	0.68
B	Silt (%)	28.65	Available N (kg ha^{-1})	194.8
C	Clay (%)	38.95	Available P_2O_5 (kg ha^{-1})	17.1
D	Bulk density (%)	1.35	Available K_2O (kg ha^{-1})	255.3
E	Particle density (%)	2.64		
F	Porosity (%)	28.21		

3.4 LAYOUT

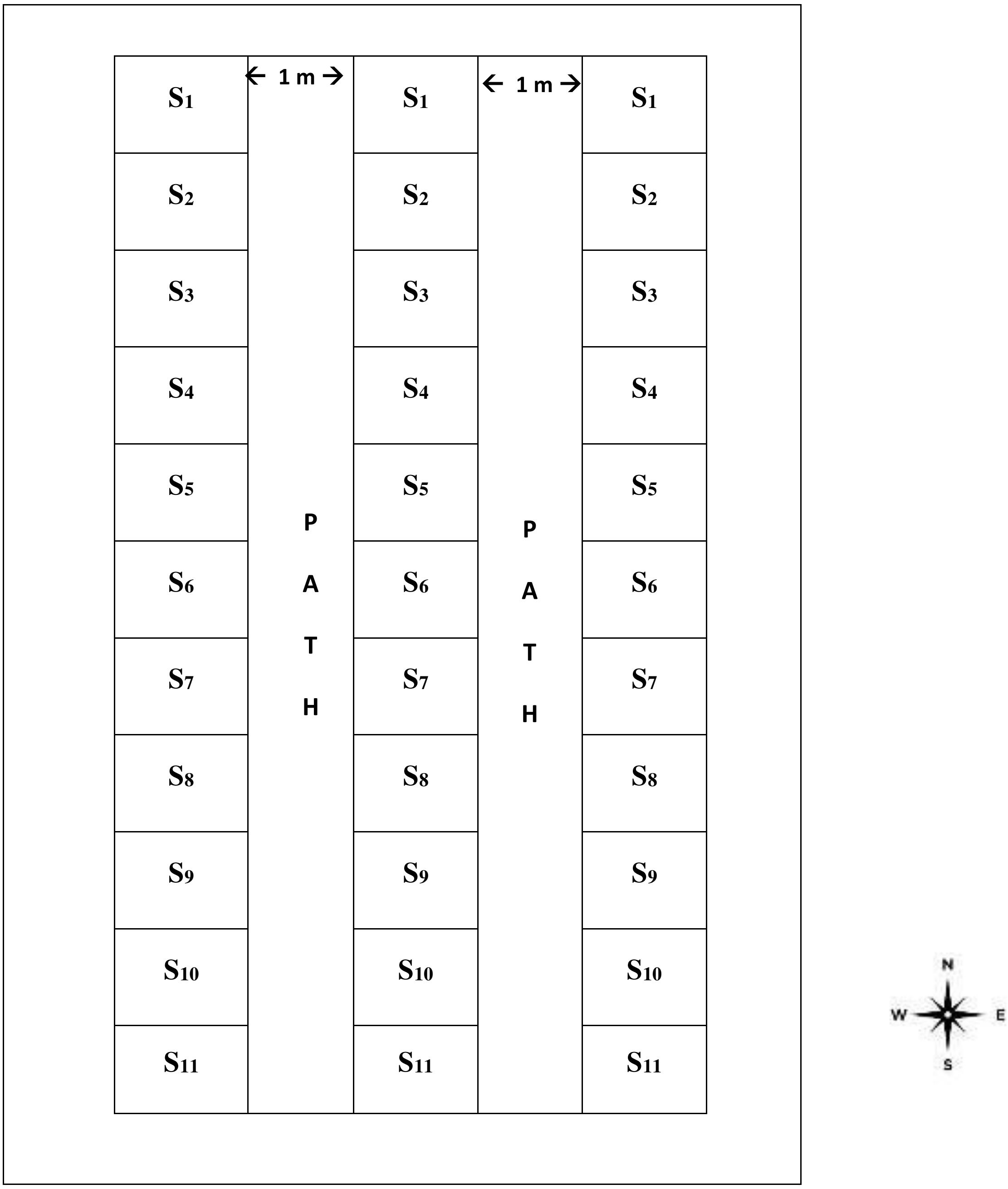


Figure 3.2 Layout Plan

Plate 1.View of experimental field

Plate 2. Fruits analysis for yield and quality parameters

3.5 EXPERIMENTAL DETAILS

1.	Season	:	*Rabi* (2020-21)
2.	Crop	:	Strawberry (*Fragaria* × *ananassa*)
3.	Duration	:	Six months (October, 2020 to March, 2021)
4.	Cultivar	:	Winter Dawn (Chandler, 2009)
5.	Planting System	:	Raised Bed System
6.	Total number of treatment	:	11
7.	Total number of replication	:	3
8.	Total number of plot	:	33
9.	Total sprays	:	3
10.	Spray time	:	30, 45 and 60 DAP
11.	Experimental design	:	Randomized Block Design
12.	Plot size	:	1.8 m^2
13.	Number of row per plot	:	3
14.	Number of plant per row	:	6
15.	Number of plant per plot	:	18
16.	Spacing	:	60 cm row to row 30 cm plant to plant
17.	Site of experiment	:	Horticulture Farm, RCA, Udaipur

3.6 TREATMENT DETAILS

Symbol		**Treatment**
S_1	:	RDF + Control (Water spray)
S_2	:	RDF + Borax (0.1%)
S_3	:	RDF + $ZnSO_4$ (0.2%)
S_4	:	RDF + $FeSO_4$ (0.2%)
S_5	:	RDF + Borax (0.2%)
S_6	:	RDF + $ZnSO_4$ (0.4%)
S_7	:	RDF + $FeSO_4$ (0.4%)

S_8 : RDF + Borax (0.1%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%)

S_9 : RDF + Borax (0.1%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)

S_{10} : RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%)

S_{11} : RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)

NOTE: RDF 100:80:80 kg/ha

3.7 EXPERIMENTAL METHODOLOGY

3.7.1 Experimental materials

Planting material of the cultivar Winter Dawn (Strawberry) was procured from Kimya Biotech Pvt. Ltd. Kasaba, Pune. In order to maintain the vigor of plant growth, experiment plots were augmented with recommended doses 25 tonnes/ha FYM, 100 kg N, 80 kg P_2O_5, 80 kg K_2O/ha. Raised beds prepared and were covered with black polythene mulch and drip system was installed to provide irrigation. Plants were planted at 60×30 cm spacing during Nov. 2020. The site of experiment was at the Horticulture Farm, RCA, MPUAT, Udaipur.

3.7.2 Preparation of chemicals solution

Boron application, 1g and 2g of borax were weighed and solutions were made in one litre of distilled water for making 0.1 per cent and 0.2 per cent concentrations, respectively.

2g and 4g of zinc sulphate were weighed and solutions were made in one litre of distilled water separately for making 0.2 per cent and 0.4 per cent $ZnSO_4$ solution respectively.

2g and 4g of iron sulphate were weighed and solutions were made in one litre of distilled water separately for making 0.2 per cent and 0.4 per cent $FeSO_4$ solution respectively.

3.8 OBSERVATION RECORDED

3.8.1 Plant growth parameters

Five plant were selected randomly in each replication for taking observation on growth parameter of the plants.

3.8.1.1 Petiole length (cm)

After completion of the harvesting period, petiole length (cm) of the leaves was recorded with meter scale from five tagged plant in each replication.

3.8.1.2 Leaves per plant

After harvesting period, total number of leaves were counted from five tagged plants in each replication and expressed as average number of leaves per plant.

3.8.1.3 Plant spread (cm)

Meter scale was used to determine the plant spread from five tagged strawberry plants in East-West and North-South direction separately and the average for each direction was expressed in cm.

3.8.1.4 Runner per plant

After harvesting period that total number of runner were counted on five tagged plants in each replication and was deliberate as average runner production per plant.

3.8.2 Production parameter

3.8.2.1 Days to first flower initiation

Data were recorded on the basis of average number of days taken from planting date to start flowering after planting (minimum 5-6 plants in each replication).

3.8.2.2 Days to initiation of fruit set

The number of days to first fruit set was recorded when flower petals were observed dried off in the flower and achenes on fleshy receptacle started swelling. It was recorded when 5-6 plants in each replication fruit set took place.

3.8.2.3 Days to first harvest and final harvest

Data on number of days taken to final harvest was counted from the date of first harvesting to the last harvesting in each treatment. The average numbers of days taken from planting date were drawn to record the data.

3.8.2.4 Number of pickings

The number of pickings was observed from the tagged plants in each replication by counting the number of time the fruits were harvested and average was drawn to record the data.

3.8.2.5 Fruit length and width (mm) and length diameter ratio

Fruit length and width was determined with digital Vernier Caliper in mm from 20 strawberry fruit from each treatment. The ratio (length: diameter) was also calculated of 20 fruits.

3.8.2.6 Fresh weight of fruit (g)

After ripening, average fruit weight of fruit was calculated from each tagged plants with the help of electronic balance and the mean five of fruit was express in grams.

3.8.2.7 Fruits per plant and fruit yield per plant (g)

The number of fruits per plant was recorded on the same five tagged plants on which fruit set was studied. The average of all the harvests was expressed as number of fruits per plant (kg).

3.8.3 Quality parameters

These observations were recorded as per the A.OA.C. (2012) protocols.

3.8.3.1 TSS (^{O}B)

Digital hand refractometer was used to calculate total soluble solid. Juices of 10 strawberry fruits were taken and few (2-3) drops were dropped over the prism of the refractometer. The value as observed was average to record the TSS in ^{o}Brix.

3.8.3.2 Titratable acidity (%)

Standard N/10 NaOH solution and phenolphthalein as an indicator were used to determine the titratable acidity of strawberry fruit juice until faint pink color appeared.

$$\text{Acidity (\%)} = \frac{\text{Titre Volume x 0.1 x 64 x 10}}{\text{Aliquot x 10}}$$

3.8.3.3 TSS: Acid Ratio

TSS/acid ratio was calculated by dividing the value of total soluble solids content by per cent acidity.

3.8.3.4 Juice content (%)

The ripe strawberry fruits were crushed and pass through muslin cloth. The weight of strawberry juice was measured with electronic balance and the percentage of juice was worked out on the basis of total weight of fruit taken for juice extraction.

$$\text{Percentage of juice content} = \frac{\text{Weight of juice}}{\text{Weight of fruit}} \times 100$$

3.8.3.5 Ascorbic acid (mg 100g^{-1} pulp)

Sample of 5 g take in 3 per cent meta-phosphoric acid and make 100 ml volume. Titrate against 2, 6- dichlorophenol indophenols dye by pipette out 5.0 ml supernantant, add 10 ml of MPA. Samples reading were taken when stable light pink color appeared. Similarly, working standard of L-ascorbic acid (3%) was prepared by dissolving 100 mg meta-phosphoric acid. Pipette out 5.0 ml of this supernatant, add 10 ml of MPA and titrate against dye until it developed pink colour at end point. Record sample and working standard reading their after, used in calculation of ascorbic acid/100 ml juice by using below formula (Sadasivam and Theymoli, 1987).

$$Ascorbicacid\ (\frac{mg}{100}g) = \frac{\text{Titrate (ml)} \times \text{dye Factor} \times \text{Volume made up (ml)}}{\text{Aliquot (ml)taken for estimation} \times \text{Volume of juice (ml)}} \times 100$$

3.9 Economic feasibility

The cost of cultivation was calculated, the gross income was estimated on the basic of selling price of the fruits.

1. **Net income = Gross income – cost of cultivation**

   The cost of cultivation included that money spend on micronutrient, plants of strawberry, fertilizer, fertilizer application, irrigation, weeding, hoeing and plant protection.

   Net return per rupee investment was calculated by following formula:

2. **Returns per rupee** $= \frac{\textbf{Net income (Rs./ha)}}{\textbf{Total cost (Rs./ha)}}$

3.10 STATISTICAL ANALYSIS

The data recorded for the evaluation of different parameters was statistical analyzed using standard procedure for ANOVA of Random Block Design in order to test the significance of experimental results. The methods of analysis of variance were used, which was described by Panse and Sukhatme (1985).

Source of variance	**d.f.**	**SS**	**MSS**	**F_{cal}**
Replication	r-1	SS_r	SS_r /r-1	SS_r/r-1/SS_e/(t-1)(r-1)
Treatment	t-1	SS_t	SS_t/t-1	SS_t/r-1/SS_e/(t-1)(r-1)
Error	(r-1)(t-1)	SS_e	SS_e /(t-1)(r-1)	
Total	rt-1	Total SS		

4. EXPERIMENTAL RESULT

The present experimental entitled "Response of foliar spray of iron, zinc and boron in strawberry (*Fragaria* × *ananassa***Duch.**) cv. Winter Dawn" was conducted from October, 2020 to March, 2021 at the Horticulture Farm, Department of Horticulture, MaharanaPratap University of Agriculture and Technology, Udaipur. The data recorded for various parameters are statistically analyzed, their mean value are presented in Table 4.1 to 4.8, Fig. 4.1 to 4.12 and appendix from I to XXII.

4.1 GROWTH PARAMETERS

The average data are presented for vegetative parameters like petiole length, number of leaves per plant, plant spread and runner production per plant are presented in Table 4.1, 4.2 and depicted in Fig. 4.1, 4.2.

4.1.1 Petiole length

The mean data recorded on petiole length was influenced by the foliar application of the iron, zinc and boron. It is clear from analyzed data that treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) were recorded higher petiole length (8.57 cm) followed by S_{11} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%) which recorded 8.50 cm over the S_1– control as RDF + water spray (7.10 cm). Whereas, treatment like S_3, S_5, S_6, S_7, S_8, S_9 and S_{11} was statistically at par with best treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%).

4.1.2 Leaves per plant

The mean data on leaves per plant was influenced by the foliar application of the iron, zinc and boron were recorded and presented in Table 4.1 and graphically depicted in Fig. 4.1.

Analyzedmean data showed leaves per plant was significantly influenced by different treatments. The maximum leaves per plant (25.07) were recorded in treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) followed by S_{11} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%) which recorded 24.93. However, minimum leaves per plant were recorded under the treatment S_1– control as RDF + water spray (20.07). While treatments like S_8, S_9 and S_{11} were statistically at par with best treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%).

4.1.3 Plant spread E-W and N-S (cm)

Analyzed data for plant spread were significantly influenced by foliar application of iron, zinc and boron were recorded and presented in Table 4.1 and graphically depicted in Fig. 4.2. The treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) significantly recorded for maximum plant spread 28.37 cm (E-W) and 24.70 cm (N-S) followed by S_{11} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%) which recorded 27.87 cm (E-W) and 23.87 cm (N-S). Whereas, treatment S_1– control as RDF + water spray, was recorded minimum plant spread 24.60 cm (E-W) and 20.63 cm (N-S). However, treatments like S_6, S_8, S_9 and S_{11} were significantly at par with best treatment S_{10} - RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) in the both direction i.e. E-W and N-S.

4.1.4 Runner production per plant

The average data on runner production per plant was influenced by the foliar application of the iron, zinc and boron were recorded and presented in Table 4.2 and graphically depicted in Fig. 4.2.

It is clear from the analyzed mean that treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) were recorded higher runner production per plant (3.67) followed by S_{11} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%) which recorded 3.60 over the S_1– control as RDF + water spray (3.27). Whereas, treatment like S_9 and S_{11} was statistically at par with best treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%).

4.2 YIELD PARAMETERS

The mean data are presented for the yield parameter like days taken to first flower initiation, days taken to initiation to of fruit set, days taken to first harvest, days taken to final harvest, number of picking, fruit length (mm), fruit width (mm), Length Diameter ratio, fresh weight of fruit (g), number of fruit per plant and fruit yield per plant (g) are presented in Table 4.3 to 4.8 and depicted in Fig. 4.2 to 4.8. The ANOVA is given in appendix VI to XVI.

4.2.1 Days to first flower initiation

However mean data showed days to first flower initiation was significantly influenced by different treatments. The minimum days to first flower initiation (56.47

Table: 4.1 Response of micronutrient on petiole length, leaves per plant and plant spread

Notations	Treatments	Petiole length (cm)	Leaves plant^{-1}	Plant spread(cm)	
				E-W	N-S
S_1	RDF + Control (Water spray)	7.10	20.07	24.60	20.63
S_2	RDF + Borax (0.1%)	7.17	21.60	25.03	21.10
S_3	RDF + $ZnSO_4$ (0.2%)	8.27	22.73	26.03	22.07
S_4	RDF + $FeSO_4$ (0.2%)	7.23	21.87	25.83	21.80
S_5	RDF + Borax (0.2%)	8.27	22.13	26.00	22.03
S_6	RDF + $ZnSO_4$ (0.4%)	8.17	23.07	26.83	22.73
S_7	RDF + $FeSO_4$ (0.4%)	8.27	22.87	25.30	21.70
S_8	RDF + Borax (0.1%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%)	8.30	23.80	26.87	22.87
S_9	RDF + Borax (0.1%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)	8.37	24.47	27.10	23.13
S_{10}	RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%)	8.57	25.07	28.37	24.70
S_{11}	RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)	8.50	24.93	27.87	23.87
	SEm±	**0.32**	**0.61**	**0.71**	**0.73**
	CD at 5%	**0.95**	**1.80**	**2.07**	**2.14**
	C.V.	**6.99**	**4.64**	**4.65**	**5.63**

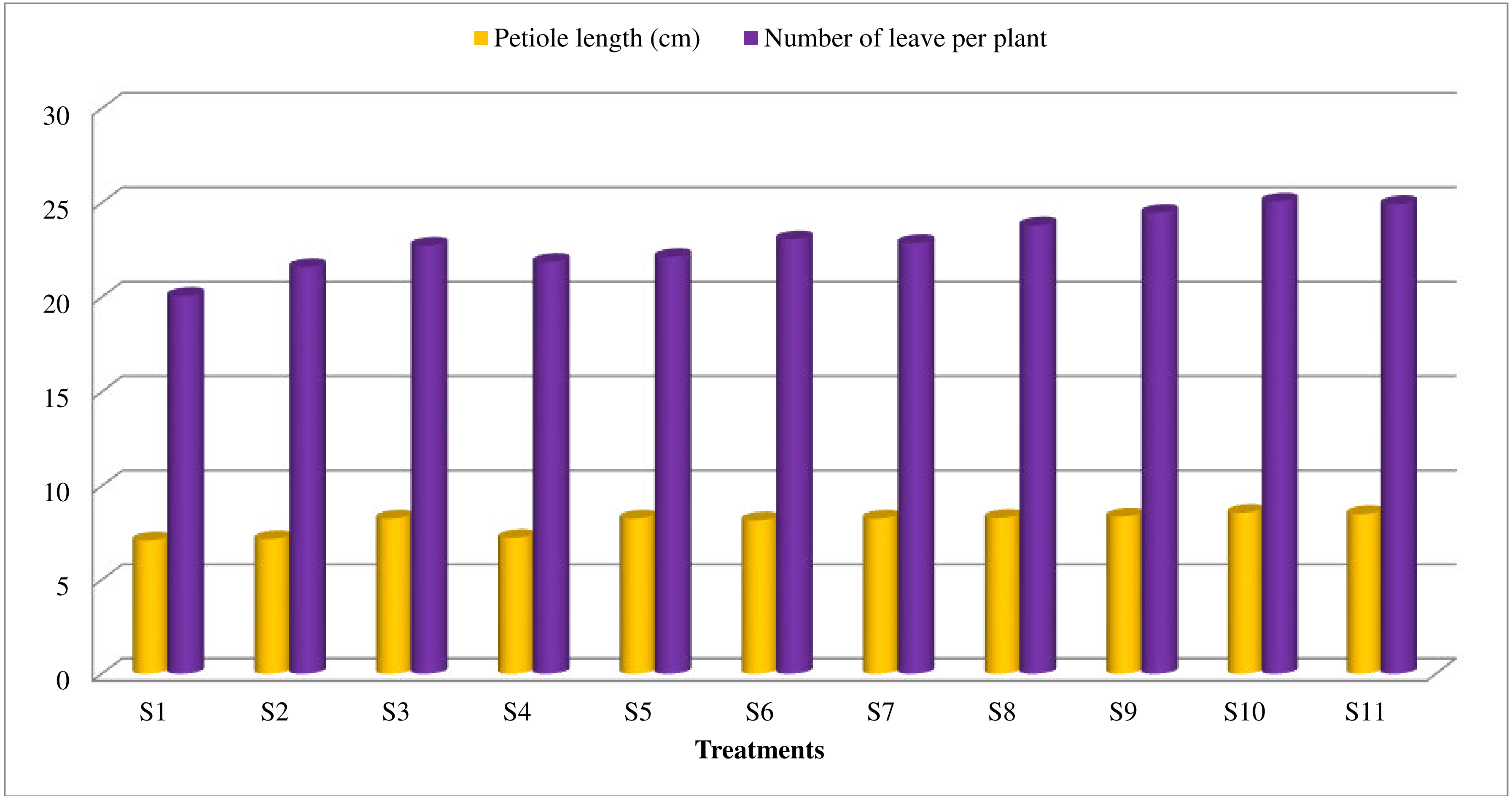


Fig. 4.1 Response of micronutrients on petiole length, number of leaves per plant

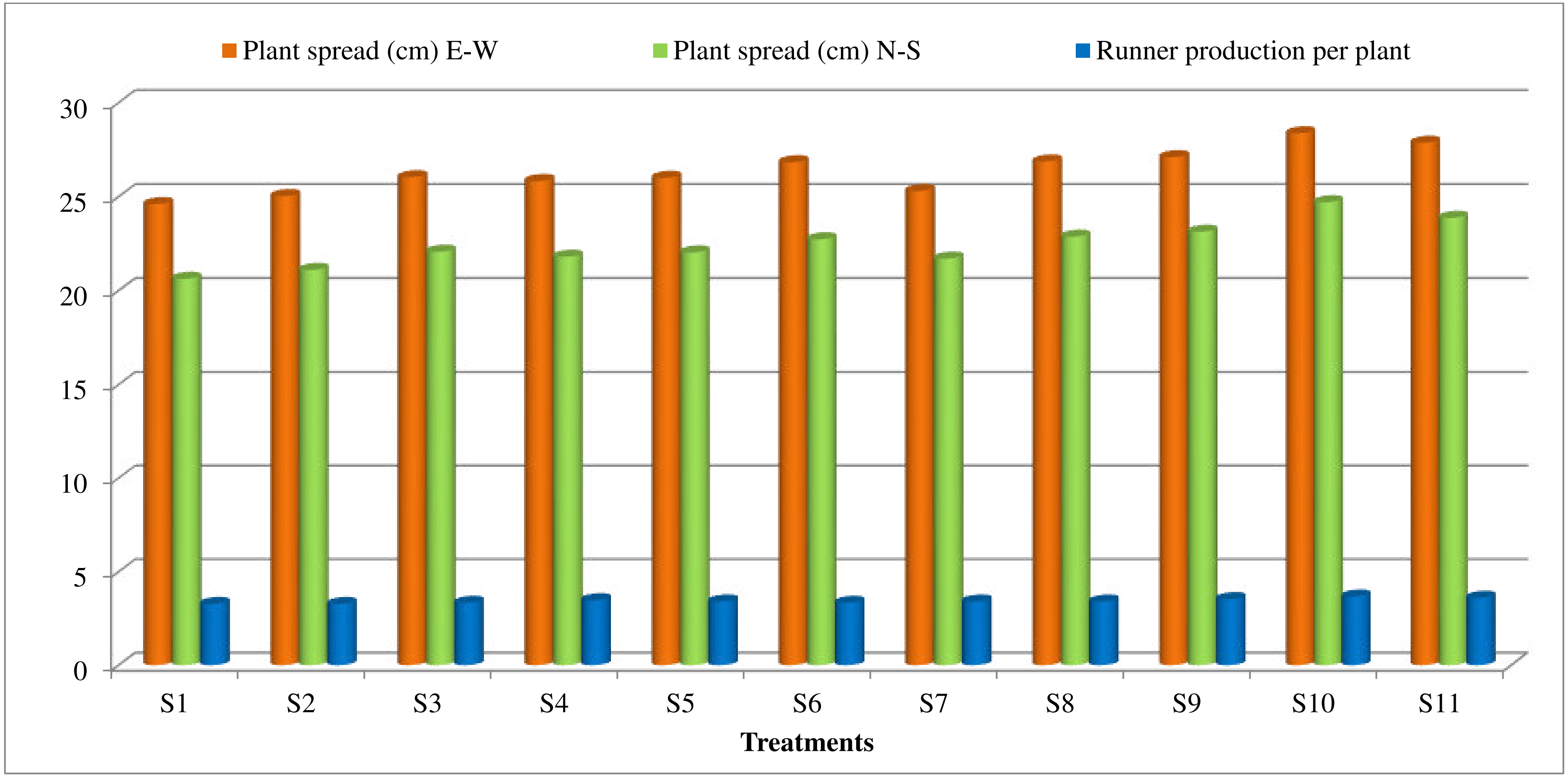


Fig. 4.2 Response of micronutrients on plant spread and runner per plant

days) were recorded in treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) followed by S_{11} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%) which recorded 57.67 days. However, maximum days taken to first flower initiation was recorded under the treatment S_1– control as RDF + water spray (64.27 days). Whereas, treatments like S_8, S_9 and S_{11} were statistically at par with best treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%).

4.2.2 Days to initiation of fruit set

Moreover, mean data showed on days to initiation of fruit set were significantly influenced by foliar application of iron, zinc and boron. The treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) significantly recorded the minimum days to initiation of fruit set (59.40 days) Followed by S_{11} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%) which recorded 60.73 days. Whereas, treatment S_1– control as RDF + water spray was recorded maximum days to initiation of fruit set 68.80 days. However, treatments like S_9 and S_{11} were significantly at par with best treatment S_{10} - RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%).

4.1.7 Days to first harvest

The perusal of the data on days to first harvest, the treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) significantly recorded the minimum days taken to first harvest (65.40 days) followed by S_{11} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%) which recorded 67.73 days. Whereas, treatment S_1– control as RDF + water spray was recorded maximum days taken to first harvest 76.80 days. However, treatments like S_9 and S_{11} were at par with best treatment S_{10} - RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%).

4.2.4 Days taken to final harvest

It is clear from the mean data indicates that treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) were recorded maximum days taken to final harvest (115.07 days) followed by S_{11} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%) which recorded 114.80 days over the S_1– control as RDF + water spray (107.07 days). Whereas, treatment like S_5, S_6, S_7, S_8, S_9 and S_{11} was statistically at par with best treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%).

4.2.5 Number of picking

However, analyzed mean data showed that number of picking was significantly influenced by different treatments. The maximum number of pickings (17.07) were recorded in treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) followed by S_{11} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%) which recorded 16.93. However, minimum number of pickings was recorded under the treatment S_1– control as RDF + water spray (15.07). Whereas, treatments like S_4, S_5, S_6, S_8, S_9 and S_{11} were statistically at par with best treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%).

4.2.6 Fruit length (mm)

Moreover, data on fruit length were significantly influenced by foliar application of iron, zinc and boron. The treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) significantly recorded the maximum fruit length (36.03 mm) followed by S_{11} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%) which recorded 35.87 mm. Whereas treatment S_1– control as RDF + water spray was recorded minimum fruit length 34.07 mm. However, treatments like S_6, S_7, S_8, S_9 and S_{11} were significantly at par with best treatment S_{10} - RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%).

4.2.7 Fruit width (mm)

The perusal of the mean data on fruit width showed that the treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) recorded the maximum fruit width (27.17 mm) Followed by S_{11} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%) which recorded 26.83 mm. Whereas treatment S_1– control as RDF + water spray was recorded minimum fruit width 25.53 mm. Data was showed non-significant difference between the treatment.

4.2.8 Length Diameter ratio

However, analyzed mean data showed that length diameter ratio was significantly influenced by different treatments. The maximum length diameter ratio (1.26) were recorded in treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) followed by S_{11} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%) which recorded 1.23. However, minimum length diameter ratio was recorded under the treatment S_1– control as RDF + water spray (1.15). Whereas, treatments like

Table: 4.2 Response of micronutrient on runner per plant, days to first flower initiation and days to initiation of fruit set

Notations	Treatments	Runner plant^{-1}	Days to First Flower Initiation	Days to initiation of fruit set
S_1	RDF + Control (Water spray)	3.27	64.27	68.80
S_2	RDF + Borax (0.1%)	3.27	60.87	65.27
S_3	RDF + $ZnSO_4$ (0.2%)	3.33	61.13	65.20
S_4	RDF + $FeSO_4$ (0.2%)	3.47	63.13	67.27
S_5	RDF + Borax (0.2%)	3.40	61.07	64.13
S_6	RDF + $ZnSO_4$ (0.4%)	3.33	61.07	65.13
S_7	RDF + $FeSO_4$ (0.4%)	3.40	62.33	65.60
S_8	RDF + Borax (0.1%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%)	3.40	60.33	64.07
S_9	RDF + Borax (0.1%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)	3.53	58.60	61.80
S_{10}	RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%)	3.67	56.47	59.40
S_{11}	RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)	3.60	57.67	60.73
	SEm±	**0.05**	**1.36**	**1.30**
	CD at 5%	**0.14**	**3.98**	**3.81**
	C.V.	**2.45**	**3.88**	**3.50**

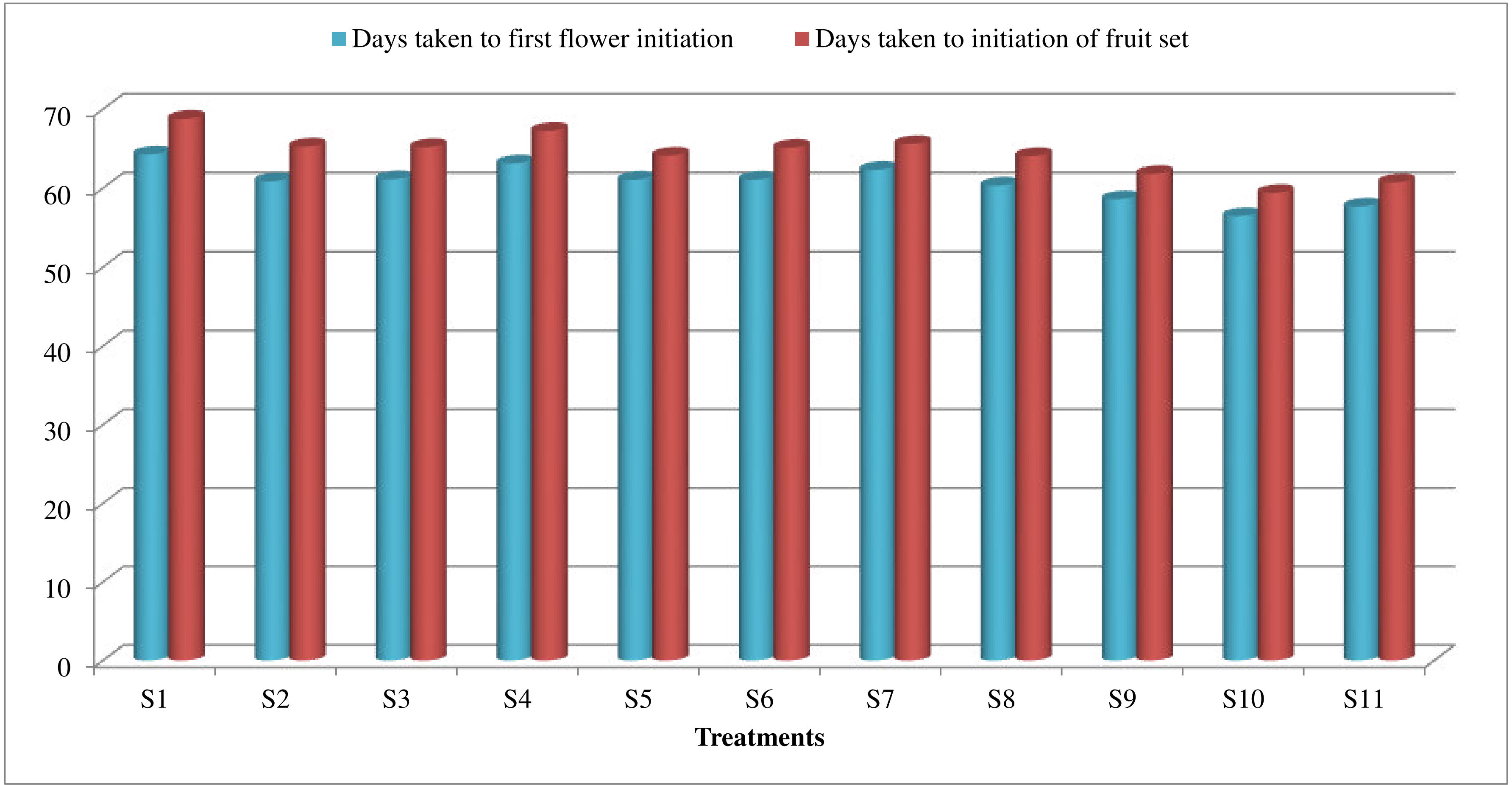


Fig. 4.3 Response of micronutrients on days to first flower initiation and days to initiation of fruit set

Table: 4.3 Response of micronutrient on days taken to first harvest, days taken to final harvest and number of picking

Notations	Treatments	Days to first harvest	Days to final harvest	Number of picking
S_1	RDF + Control (Water spray)	76.80	107.07	15.07
S_2	RDF + Borax (0.1%)	73.27	108.67	15.33
S_3	RDF + $ZnSO_4$ (0.2%)	73.20	109.00	15.53
S_4	RDF + $FeSO_4$ (0.2%)	75.27	109.73	15.73
S_5	RDF + Borax (0.2%)	72.13	110.53	15.80
S_6	RDF + $ZnSO_4$ (0.4%)	73.13	111.93	15.93
S_7	RDF + $FeSO_4$ (0.4%)	73.60	112.40	15.47
S_8	RDF + Borax (0.1%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%)	72.07	113.60	16.60
S_9	RDF + Borax (0.1%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)	68.80	114.60	16.93
S_{10}	RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%)	65.40	115.07	17.07
S_{11}	RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)	67.73	114.80	17.00
	SEm±	**1.25**	**1.72**	**0.47**
	CD at 5%	**3.67**	**5.04**	**1.37**
	C.V.	**3.01**	**2.67**	**5.06**

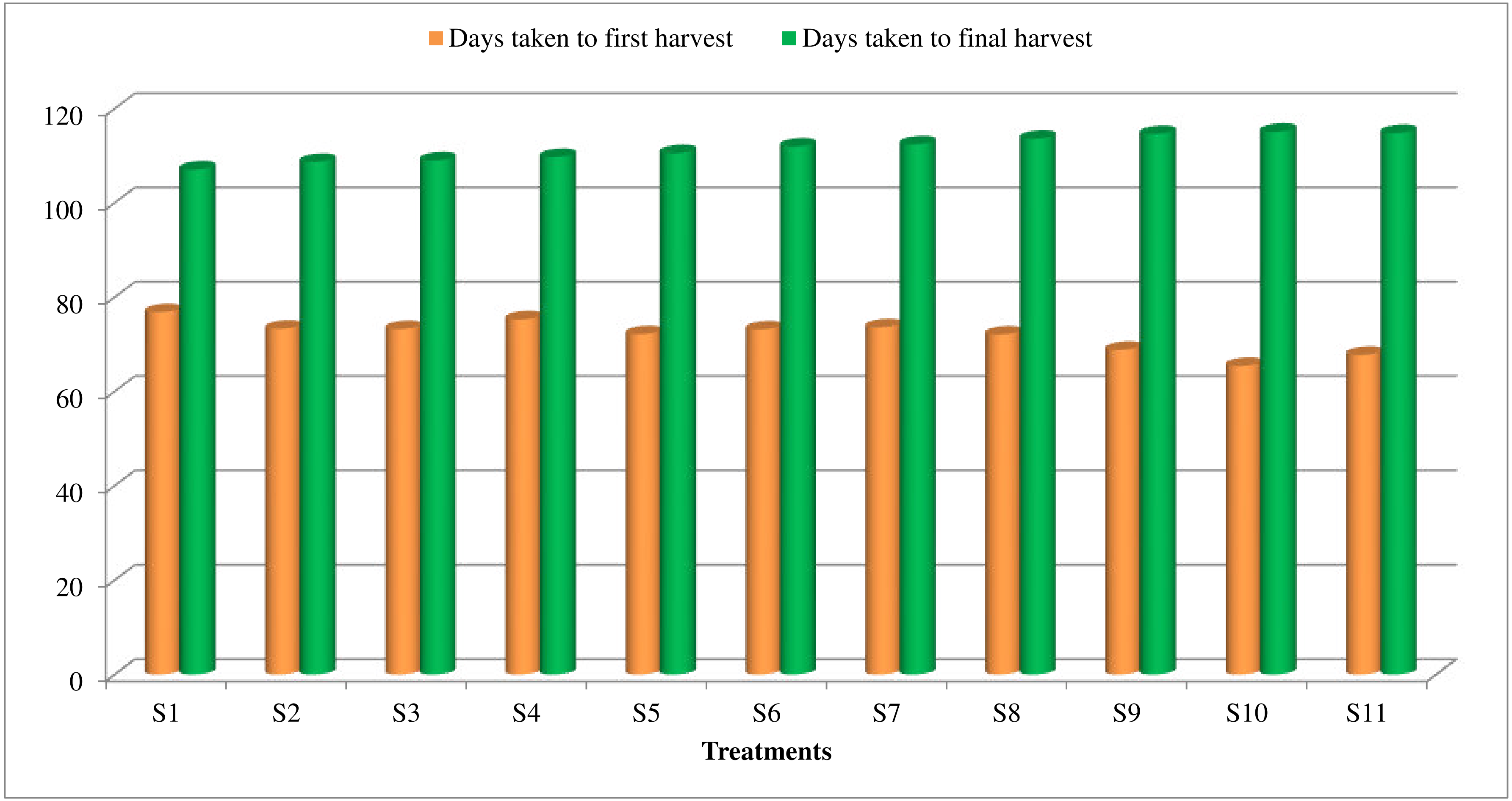


Fig. 4.4 Response of micronutrients on days taken to first harvest, days taken to final harvest

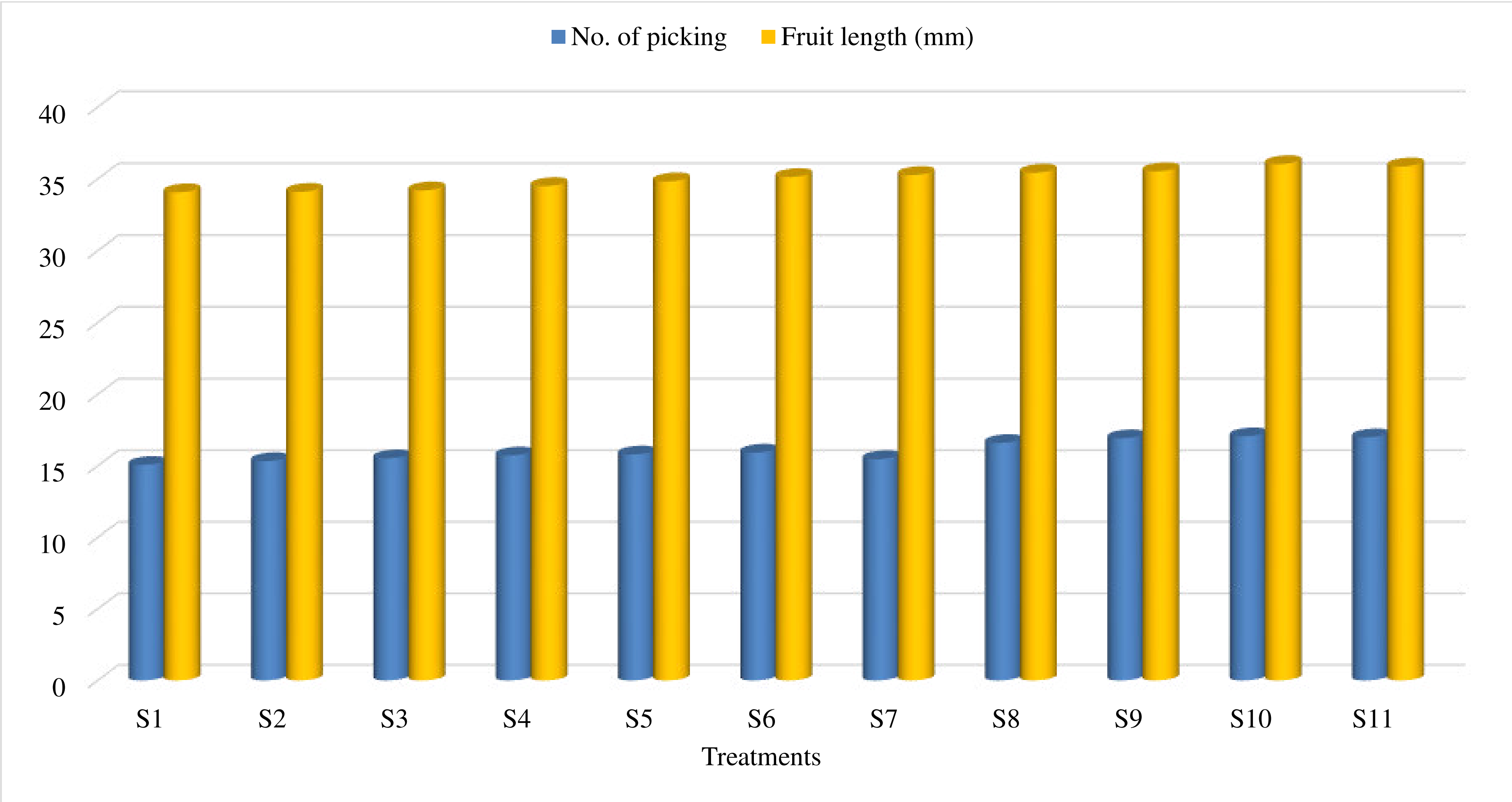


Fig. 4.5 Response of micronutrients on number of picking and fruit length

Table: 4.4 Response of micronutrient on fruit length, fruit width and length diameter ratio

Notations	Treatments	Fruit length (mm)	Fruit width (mm)	Length : Diameter
S_1	RDF + Control (Water spray)	34.07	25.53	1.15
S_2	RDF + Borax (0.1%)	34.10	26.00	1.16
S_3	RDF + $ZnSO_4$ (0.2%)	34.20	26.10	1.17
S_4	RDF + $FeSO_4$ (0.2%)	34.50	26.20	1.17
S_5	RDF + Borax (0.2%)	34.83	26.27	1.16
S_6	RDF + $ZnSO_4$ (0.4%)	35.13	26.30	1.19
S_7	RDF + $FeSO_4$ (0.4%)	35.27	26.40	1.17
S_8	RDF + Borax (0.1%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%)	35.43	26.50	1.16
S_9	RDF + Borax (0.1%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)	35.53	26.67	1.20
S_{10}	RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%)	36.03	27.17	1.26
S_{11}	RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)	35.87	26.83	1.23
	SEm±	**0.40**	**0.34**	**0.02**
	CD at 5%	**1.17**	NS	**0.06**
	C.V.	**1.98**	**2.23**	**3.16**

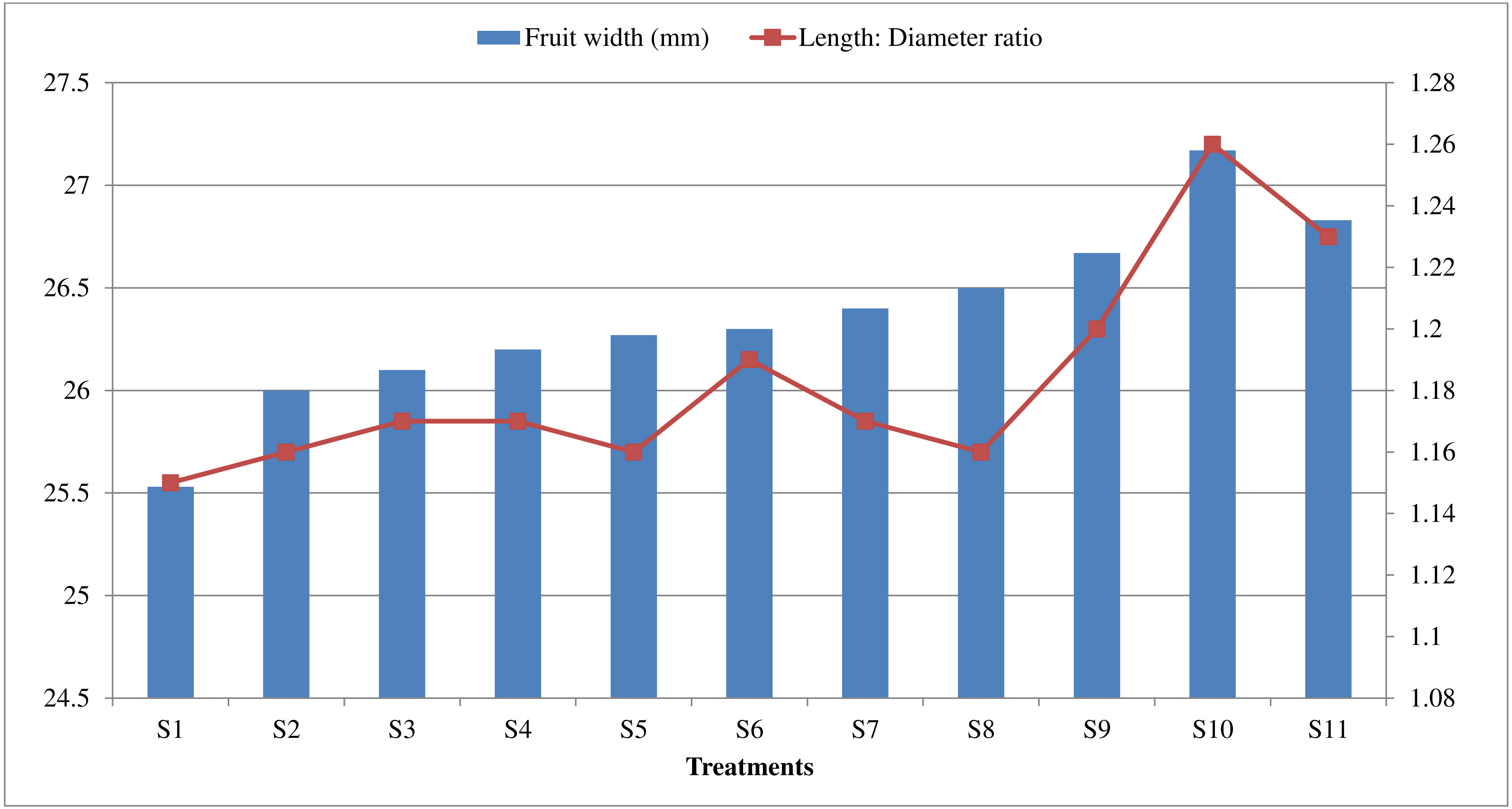


Fig. 4.6 Response of micronutrients on fruit width and length diameter ratio

Table: 4.5 Response of micronutrient on fresh weight of fruit, number of fruit per plant and fruit yield per plant

Notations	Treatments	Fresh weight of fruit (g)	Number of fruit $plant^{-1}$	Fruit yield $plant^{-1}$ (g)
S_1	RDF + Control (Water spray)	10.88	14.91	162.22
S_2	RDF + Borax (0.1%)	10.89	15.00	163.30
S_3	RDF + $ZnSO_4$ (0.2%)	10.90	15.13	164.85
S_4	RDF + $FeSO_4$ (0.2%)	10.91	15.33	167.29
S_5	RDF + Borax (0.2%)	10.91	15.52	169.37
S_6	RDF + $ZnSO_4$ (0.4%)	10.90	15.61	169.93
S_7	RDF + $FeSO_4$ (0.4%)	10.92	15.55	169.79
S_8	RDF + Borax (0.1%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%)	10.93	15.66	171.13
S_9	RDF + Borax (0.1%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)	10.94	15.87	173.60
S_{10}	RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%)	10.97	16.21	177.96
S_{11}	RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)	10.95	16.00	175.23
	SEm±	**0.19**	**0.18**	**3.51**
	CD at 5%	NS	**0.56**	**10.29**
	C.V.	**3.05**	**2.13**	**3.59**

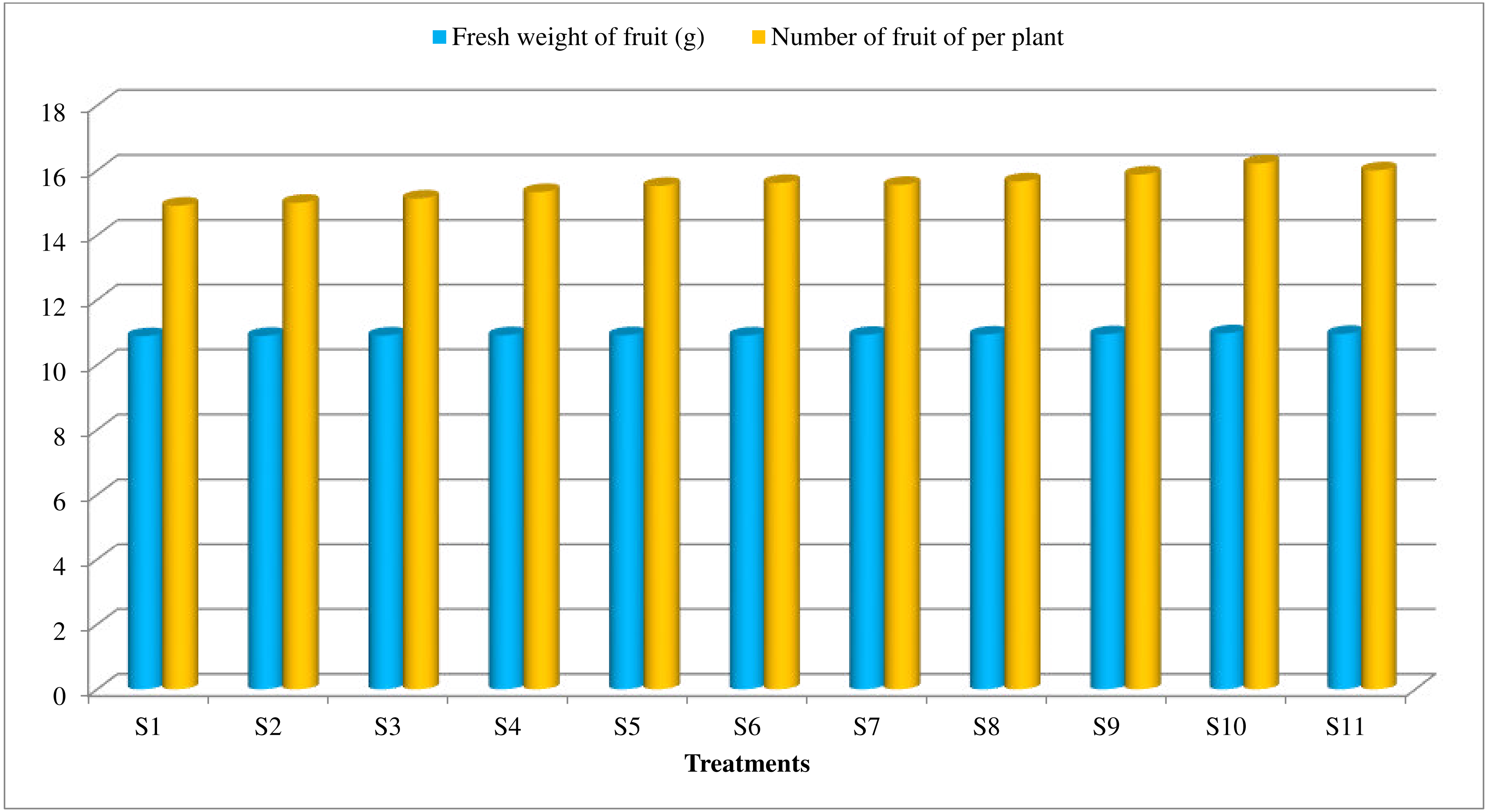


Fig. 4.7 Response of micronutrients on fresh weight of fruit and number of fruit per plant

S_9 and S_{11} were statistically at par with best treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%).

4.2.9 Fresh weight of fruit (g)

It is clear from the mean data that treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) were recorded maximum fresh weight of fruit (10.97 g) followed by S_{11} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%) which recorded 10.95 g over the S_1– control as RDF + water spray (10.88 g). Data was showed non-significant difference between the treatments.

4.2.10 Fruit per plant

Moreover, analyzed mean data on fruit per plant were significantly influenced by foliar application of iron, zinc and boron. The treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) significantly recorded the maximum fruit per plant (16.21) followed by S_{11} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%) which recorded 16.00. Whereas, treatment S_1– control as RDF + water spray was recorded minimum number of fruit per plant 14.91. However, treatments like S_8, S_9 and S_{11} were significantly at par with best treatment S_{10} - RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%).

4.2.11 Fruit yield per plant (g)

The perusal of the data on fruit yield per plant, the treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) significantly recorded the maximum fruit yield per plant (177.96 g) followed by S_{11} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%) which recorded 175.23 g. while, treatment S_1– control as RDF + water spray was recorded minimum fruit yield per plant 162.22 g. However, treatment like S_{11} was significantly at par with best treatment S_{10} - RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%). However, treatments like S_5, S_6, S_7, S_8, S_9 and S_{11} were statistically at par with best treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%).

4.3 QUALITY PARAMETERS

The mean data are presented for quality parameters like TSS, titratable acidity, TSS: Acid ratio, juice percent and ascorbic acid are presented in Table 4.6, 4.7 and depicted in Fig. 4.8 to 4.10.

4.3.1 TSS (ºB)

However mean data showed TSS was significantly influenced by different treatments. The maximum TSS (11.99 ^{O}B) were recorded in treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) followed by S_{11} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%) which recorded 11.90 ^{O}B. However, minimum TSS was recorded under the treatment S_1– control as RDF + water spray (11.10 ^{O}B). Whereas, treatments like S_4, S_7, S_8 and S_{11} were statistically at par with best treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%).

4.3.2 Titratable acidity (%)

It is clear from the analyzed mean data that treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) were recorded minimum titratable acidity of the fruit (0.87) percent followed by S_{11} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%) which also recorded 0.87 percent over the S_1– control as RDF + water spray (1.00) percent.

4.3.3 TSS Acid ratio

Moreover, data on TSS Acid ratio was significantly influenced by foliar application of iron, zinc and boron. The treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) significantly recorded the maximum TSS Acid ratio (13.89) followed by S_{11} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%) which recorded 13.79. Whereas treatment S_1– control as RDF + water spray was recorded minimum TSS Acid ratio 11.10. However, treatments like S_4, S_7, S_8, and S_{11} were significantly at par with best treatment S_{10} - RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%).

4.3.4 Juice content (%)

The perusal of analyzed mean data on juice percent, the treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) significantly recorded the maximum juice percent (64.56) followed by S_{11} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) +

Table: 4.6 Response of micronutrient on TSS, titratable acidity and TSS acid ratio

Notations	Treatments	TSS (^{O}B)	Titratableacidity (%)	TSS : Acid
S_1	RDF + Control (Water spray)	11.10	1.00	11.10
S_2	RDF + Borax (0.1%)	11.14	0.93	11.98
S_3	RDF + $ZnSO_4$ (0.2%)	11.25	0.93	12.07
S_4	RDF + $FeSO_4$ (0.2%)	11.82	0.90	13.13
S_5	RDF + Borax (0.2%)	11.32	0.93	12.17
S_6	RDF + $ZnSO_4$ (0.4%)	11.10	0.93	11.93
S_7	RDF + $FeSO_4$ (0.4%)	11.47	0.90	12.74
S_8	RDF + Borax (0.1%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%)	11.58	0.90	12.87
S_9	RDF + Borax (0.1%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)	11.25	0.90	12.50
S_{10}	RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%)	11.99	0.87	13.89
S_{11}	RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)	11.90	0.87	13.79
	SEm±	**0.21**	**0.02**	**0.43**
	CD at 5%	**0.63**	**0.07**	**1.27**
	C.V.	**3.23**	**4.25**	**5.97**

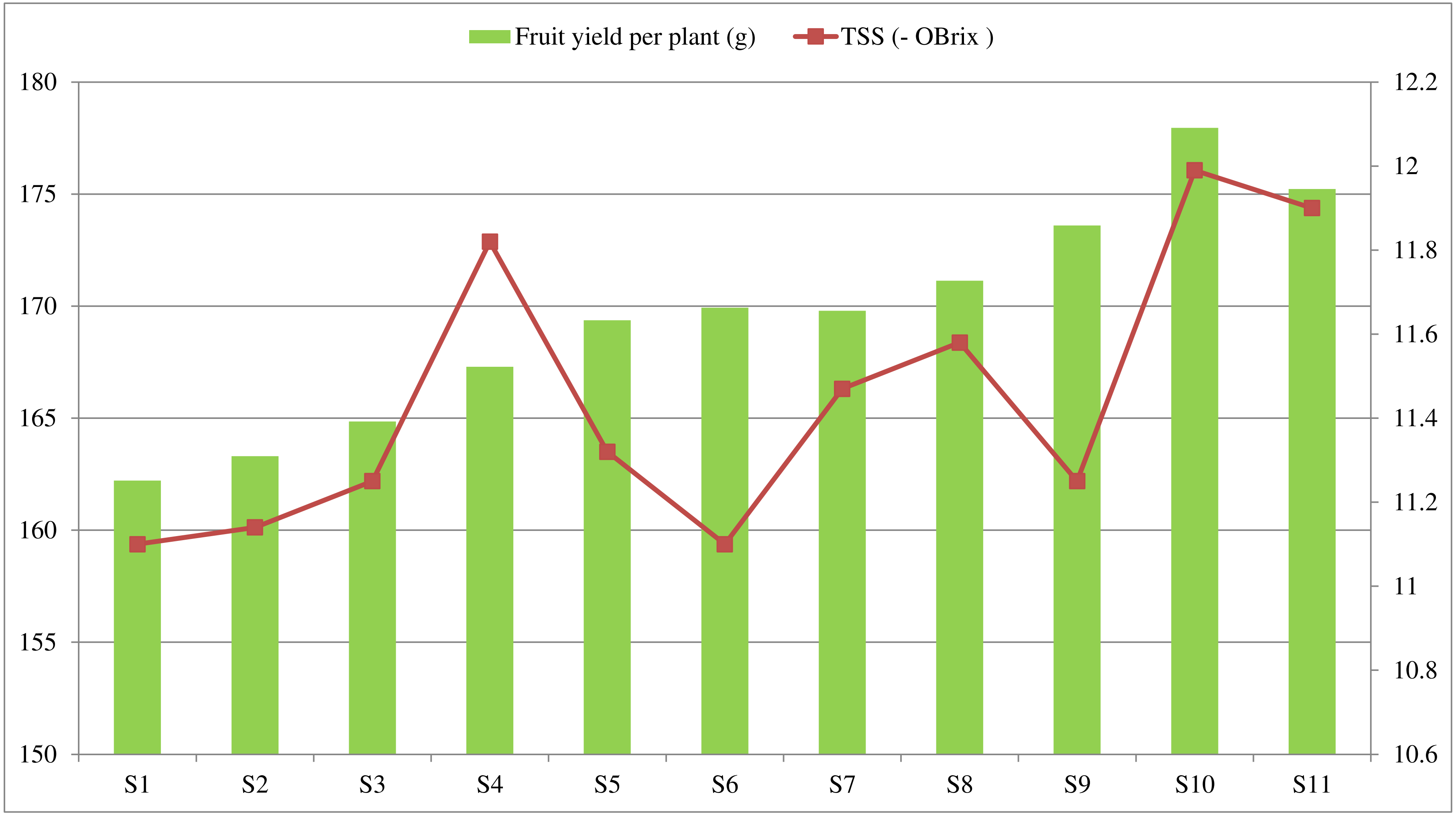


Fig. 4.8 Response of micronutrients on fruit yield per plant and TSS

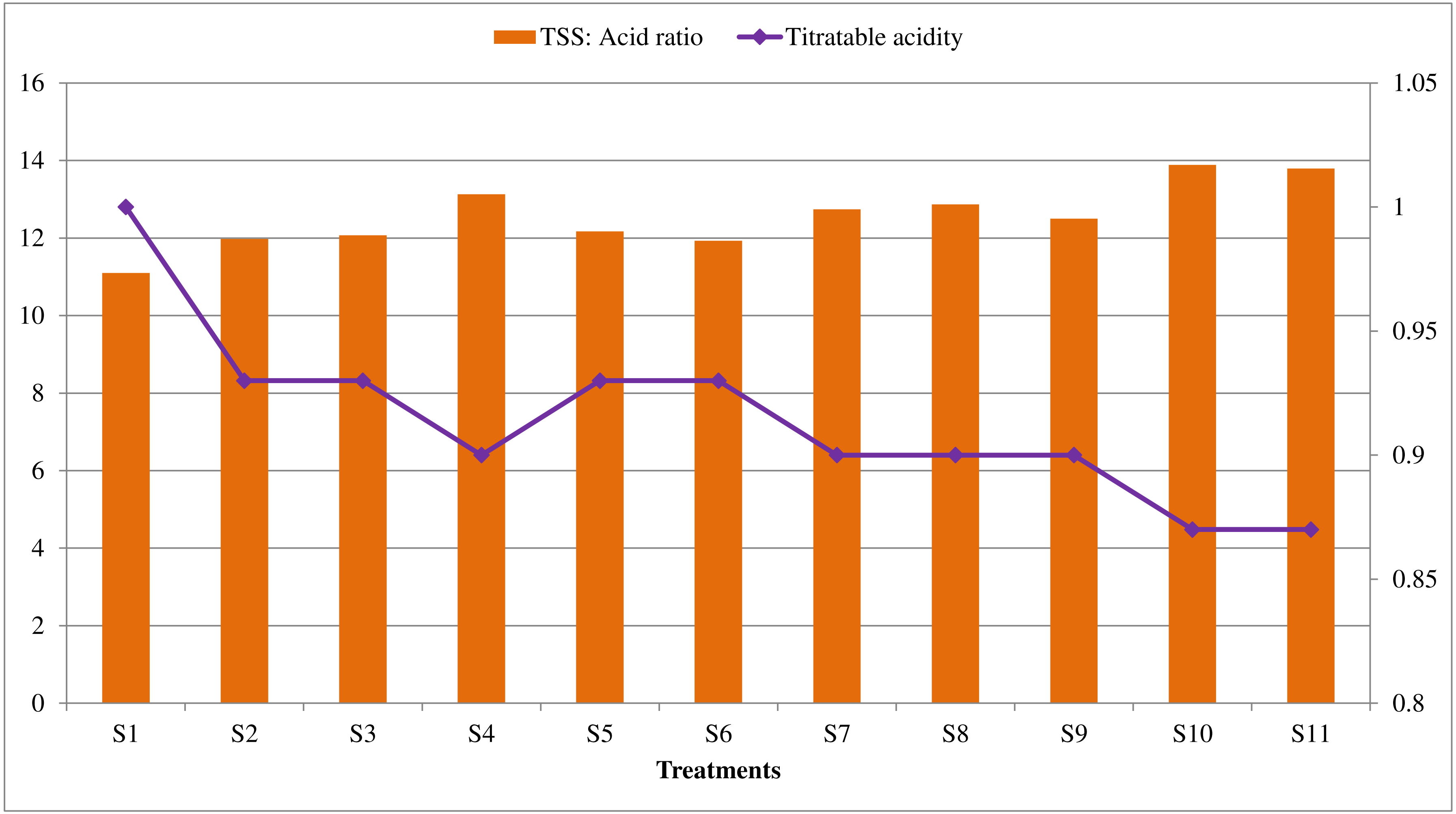


Fig. 4.9 Response of micronutrients on TSS Acid ratio and titratable acidity

$FeSO_4$ (0.4%) which recorded 63.95 percent. Whereas, treatment S_1– control as RDF + water spray was recorded minimum juice percent 57.76. However, treatments like S_3, S_4, S_7, S_8, S_9 and S_{11} were significantly at par with best treatment S_{10} - RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%).

4.1.20 Ascorbic acid (mg 100g^{-1} pulp)

However mean data showed ascorbic acid content was significantly influenced by different treatments. The maximum ascorbic acid content (60.80 mg 100g^{-1} pulp) were recorded in treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) followed by S_{11} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%) which recorded 60.62 mg 100g^{-1} pulp. However, minimum ascorbic acid content was recorded under the treatment S_1– control as RDF + water spray (57.75 mg 100g^{-1} pulp). Whereas treatments like S_4, S_5,S_6, S_7, S_8, S_9 and S_{11} were statistically at par with best treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%).

4.4 ECONOMICS OF THE TREATMENTS

The mean data are presented for economics of the treatments like B: C and net return are presented in Table 4.7, 4.8 and depicted in Fig. 4.11.

The relative economics of the treatments on the basis of 18 plants per treatment was calculated as per formula given in the material and methods. On the basis of the results obtained from this study application of combined treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) was found best for highest gross return ₹ 715439 ha^{-1} and net return ₹ 372680 ha^{-1} and benefit cost ratio 1.09, while minimum gross return (₹ 649633 ha^{-1}), net return (₹ 307633 ha^{-1}) and benefit cost ratio 0.90 were found in S_1– control as RDF + water spray.

Table: 4.7 Response of micronutrient on fruit juice, ascorbic acid and net return

Notations	Treatments	Juice content (%)	Ascorbic acid (mg $100g^{-1}$)
S_1	RDF + Control (Water spray)	57.76	57.75
S_2	RDF + Borax (0.1%)	61.15	57.89
S_3	RDF + $ZnSO_4$ (0.2%)	61.60	58.16
S_4	RDF + $FeSO_4$ (0.2%)	62.47	58.82
S_5	RDF + Borax (0.2%)	60.35	59.11
S_6	RDF + $ZnSO_4$ (0.4%)	60.38	59.31
S_7	RDF + $FeSO_4$ (0.4%)	61.90	59.86
S_8	RDF + Borax (0.1%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%)	62.18	59.99
S_9	RDF + Borax (0.1%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)	62.88	60.19
S_{10}	RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%)	64.56	60.80
S_{11}	RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)	63.95	60.62
	SEm±	**1.21**	**0.70**
	CD at 5%	**3.56**	**2.04**
	C.V.	**3.40**	**2.03**

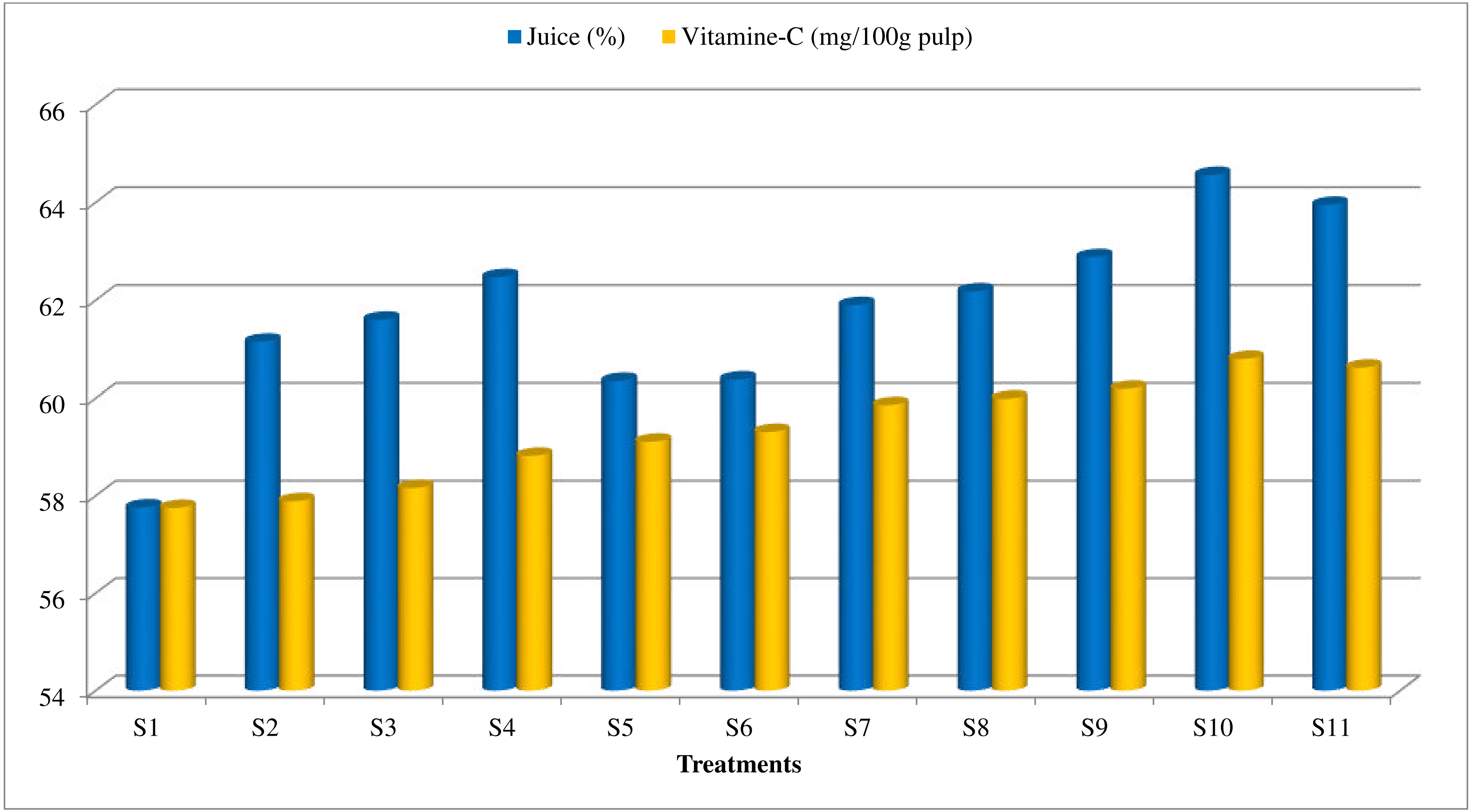


Fig. 4.10 Response of micronutrients on juice and Vitamin- C content

Table 4.8 Economics of the treatments

Treatment	Fruit yield ha^{-1} (ton)	Total fruit returnha^{-1} (Rs.)	Runner ha^{-1}	Total runner return (Rs.)	Total cost ha^{-1}	Gross returnha^{-1} (Rs.)	Net return ha^{-1} (Rs.)	B: C
S_1	9.01	540743	181483	108890	342000	649633	307633	0.90
S_2	9.07	544329	181483	108890	342046	653219	311173	0.91
S_3	9.16	549505	185187	111112	342189	660617	318428	0.93
S_4	9.29	557627	192594	115556	342315	673183	330868	0.97
S_5	9.41	564568	188890	113334	342630	677903	335273	0.98
S_6	9.44	566428	185187	111112	342255	677540	335285	0.98
S_7	9.43	565982	188890	113334	342510	679316	336806	0.98
S_8	9.51	570429	188890	113334	342664	683764	341100	1.00
S_9	9.64	578659	196298	117779	343235	696437	353202	1.03
S_{10}	9.89	593216	203705	122223	342759	715439	372680	1.09
S_{11}	9.74	584110	200002	120001	343329	704111	360782	1.05
SEm	**0.19**	**11697.20**	**2689.41**	**1613.65**		**12514.38**	**12514.38**	**0.04**
CD 5%	**0.57**	**34303.64**	**7887.07**	**4732.24**		**36700.13**	**36700.13**	**0.11**
CV	**3.59**	**3.59**	**2.45**	**2.45**		**3.19**	**6.44**	**6.43**

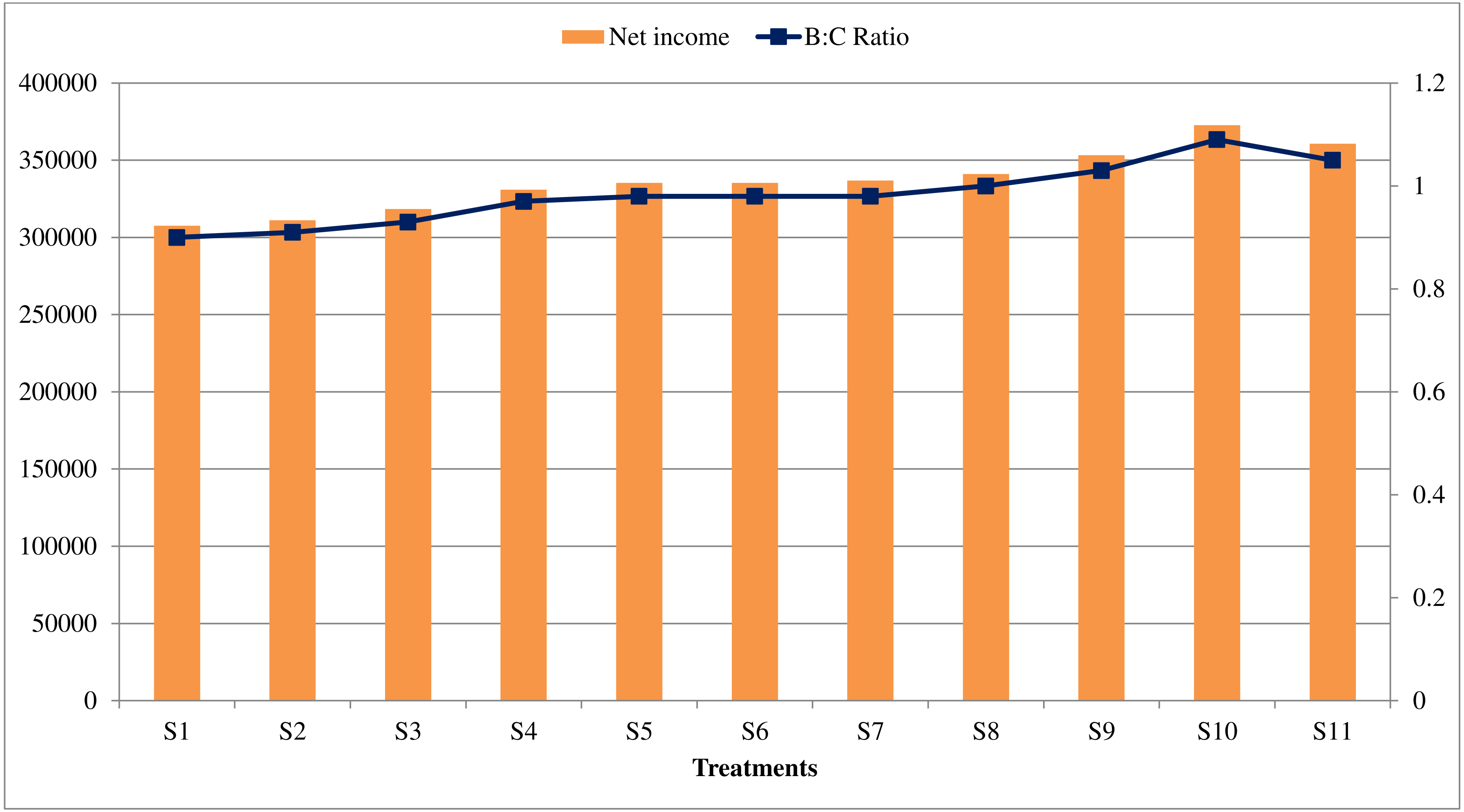
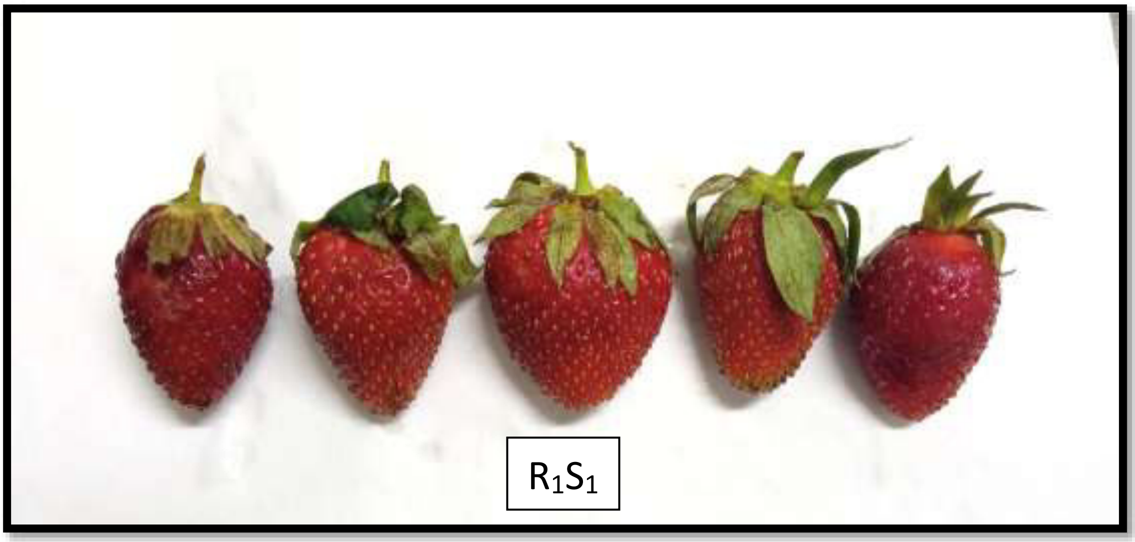


Fig. 4.11 Response of micronutrients on net return and BC ratio



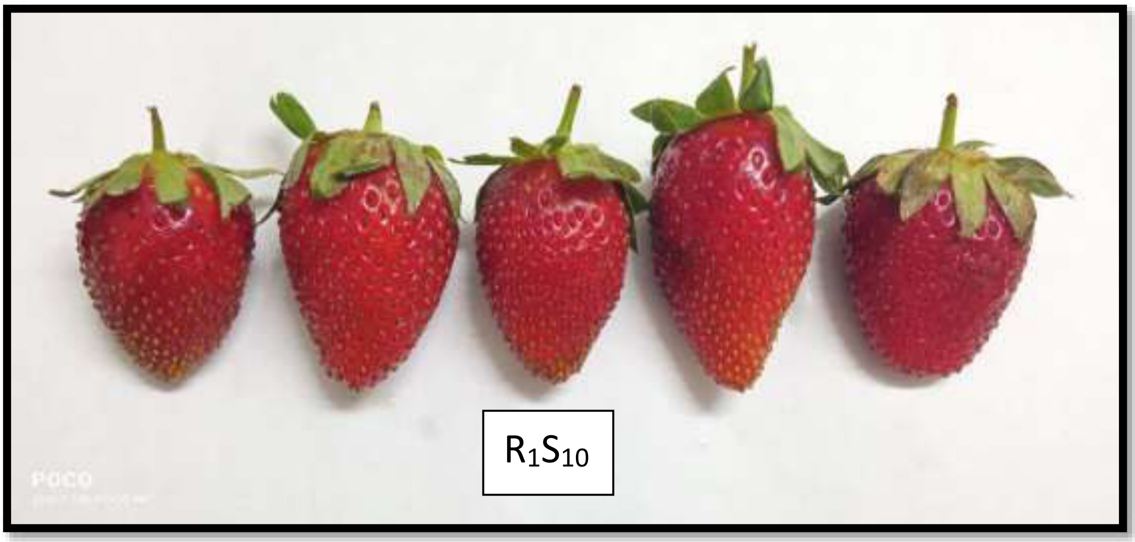


Plate 3. Difference between control and superior treatment

5. DISCUSSION

The result of present investigation entitled "Response of foliar spray of iron, zinc and boron in strawberry (*Fragaria* × *ananassa***Duch**.) cv. Winter Dawn" has been discussed with all relevant review literature and deliver significant insights in the objectives of the study with suitable hypothesis in the support of finding of the investigation. The discussion is concerned with respective growth, yield and quality.

5.1 VEGETATIVE PARAMETERS

It is evidential from above mean data confirmed in previous chapter that the different concentration of iron, zinc and boron treatments had significantly impact on vegetative growth parameters *viz*. petiole length, leaves per plant, plant spread and runner per plant show in Table 4.1 to 4.2 and depicted in Fig. 4.1 to 4.2.

It is clear that maximum petiole length (8.57 cm) was noted in treatment S_{10} i.e. RDF (100: 80: 80 NPK) + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) whereas S_1 i.e. RDF + Control (Water spray) recorded minimum petiole length (7.10 cm). This change might be due to that iron, zinc and boron help in cell division, elongation and growth of meristamatic tissue and also due to enhanced photosynthetes which forced plant to produce higher petiole length. Similar findings were observed by Saadati and Moallemi (2012), Bakshi*et al.* (2013), Gurjar*et al.* (2015) in sweet orange, Chandrakar*et al.* (2019) in strawberry, Pawar*et al.* (2019) in mandarin, Bhanukar*et al.* (2021).

Similarly highest leaves per plant (25.07), plant spread i.e. E-W (28.37 cm) and N-S (24.70 cm) and runner per plant (3.67) was recorded in the treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) whereas treatment S_1 i.e. RDF + Control (Water spray) recorded minimum leaves per plant (20.07), plant spread i.e. E-W (24.60 cm) and N-S (20.63 cm) and runner per plant (3.27). This change might be due to Zn is necessary for the production of tryptophan which is the precursor of indole acetic acid synthesis resulting in the growth and development of tissues which leads to vegetative growth of plant. It added cell membrane integrity, stabilizes sulflahydryl groups in membrane proteins involved in ion transport. The increase in vegetative growth has been reported by Haque*et al.* (2000) in mandarin orange, Ahmad *et al.* (2012) in tangerine, Gurjar*et al.* (2015) in kinnow, Chandrakar*et al.* (2018) in strawberry, Pawar*et al.* (2019) in mandarin.

5.2 YIELD PARAMETERS

It is evident from the average data presented in the preceding chapter that various characteristics had significant effects on yield parameter like days to first flower initiation, days to initiation of fruit set, days to first harvest, days to final harvest, number of picking, fruit length (mm), fruit width (mm), Length Diameter ratio, fresh weight of fruit (g), number of fruit per plant and fruit yield per plant (g) show in Table 4.2 to 4.5 and depicted in Fig. 4.3 to 4.8.

The foliar application of iron, zinc and boron exhibited significant effect on yield parameter of strawberry. Treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) recorded minimum days to first flower initiation (56.47 days) which was found to be better over the S_1– control as RDF + water spray (64.27 days). This change might be due to foliar spray of micronutrient mainly boron Fe promotes the formation of florigin (hypothetical hormone) from leaf to the leaf axils thus produces early flowering and fruiting. This findings are close conformity with the findings by the Yadlod and Kadam (2003) in banana and Mehraj*et al.* (2015) in strawberry crop, Similar results about days to fruit setting were also observed by Ashoori*et al.* (2013), Chandrakar*et al.* (2018) in strawberry, Pawar*et al.* (2019) in mandarin.

Similarly minimum days to initiation of fruit set (59.40 days) and days to first harvest (65.40 days) and maximum days to final harvest (115.07 days), number of picking (17.07) was recorded under the treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) whereas treatment S_1 i.e. RDF + Control (Water spray) recorded maximum days to initiation of fruit set (68.80 days) and days to first harvest (76.80 days) and minimum days to final harvest (107.07 days), number of picking (15.07).

It is clear that maximum fruit length (36.03 mm) and fruit width (27.17 mm) was noted in treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) whereas, S_1 i.e. RDF + Control (Water spray) recorded minimum fruit length (34.07 mm) and fruit width (25.53 mm). it might be due to the effect of zinc, as zinc plays a vital role in the promote of starch formation and other activity involve in the plant is transportation of carbohydrate and another function of zinc in plant is faster loading and mobilization of photo assimilates to the fruits and involvement in cell division, cell expansion, ultimately reflected into more length of the fruits in treated plants. Related results were also obtained by Bakshi*et al.* (2013) and Etehadnejad and Aboutalebi (2014), Mehraj*et al.* (2015) in strawberry, Chandrakar*et al.* (2019) in strawberry, Pawar*et al.* (2019) in mandarin.

The maximum fresh weight of fruit, fruit per plant and fruit yield per plant (10.97 g, 16.21 and 177.96 g respectively) was recorded under the treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) whereas S_1 i.e. RDF + Control (Water spray) recorded minimum fresh weight of fruit, fruit per plant and fruit yield per plant (10.88 g, 14.91 and 162.22 g respectively). It might be due to higher number of fruit might be due to the effect of zinc, as zinc plays a vital role in the promote of starch formation and other activity involve in the plant is transportation of carbohydrate and another function of zinc in plant is faster loading and mobilization of photo assimilates to the fruits and involvement in cell division, cell expansion similar findings were also obtained by Bakshi*et al.* (2013), Kazemi*et al.* (2014), and Mehraj*et al.* (2015) in strawberry, Thorat*et al.*(2018), Chandrakar*et al.* (2019) in strawberry, Pawar*et al.* (2019) in mandarin. The reason behind that increase in fresh weight of the fruits might be due to more growth of the fruit by accelerate rate of cell enlargement (increase in cell size) & cell division (increase in number of the cells) and larger intercellular space and another reason for that due to increase the photosynthetic activities & accumulation of more carbohydrate. The increase in number of fruit per plant could be attributed to increased fruit size, diameter and fruit weight. Furthermore, probably there was a larger diversion of photosynthates to sink (Fruit), which was ultimately added to the number of fruits. Related results were also obtained by, Cakici and Arslan (2012), Bakshi*et al.* (2013), Mehraj*et al.* (2015) in strawberry, Chandrakar*et al.* (2018) in strawberry.

5.3 QUALITY PARAMETERS

It is obvious from above mean data confirmed in previous chapter that the different concentration of iron, zinc and boron treatments had significantly impact on qualitative parameter *viz*. TSS, titratable acidity, TSS Acid ratio, juice percent and ascorbic acid content show in Table 4.6, 4.7 and depicted in Fig. 4.8 to 4.10.

The maximum TSS (11.99) was recorded under the treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) whereas, S_1 i.e. RDF + Control (Water spray) recorded minimum TSS (11.10). The increase in TSS might be due to hydrolysis of the polysaccharides, conversion the organic acids to the soluble sugars and improved solubilization of insoluble starch and pectin are present in cell wall as well as middle lamella. In conformity of its similar observations were reported by Chaturvedi*et al.* (2005) in strawberry, Kumar *et al.* (2010), Bakshi*et al.* (2013), Thorat*et al.*(2018) in sweet orange, Chandrakar*et al.* (2018) and Chandrakar*et al.* (2019) in strawberry, Pawar*et al.* (2019) in mandarin.

It is clear from the mean data showed that treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) were recorded minimum titratable acidity of the fruit (0.87%) whereas, S_1 i.e. RDF + Control (Water spray) recorded maximum titratable acidity (1.0%). The decrease in acidity might be due to the metabolic changes with fast conversion of organic acids to the sugars and its derivatives and utilization as the respiratory substrate during growth and development of the fruits, which was stimulated by zinc and iron foliar spray. These finding are collaborates with the findings of Chaturvedi*et al.* (2005) in strawberry, Kumar *et al.* (2010), Pathak *et al.* (2011) in banana, Bakshi*et al.* (2013), Thorat*et al.*(2018) in sweet lemon.

The highest TSS Acid ratio (13.89) was recorded treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) whereas S_1 i.e. RDF + Control (Water spray) recorded lowest TSS Acid ratio (11.10). The increase in TSS Acid ratio might be due to the increase in TSS content and decrease in acidity of the fruit and this change have stimulated by $ZnSO_4$ and $FeSO_4$ foliar spray. These finding are collaborates with the findings of Kumar *et al.* (2010), Chandrakar*et al.* (2018 & 19), Bakshi*et al.* (2013), Chaturvedi*et al.* (2005) in strawberry, Pathak *et al.* (2011) in banana, Pawar*et al.* (2019) in mandarin.

The highest juice content (64.56 %) were recorded under the combined treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) whereas S_1 i.e. RDF + Control (Water spray) recorded lowest juice content (57.76%). The increase in juice per cent might be due to the metabolic changes with fast conversion of organic acids in to sugars and its derivatives and utilization as the respiratory substrate during growth and development of the fruits, which was stimulated by zinc and iron foliar spray. These finding are collaborates with the findings of Chaturvedi*et* *al.* (2005) in strawberry, Kumar *et al.* (2010), Singh *et al.* (2012), Chandrakar*et al.* (2018) and Chandrakar*et al.* (2019) in strawberry.

Highest ascorbic acid content (60.80 mg $100g^{-1}$ pulp) was recorded in combined treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) whereas S_1 i.e. RDF + Control (Water spray) recorded lowest ascorbic acid content (57.75 mg $100g^{-1}$ pulp). In conformity of its similar observations were well reported by Chaturvedi*et al.* (2005) in strawberry, Kumar *et al.* (2010), Pathak *et al.* (2011) in banana, Bakshi*et al.* (2013), Chandrakar*et al.* (2018) and Chandrakar*et al.* (2019) in strawberry,Pawar*et al.* (2019) in mandarin.

6. SUMMARY

Response of foliar application of iron, zinc and boron on the strawberry plant under southern Rajasthan are studied for to find out the effective dose of foliar application on plant growth, fruit yield and quality of strawberry at Horticulture Farm, MPUAT, Udaipur. Eleven treatment combinations comprising iron, zinc and boron in different concentration were tried in Randomized Block Design (RBD) with three replications at 60 × 30 cm spacing. The statistically analyzed results are summarized below.

The treatment in different concentration of iron, zinc and boron application significantly increase the petiole length, leaves per plant, plant spread and runner per plant showed that 8.57 cm, 25.07, E-W (28.37 cm), N-S (24.70 cm) and 3.67 respectively were recorded under the treatment S_{10} i.e. RDF (100:80: 80 NPK) + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) were better over the control.

The earliest days to flower initiation (56.47 days), days to initiation of fruit set (59.40 days) and days to first harvest (65.40 days) were recorded under the treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) while latest 64.27 days, 68.80 days and 76.80 days respectively were recorded in S_1 i.e. RDF + Control (water spray).

The significantly increase the days to final harvest (115.07 days), number of picking (17.07), fruit length (36.03 mm), fruit width (27.17 mm) and length diameter ratio (1.26) were recorded maximum under the treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) were better over the control.

The highest fresh weight of the fruit (10.97 g) was recorded in the treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) while, lowest (10.88 g) was recorded in S_1 i.e. RDF + Control (water spray).

Highest fruit per plant and fruit yield per plant i.e. 16.21 and 177.96 g respectively obtained from the treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%). However, lowest 14.91 and 162.22 g respectively were obtained in the treatment S_1 i.e. RDF + Control (water spray).

The higher increase in TSS (11.99°B), TSS Acid ratio (13.89), juice content (64.56%) and ascorbic acid (60.80) were recorded in the treatment S_{10} i.e. RDF +

Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) as compare to minimum TSS (11.10°B), TSS Acid ratio (11.10), juice content (57.76%) and ascorbic acid (57.75 mg 100^{-1}) in S_1 i.e. RDF + Control (water spray).

The minimum titratable acidity (0.87%) was clearly showed in S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) while, maximum (1.0%) was in treatment S_1 i.e. RDF + Control (water spray).

Net return which was maximum (₹ 372680 ha^{-1}) obtained from the treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%). However, minimum ((₹ 307633 ha^{-1}) obtained from the treatment S_1 i.e. RDF + Control (water spray).

The benefit cost ratio highest (1.09) was recorded under the treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) while, lowest (0.90) was recorded in S_1 i.e. RDF + Control (water spray).

7. CONCLUSION

On the basis of results which were obtained in the present investigation entitled “Response of foliar spray of iron, zinc and boron in strawberry (*Fragaria* × *ananassa*Duch.) cv. Winter Dawn” It can be concluded that among the various treatment S_{10} i.e. RDF (100: 80: 80 NPK) + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) was found the superior treatment in petiole length, leaves per plant, plant spread (E-W and N-S), runner per plant, days to first flower initiation, days to initiation of fruit set, days to first harvest, days to final harvest, number of picking, fruit length, fruit width, length diameter ratio, fresh weight of fruit, fruit per plant and fruit yield per plant.

The treatment S_{10} i.e. RDF (100: 80: 80 NPK) + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) were found increase in term of TSS, TSS Acid ratio, juice content and ascorbic acid content while, decrease in titratable acidity.

The treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) was also found economically viable resulting in highest gross return (₹ 715439 ha^{-1}), net return (₹ 372680 ha^{-1})and benefit cost ratio (1.09) than other treatments under the study.

It is mentioned that results of the present investigation are only indicative and based on one year of experimentation and suggested that to confirmation trial for one more year is needed to develop technology.

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Response of Foliar Spray of Iron, Zinc and Boron in Strawberry (*Fragaria* × *ananassa*Duch.) cv. Winter Dawn

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ABSTRACT

An experiment entitled "Response of foliar spray of iron, zinc and boron in strawberry (*Fragaria* × *ananassa***Duch.**) cv.Winter Dawn" was conducted at Horticulture Farm, MPUAT, Udaipur during the year 2020-21 to find out the suitable treatment for fruit growth, yield and quality of strawberry. The experiment was tried in Randomized Block Design (RBD) with eleven treatments replicated thrice times.

The treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) was found best in term of vegetative parameters like petiole length, plant spread (E-W & N-S), number of leaves per plant and runner per plant, fruit yield parameters like days to first flower initiation, days to initiation to fruit set, days to first harvest, days to final harvest, number of picking, fruit length, length diameter ratio, fruit per plant and fruit yield per plant, quality parameter characters like TSS, TSS: Acid ratio, juice per cent and ascorbic acid were significantly increased while, decrease in acidity.

The treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) was also found economically viable resulting in highest gross return of ₹ 715439 Lakh ha^{-1}, net return ₹ 372680 Lakh ha^{-1} as compare to other treatment studied..

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स्ट्रॉबेरी (फ्रैगरिया × अनासा डच.) सीवी. विंटर डॉन में लौह, जस्ता और बोरोन के पर्णीय छिडकाव की प्रतिक्रिया

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अनुक्षेपण

एक प्रयोग शीर्षक "स्ट्रॉबेरी में आयरन, जिंक और बोरॉन के पर्ण स्प्रे का प्रभाव (फ्रैगरिया × अनासा डच।) सीवी. विंटर डॉन" वर्ष 2020-21 के दौरान बागवानी **क्षेत्र**, एमपीयूएटी, उदयपुर में 'विंटर डॉन' **किस्म परीक्षण** किया गया ताकि स्ट्रॉबेरी के फलों की वृद्धि, उपज और गुणवत्ता के लिए उपयुक्त उपचार का पता लगाया जा सके। प्रयोग को यादृच्छिक ब्लॉक डिजाइन (आरबीडी) में आजमाया गया था, जिसमें ग्यारह उपचार तीन बार दोहराए गए थे।

उपचार S_{10} यानी RDF + बोरेक्स (0.2%) + **ज़िंक सल्फेट** (0.2%) + **आयरन सल्फेट**(0.2%) वनस्पति मापदंड जैसे पेटियोल लंबाई, पत्तियों की संख्या, पौधे का फैलाव, प्रति पौधे रनर की संख्या के मामले में सबसे अच्छा पाया गया। प्रति पौधे, फल उपज मापदंड जैसे पहले फूल की शुरुआत के दिन, फल लगने के शुरुआत के दिन, पहली कटाई के दिन, अंतिम कटाई के दिन, तुडायी की संख्या, फल की लंबाई, फल का व्यास, लंबाई व्यास अनुपात, फल का ताजा वजन, प्रति पौधे फल और प्रति पौधा फल उपज, गुणवत्ता पैरामीटर जैसे टीएसएस, टीएसएस: एसिड अनुपात, रस का प्रतिशत और एस्कॉर्बिक एसिड, में काफी वृद्धि हुई, जबकि अम्लता में कमी आई।

उपचार S_{10} अर्थात RDF + बोरेक्स (0.2%) + **ज़िंक सल्फेट** (0.2%) + **आयरन सल्फेट** (0.2%) भी आर्थिक रूप से लाभदायक पाया गया जिसके परिणामस्वरूप ₹ 7.15 लाख प्रति हेक्टेयर उच्चतम सकल लाभ प्राप्त हुआ, शुद्ध लाभ ₹ 3.72 लाख प्रति हेक्टेयर का मिला। अध्ययन किए गए अन्य उपचारों की तुलना में!

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