SILICON, BORON AND ZINC NUTRITION OF BITTER GOURD
(*Momordica charantia* L.) var. PREETHI

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(2013 - 11 - 187)

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PADANNAKKAD, KASARAGOD – 671314

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by

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THESIS

Submitted in partial fulfillment of the requirement for the degree of

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2015

DECLARATION

I, hereby declare that this thesis entitled **"SILICON, BORON AND ZINC NUTRITION OF BITTER GOURD (*Momordica Charantia* L.) var. PREETHI"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society

Place Padannakkad

Date 27/11/2015

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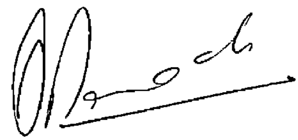
CERTIFICATE

Certified that this thesis entitled **"SILICON, BORON AND ZINC NUTRITION OF BITTER GOURD (*Momordica Charantia* L.) var. PREETHI"** is a record of research work done independently by Mr Mohammed Shahid Salam, C H (2013-11- 187) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him



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Mohammed Shahid Salam. C H

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LIST OF ABBREVIATIONS

%	-	per cent
@	-	at the rate of
B	-	Boron
Ca	-	Calcium
CD	-	Critical difference
cm	-	centimetre
ds/m	-	desi Siemens per meter
EC	-	Electrical conductivity
et al	-	and co-workers
g	-	gram
g plant^{1}	-	gram per plant
ha^{1}	-	per hectare
K	-	Potassium
KAU	-	Kerala Agricultural University
l	-	litre
m	-	metre

Mg	-	Magnesium
N	-	Nitrogen
NS	-	Not significant
pH	-	power of hydrogen
plant $^{-1}$	-	per plant
P	-	Phosphorus
ppm	-	Parts per million
POP	-	Package of practices
S	-	Sulphur
Si	-	Silicon
SE	-	standard error
t ha $^{-1}$	-	tonnes per hectare
viz	-	namely
Zn	-	Zinc

Introduction

1. INTRODUCTION

The vegetable crop *Momordica charantia* L , family Cucurbitaceae, is known variously as bitter gourd, balsam pear, bitter melon, bitter cucumber, and African cucumber (Heiser, 1979) It is an important vegetable in South Indian states, particularly in Kerala and is grown for its immature tuberculate fruits which have a unique bitter taste The fruits rank first among the cucurbits in respect of iron and ascorbic acid (vit C) content Bitter gourd fruits have medicinal value and are used for curing diabetes, asthma, blood diseases and rheumatism Drinking fresh bitter gourd juice is recommended by naturopaths Roots and stem of wild bitter gourd are used in many ayurvedic medicines (Vala and Savaliya, 2014) Although it has many culinary uses, especially in south, southeast and east Asia, it is also grown as an ornamental and is used extensively in folk medicine (Heiser, 1979)

The center of origin of bitter gourd domestication likely lies in eastern Asia, possibly eastern India or southern China (Walters and Decker-Walters, 1988, Miniraj *at al* , 1993) Bitter gourd has been used for centuries in the ancient traditional medicine of India, China, Africa, and Latin America Bitter gourd cultivation is mentioned in Ayurvedic texts written in Indian Sanskrit from 2000 to 200 BC by members of the Indo-Aryan culture (Decker-Walters 1999), indicating an early cultivation of bitter gourd in India The lack of a unique set of Indo-Aryan words indicates that the Aryans did not know bitter melon before entering India (Walters and Decker-Walters, 1988)

The bitterness of bitter gourd is due to the cucurbitacin-like alkaloid momordicine and triterpene glycosides (Jeffrey, 1980, Okabe *et al* , 1982) These compounds lack the oxygen function that characterizes "true" cucurbitacins (Neuwinger, 1994) Bitter gourd extracts possess antioxidant, antimicrobial, antiviral, antihepatotoxic and antiulcerogenic properties while also having the ability to lower blood sugar (Welthinda *et al* , 1986, Raman and Lau, 1996)

In Kerala, soil condition is generally acidic and oxisols in particular have low level of plant nutrients, low cation exchange capacity, deficient in Ca, Mg, B and many times having toxic concentration of Fe, Mn and Al Red soil cover 26 8% of the total area of the country It covers an area of 87,989000 ha The red colour is due to the presence of Fe_2O_3 Mostly localised in southern parts of Thiruvananthapuram The soil is almost homogeneous Acidity ranges from 4 8 to 5 9 The gravel content is comparatively less Low in essential nutrients and organic matter In such condition, application of micronutrient is very much important

Silicon is assimilated by plant roots as monosilicic acid (H_4SiO_4) where it accumulates in leaves and other plant tissue primarily as amorphous silicates or phytolithic opal (Epstein, 1994) Once deposited in this form, Si is immobile and is not redistributed within the plant (Ma *et al* , 1989; Epstem, 1994) Hydrated, amorphous silica is deposited in cell lumens, cell walls, and intercellular spaces It also accumulates in external layers below and above the cuticle of leaves Silicon is present in roots, leaves, and in the inflorescence bracts of cereals, especially in rice, wheat, oats and barley (Epstein, 1999)

Boron is an important micronutrient required for plants in obtaining quality high yields It has a primary role in cell wall biosynthesis, fruit and seed setting, regulation of the carbohydrate metabolism, sugar transport, lignification, nucleotide synthesis, respiration, pollen viability and synthesis of amino acids and proteins However, it has been observed that in most plant species the boron requirement for reproductive growth is much higher than for vegetative growth (Matoh *et al* , 1996)

Zinc is one of the trace elements found essential for the normal healthy growth of higher plants, animals and human beings and is found in varying concentrations in all the soils This nutrient is required in small concentration, but if availablity is not adequate, plants as well as animals will suffer from physiological stress, brought about by the malfunctioning of several enzyme systems and other metabolic functions Among the different micronutrients (zinc, copper, boron, manganese, iron, chlorine, molybdenum, and nickel), zmc deficiency is the most common and widespread (Holmgren *et al* , 1993)

Foliar application of Zn improved total chlorophyll content, chlorophyll *a*, soluble protein, ascorbic acid, harvest index and yield Zn resulted in significant increase in chlorophyll *a* and stability of this pigment (Nandini, K and Potty, N N, 2000) Zmc deficiency is a critical nutritional and health problem world wide It affects, on an average, one-third of the world's population, ranging from 4 to 73 % in different countries (Hotz and Brown, 2004) The average Zn content of the lithosphere is about 80 mg/kg and the common range for the soil is 100-300 mg/kg (Alloway, 2008) The total zinc content of a soil is largely dependent upon the geochemical composition of the parent materials, manures, fertilizers, industrial waste, agrochemicals, sewage and sludges The biological requirement for zinc was first identified by Raulin in 1869 when the common bread mould *(Aspergillus niger)* was found unable to grow in the absence of zinc

Cucurbits need silicon as a beneficial element and in bittergourd silicon help in production of fruits with good colour and sturdy spines which will not break away on packing and transport (Laane and Witterland, 2010). So the present study on silicon, boron and zinc nutrition of bitter gourd was undertaken to study the effect on yield and quality of this crop grown in red soil The study was conducted with the following objectives

1 To standardizing the dose and method of application of Si, B and Zn fertilizers to bitter gourd crop

2 To evaluate the effect of Zn, B and Si on available nutrient status of soil and yield of bitter gourd under pot culture experiment and field experiment conditions

Review of literature

2. REVIEW OF LITERATURE

Bitter gourd (*Momordica charantia* L.) is an important cucurbitaceous vegetable grown all over India. The fruits rank first among the cucurbits in respect of iron and ascorbic acid (vit. C). It also contains proteins, fats, minerals, carotein, thiamine and riboflavins. Although many varieties and hybrids with higher yield potentials had been developed, the potential could be harnessed only under favourable edaphic conditions. The ever increasing demand for vegetables and shrinking land and other agricultural resources necessitates cultivation of crops even under marginal soils.

Bitter melon grows in tropical areas, including parts of the Amazon, east Africa, Asia, and the Caribbean, and is cultivated throughout South America as a food and medicine. The Latin name *Momordica* means "to bite" (referring to the jagged edges of the leaf, which appear as if they have been bitten). All parts of the plant, including the fruit, taste very bitter. In herbal medicine, bitter melon is used for tumors, wounds, rheumatism, malaria, leucorrhea, inflammation, menstrual problems, diabetes, colic, fevers, worms, and as an aphrodisiac (Taylor, 2002).

2.1. SILICON

The word silicon is derived from the Latin word *silex*, meaning flint. Silicon (Si) is the second most abundant element in the earth's crust after oxygen, with the chemistry second only in complexity to that of carbon (Bond and McAuliffe, 2003). It's very complex chemistry is of great geochemical significance (Basile *et al.*, 2005). Although silicon (Si) is one of the most abundant elements found in the earth's crust, it is mostly inert and only slightly soluble and available to plants (J.H. Meyer and M.G. Keeping).

As for other nutrients, both macro and micro (N, P, K, B, etc.) silicon has been shown to have a moderating effect, reducing uptake under high soil levels, or decreasing uptake under low/deficient levels. Of interest is the tendency to measure plant silicon uptake by focusin only on shoot concentration. Some plants however, can accumulate higher levels of silicon in roots than shoots. And in shoots, silicon content can vary by organ and age with silicon concentration increasing with age and often around floral bracts. However, once deposited silicon becomes immobile so that a steady supply of soluble (plant available) silicon is needed (Mary Provance-Bowley,) When comparing calcium silicate to calcium carbonate soil amendment applications to field grown pumpkin, both were equally effective in neutralizing soil acidity However, calcium silicate increased pumpkin yields regardless of fungicide treatment for powdery mildew control in the year of application A residual effect of calcium silicate was seen in year two when a synergistic effect with the fungicide resulted in disease reductions (Heckman 2002)

Silicon is the only element known that does not damage plants upon excess accumulation (Prakash, 2002) Silicon is often a major constituent of plant tissues, although it is not considered as an essential nutrient for terrestrial plants However, horsetails (class Equisetaceae) have been conclusively shown to require silicon as an essential nutrient No other, non-essential element apart from silicon is present in such consistently high amounts in the terrestrial plants Silicon concentration in the plant tissues sometimes exceeds the concentrations of nitrogen and potassium (Epstein, 1994)

2.1.1. Sources of silicon

Silicon sources are available as natural resources as industry by-products the supplementation of Si by plant residues enhances plant growth and yield, but the plant demands are often higher Therefore, most commercial applications are from industry by-products with high Si concentrations The most common commercially used Si sources are calcium silicate slag ($CaSiO_3$), wollastonite (calcium meta-silicate, $CaSiO_3$), sodium silicate ($NaSiO_3$), magnesium silicate ($MgSiO_3$), potassium silicate ($KSiO_3$) and silica gel (soluble SiO_2) (Ma and Takahashi, 2002)

2.1.2. Silicon in plant nutrition

2.1.2.1. Role of silicon in plants

Si is accumulated primarily in the *epidermal* tissues of both roots and leaves in the form of a silica gel This thickened epidermis increases the mechanical stability of plants, increasing the light-receiving posture of the plant and hence growth The deposition of Si in the plant tissues also reduces transpiration, thereby diminishing the impact of drought and salinity stress Si deposition in tissues has been proven to provide a mechanical barrier against various pests and diseases Addition of Si will alleviating Mn toxicity in Cucurbitaceae plants (Iwasaki and Matsumura, 1999) The role of silicon in plants are enhancement of growth and yield, resistance against lodging, enhances photosynthesis, effect on surface properties, resistance against disease causing organisms, resistance to herbivores, resistance to metal toxicity, resistance to salinity stress, reduction of drought stress and protection against temperature extremes (Epstein, 2001)

2.1.2.2. Silicon transport

Different transporters mediate silicon transport from soil to above ground plant organs It is responsible for soil uptake into root cells in both dicots and monocots differing in expression patterns and cellular localization by plant species A homolog of the rice (*Oryza sativa* L) transporter, Lsi1, is CmLsi in pumpkin (*Cucurbita pepo* L), which is localized in all root cells Lsi2 an active efflux transporter mediates transport from root cells toward the stele Polar localization is at the distal (Lsi1) and proximal (Lsi2) sides of both the exodermis and endodermis, in rice xylem sap silicon, in the form of monosilicic acid and it is unloaded by Lsi6, a homolog of Lsi1 Lsi6 also affects inter-vascular transfer at the node, which determines distribution of silicon within the panicles Lsi6 differs from Lsi1 and Lsi2 as it is expressed in leaf sheaths and blades in addition to root tips In leaf sheaths and blades Lsi6 is localized in the adaxial side of the xylem parenchyma cells Knockout of Lsi6 does not affect root uptake, but does affect the deposition pattern in leaf blades and sheaths Within leaf blades, two types of silicified cells are found, silica cells, and silica bodies otherwise known as silicified motor cells Loss of function following knockout of Lsi6 results in an altered silicon pathway Lsi6 is required in silicon delivery to specific cells, and this cell-type specificity is dependent on symplastic pathway delivery by Lsi6 (Ma et al , 2011)

2.1.2.3. Importance of silicon in bitter gourd

Bitter gourd (*Momordica charantia*) seeds subjected to salt stress (NaCl) had reductions in germination rate, germination index and vitality index However, exogenous silicon applications increased germination rate, germination index and vitality index, while decreasing malondialdehyde content and increasing antioxidant enzyme (superoxide dismutase, peroxidase, and catalase) activities under NaCl stress (Wang et al , 2010)

Cucumber (*Cucumis sativus* L) yields were increased 46% with foliar silicon treatments (10 kg/ha) at the 3rd leaf stage and subsequent bi-weekly applications during the season Soil silicon applications (40 kg/ha) also increased yields Additional benefits of silicon included stimulation of fruit formation and accelerated fruit maturation (Matichenkov and Bocharnikova, 2008)

Silicon supplements to cucumber (*Cucumis sativus*) nutrient solution increased root apoplastic Fe pools and enhanced Fe acquisition by regulation of gene expression levels of proteins, resulting in increases in Fe mobilizing compounds under Fe deficiency (Pavlovic et al, 2013) Cucumber (*Cucumis sativus* L) yields were increased 46% with foliar silicon treatments (10kg/ha) at the 3rd leaf stage and subsequent bi-weekly applications during the season Soil silicon applications (40 kg/ha) also increased yields Additional benefits of silicon included stimulation of fruit formation and accelerated fruit maturation (Matichenkov and Bocharnikova, 2008)

2.1.3. Forms of silicon and silicon availability in soils

In soil solution, Si occurs mainly as monosilicic acid (H_4SiO_4) and is taken up by plants in this form (Ma and Takahashi, 2002)

When comparing calcium silicate to calcium carbonate soil amendment applications to field grown bittergourd, both were equally effective in neutralizing soil acidity However, calcium silicate increased bittergourd yields regardless of fungicide treatment for powdery mildew control in the year of application A residual effect of calcium silicate was seen in year two when a synergistic effect with the fungicide resulted in disease reductions (Heckman 2002)

The average available Si status of eight different soil types of Kerala as adjudged by four different extractants revealed that Silica extracted by 0 025 M citric acid ranged between 250 to 1500 kg ha-1 with an average of 700 kg ha-1 (Nair and Aiyer, 1968)

Silicic acid is also dissolved in soil solution with some part of the silicic acid adsorbed to soil minerals, particularly oxides and hydroxides of iron and aluminium (Dietzel, 2000) Dissolved silicic acid in soil solutions primarily occurs as monomeric or oligomeric silicic acid (Iler, 1979)

2.1.4. Effect of silicon on nutrient availability

2.1.4.1. Nitrogen

Application of silicate fertilizers raised the available nitrogen content in soil (Ma and Takahashi, 2002)

2.1.4.2. Phosphorous

Increasing silicon levels increased phosphorus availability due to decreased retention capacity of soil and increased solubility of phosphorus leading to increased efficiency of phosphotic fertilizer (Subramanian and Gopalswamy, 1990)

2.1.4.3. Potassium

Several studies found that Si increases potassium availability m soil, this may be due to the production of hydrogen ions during reduction of Fe and Al toxicity which would have helped the release of K from the exchange site or from the fixed pool This may leads to greater availability of K to rice in flooded soils (Patrick and Mikkelsen, 1971, Marschner, 1995)

2.1.4.4. Calcium and magnesium

The application of Si along with other nutrients in the culture solution has decreased the potassium uptake of rice plants This is due to more absorption of Ca and Mg ions promoted by Si application (Islam and Saha, 1969).

2.1.4.5. Iron

Silicon supplements to cucumber (*Cucumis sativus*) nutrient solution increased root apoplastic Fe pools and enhanced Fe acquisition by regulation of gene expression levels of proteins, resulting in increases in Fe mobilizing compounds under Fe deficiency (Pavlovic *et al*, 2013)

2.1.4.6 Manganese

Bloom-type (*Curcurbita moschata* Duch cv Shintosa) pumpkin grafting stock was suppressed in growth when supplied with toxic levels of Mn in the absence of silicon to the nutrient solution Additions of silicon alleviated these symptoms and these effects were more profound as silicon concentrations increased This alleviation of growth depression was not due to reduced plant Mn concentrations Without silicon, Mn deposits were located surrounding necrotic leaf lesions and at the base of trichomes With silicon, Mn was located at the base of trichomes only in conjunction with silicon deposits Localized accumulation of metabolically inactive forms of Mn with Si at the base of leaf trichomes is a suggested mechanism of alleviating Mn toxicity with silicon supplements (Iwasaki and Matsumura, 1999)

Symptoms of Mn toxicity were not apparent in leaves of cucumber (*Cucumis sativus* L) supplied with excess Mn (100 μM) when supplied with silicon although leaf Mn concentrations were extremely high Leaf apoplast free Mn^{+2} and hydrogen peroxide of Si treated plants under high levels of Mn was decreased Silicon contributed indirectly to reductions in hydroxyl radical in leaf apoplasts by reducing free apoplastic Mn and regulating the Fenton reaction Direct inhibitory effects of silicon on guaiacol-peroxidase activity may also be contributing to reductions in peroxidase-mediated hydroxyl radical production (Maksimovic *et al* , 2012)

2.1.4.7. Zinc

Silicon has been shown to alleviate the detrimental nutrient imbalance of zinc and phosphorus (Epstain, 1994, Marschner, 1995)

2.1.5. Effect of silicon on tissue strength

Agarie *et al* (1998) report that "silicon prevents the structural and functional deterioration of cell membranes when plants are exposed to environmental stress," and that silicon may also be "involved in the thermal stability in cell membranes " Kaya *et al* (2006) showed that 2 mM Na_2SiO_3 decreased electrolyte leakage by 18 3% in water-stressed corn (50% of FC) According to Gunes *et al* (2008a), silicon applied to the soil prevented membrane damage in shoots via a reduction in H_2O_2. Calcium and magnesium silicates decreased potato stem lodging (weak lower stems) in drought conditions (Pulz *et al* 2008) According to Shen *et al* (2010), silicon reduced osmolyte leakage and lipid peroxidation

2.1.6. Effect of silicon on controlling diseases

Si nutrition have the potential as an environmental friendly method for the control of numerous diseases A reduction in disease incidence in rice caused by *Magnaporthe grisea* by Si application was first reported from Japanese researchers (Ishiguro, 2001) and subsequently confirmed by other countries Si nutrition also proved to be an effective means for the control of *Leptosphaeria sacchari* in sugarcane (Raid *et al*, 1992)

Among the dicotyledons most results related to Si and disease resistance were reported from cucumber where Si amendment to the nutrition solution increased resistance against *Sphaerotheca fuliginea* (Adatia and Besford, 1986) and root rot caused by *Pythium ultimum* (Cherif and Belanger, 1992) and *Pythium aphanidermatum* (Cherif *et al*, 1994) In field experiments with cucumber, Miyake and Takahashi (1983) found a reduction of Fusarium wilt by Si treatment

2 2 BORON

Boron is the most electronegative element in the Group III of the periodic table, with properties intermediate between metals and electronegative non-metals The requirement of boron for plant growth was first established in the beginning of the 20th century, and now a days it is widely known that boron is an essential element for all vascular plants whose deficiency or toxicity causes impairments in several metabolic and physiological processes (Nable *et al*, 1997) To date, one of the primary functions of boron in vascular plants has been related with the cell wall structure and function There is direct evidence for a role of boron in cross linking of cell wall rhamnogalacturonan II (RGII) and pectin assembly showing that boron is essential for cell wall structure and function (Neill *et al*, 2004)

2.2.1. Boron in plant nutrition

Boron deficiency and toxicity cause major disorder that can limit plant growth on soils with high rainfall, and of arid and semiarid environments, respectively (Nable *et al*, 1997) Hence, awareness should be taken to understand the mechanisms that take part in boron transport and distribution in plants in order to improve agricultural production In soil solution boron is found mainly as the soluble uncharged boric acid [$(B(OH)_3$] It has long been believed that this nutrient is passively absorbed by root cell through simple diffusion mechanism, which can meet the plant requirement of this element under condition of adequate or excessive boron availability This affirmation was supported by experimental data from lipid permeability coefficients calculated in both the membrane vesicles isolated from *Cucurbita pepo* (Das *et al*, 2000)

Physiological studies have also suggested the occurrence of an active boron transport in roots This hypothesis is supported by experimental data showing that both metabolic inhibitors and cold treatments inhibit boron absorption by roots As root cells absorb boron, micronutrient must be exported from endodermal, pericycle or xylem parenchyma cells into the stelar apoplasm (xylem loading) When plants grow in media with enough boron availability, xylem loading of boron is performed both by boron diffusion across lipid bilayer and facilitated permeation via protein channel (Dannel *et al*, 2000) Depending on boron availability, boron transport can be performed by (1) passive transport across plasmalemma mediated by simple diffusion This system operates mainly when adequate or excessive boron is available in the soil (2) energy dependent high affinity transport that is induced in response to low boron supply, and it is mediated via BOR transporters and (3) facilitated transport carried out by NIP channel proteins (Tanaka and Fujiwara, 2008)

Boron is an essential micronutrient for plant growth Its deficiency symptoms appear when plant faces reduced supplies of boron Its severe deficiency causes abnormal development of reproductive organs (Huang *et al*, 2000) and ultimately results in reduction of plant yield (Nabi *et al*, 2006) Once boron is into xylem, it is transported towards shoot in a process mediated by transpiration stream (Shelp *et al*, 1995) In addition, boron can also be transported via phloem to both reproductive and vegetative tissues (Matoh and Ochiai, 2005) The role of boron in promoting pollen tube growth is well established but the mechanism of its action is still unknow (Sutcliffe and Baker, 1981) Thus a significant positive correlation could be found between boron in the plant and number of flowers, the proportion of flowers not aborted and the weight of fruit (Oyewole and Aduayi, 1992)

Fruits, vegetables, and hazelnuts are known to be primary sources of boron (Hunt *et al*, 1991) Mishra and Shukla (1986) reported considerable increase in plant height, metabolic rate, content of photosynthetic pigment and all dry weight fractions measured after the application of B containing amendment to maize The activity of nitrogenase is sensitive to B deficiency Under B deficient conditions, nodule weight and N_2 fixation capacity of legumes ıs usually decreased, for example ın pea (*Pısum satıvum* L) and soybean plants (Bolanos *et al* , 1994)

2.2.2. Boron availabılıty ın soil

The abundance of boron ın the unıverse ıs extremely low, about 10^9-fold less than hydrogen and about 10^6-fold less than carbon, nıtrogen, or oxygen (Kot 2009) In spıte of thıs scarcıty, boron ıs broadly dıstrıbuted ın both lıthosphere and hydrosphere, boron concentratıon rangıng from 5 to 10 mg kg^{-1} ın rocks (Shorrocks, 1997), 3-30 µg kg^{-1} ın rıvers (Power and Woods 1997) and about 4-5 mg L^{-1} ın oceans (Lemarchand *et al* , 2000)

Boron ıs never found ın ıts elemental form ın nature, but ıs found ın rocks and concentrated ın deposıts as borates, ı e, bound to oxygen together wıth sodıum, calcıum, sılıcon, or magnesıum (Argust, 1998) Most soıls have less than 10 mg boron kg^{-1} and, hence, are consıdered to be poor ın boron (Woods 1994) Alumınıum and ıon oxıdes, magnesıum hydroxıde, calcıum carbonate, organıc matter, or clays can act as soıl adsorbıng surfaces for boron (Gold berg, 1997)

Boron deficıency can occur ın hıghly weathered red acıd soıls, sandy rıce soıls, and soıls derıved from ıgneous rocks Rıce plants were unable to produce panıcles ıf affected by B deficıency at the panıcle formatıon stage (Doberman and Faırhurst, 2000) Durıng rock weatherıng, boron goes easıly ınto soıl solutıon maınly as borıc acıd (Nable *et al* , 1997) and ıs readıly avaılable for plant uptake, but thıs pool constıtutes about 10 % of total soıl boron (Power and Woods 1997)

Boron deficıency can occur ın hıghly weathered red acıd soıls, sandy rıce soıls, and soıls derıved from ıgneous rocks Boron avaılabılıty can be affected by several soıl factors such as pH, texture, temperature, and organıc matter, among others soıl pH beıng one of the most ımportant parameters (Goldberg, 1997) In fact, borıc acıd ıs a very weak acıd and when the pH ıs below 7 appears ın ıts undıssocıated form, at alkalıne pH, borıc acıd dıssocıates to form the borate anıon (Doberman and Faırhurst, 2000) Therefore, ın neutral or slıghtly acıd soıls boron occurs maınly as undıssocıated borıc acıd, and ın thıs form ıs absorbed by plant roots (Hu and Brown 1997)

In soıls, B ıs consıdered to be the most mobıle and often deficıent element compared to other trace elements The avaılabılıty of soıl B depends on soıl texture, pH, lımıng, organıc matter content, soil moisture and relationship with certain cations and anions in soils (Tisdale *et al*, 1985)

2.2.3. Effect of boron on nutrient availability

Bitter gourd has a high nutrient requirement particularly macro and micronutrient such as nitrogen, phosphorus, potash, zinc, iron, boron and molybdenum Bitter gourd fruit yield has been set aside by the deficiency of micronutrients, which leads to certain physiological disorders

2.2.3.1. Macronutients

Barman *et al* (2014) observed that application of boron (20 mg/kg) and lime (1/3 LR) significantly increased N, P, K, Ca, Mg, S and Zn content in soil while the availability of Cu, Fe and Mn in soil was reduced due to application of boron and lime

2.2.3.2. Micronutrients

The boron chemistry in soil and its role in plant is differs from other micronutrients, such as Zn, Cu, Fe, Mn and Mo, but its deficiency or excess may affect the solubility of these micronutrients in soil (Santra *et al*, 1989)

Zinc was equally distributed or not translocated from roots to tops, and this may be due to boron effects on zin cmobility in plants The Cu concentration in plants tops tended to increase while roots decreases with increase in boron level Iron concentration in top increases up to 2 mg B L^{1} then decreases (Shelp *et al*, 1987)

2.2.4. Effect of boron on yield, fruit set and fruit quality of the crop

Boron is important in pollen germination and pollen tube growth, which is likely to increase fruit set Therefore, boron fertilization may increase yield, particularly when plants are grown on sandy soil with a low content of available boron, as shown by (Wojcik *et al*, 2008) The author also reported an increase in total soluble solids as well as total acidity due to soil boron application This can be attributed to transportation of higher amount of assimilates into fruit tissues

The reciprocal crosses between pollinizer and pistil donor trees that received varying rates of boron showed higher initial fruit set percentages in comparison to crosses from non-treated trees, with the exception of crosses that involved combinations of non treated trees and trees receiving highest rate of boron Irrespective of the boron treatment in pistil donor trees, pollen from pollinizer trees treated with the control or highest rate of boron (0 or 2 5 kg ha^{-1}) had the lowest initial fruit set Highest fruit set occurred in the treatment combination in which the pollinizer trees received boron at 0 8 kg $ha^{-1}$and the pistil donor trees received boron at 0 8–1 7 kg ha^{-1} Likewise, boron at 0 8–1 7 kg ha^{-1} in both tree types gave the highest final set of 60–70%, whereas pollen from non-treated trees and from trees which had received the highest rate of boron resulted in the lowest final fruit set (40%) (Nyomora *et al* , 2000)

Verma *et al* (1984) reported that application of boron at 3 or 4 ppm gave the highest number of female flower per plant (28-32) and fruits per plant (23-26 4) in bitter gourd cv Pusa Application of boron 2, 4 and 6 ppm in bitter gourd increased fruit and seed yield and fruit maturity was earliest in the application of boron 4 ppm Fruit yield was also highest in this treatment But very little information regarding effect of zinc, iron and boron on growth, yield and quality of bitter gourd are available (Mousmi and Gedam *et al* , 1998)

2 3 ZINC

Zinc is an essential micronutrient and has particular physiological functions in all living systems, such as the maintenance of structural and functional integrity of biological membranes and facilitation of protein synthesis and gene expression Among all metals, Zn is needed by the largest number of proteins Zinc-binding proteins make up nearly 10 % of the proteomes in eukaryotic cells, and 36% of the eukaryotic Zn-proteins are involved in gene expression Zinc deficiency appears to be the most widespread and frequent micronutrient deficiency problem in crop and pasture plants worldwide, resulting in severe losses in yield and nutritional quality (Andreini *et al* , 2006)

Zinc deficiency in humans is a critical nutritional and health problem in the world It affects, on average, one-third of the world's population, ranging from 4 to 73 % in different countries (Hotz and Brown, 2004) Zinc is needed in small but critical concentrations and if the amount available is not adequate, plants and or animals will suffer from physiological stress brought about by the dysfunction of several enzyme systems and other metabolic functions in which zinc plays a part When the supply of zinc to the plant is inadequate, one or more of the many important physiological functions of zinc is unable to operate normally and plant growth is adversely affected

2.3.1. Zinc in plant nutrition

A biological requirement for zinc was first identified by Raulin in 1869 when the common bread mould *(Aspergillus niger)* was found not to be able to grow in the absence of zinc The changes in plant physiological mechanisms brought about by a deficiency of zinc can result in the plant developing visible symptoms of stress which might include one or more of the following stunting (reduced height), interveinal chlorosis (yellowing of the leaves between the veins), bronzing of chlorotic leaves, small and abnormally shaped leaves and/or stunting and rosetting of leaves (where the leaves form a whorl on shortened stems). These different types of symptoms vary with plant species and are usually only clearly displayed in severely deficient plants

The essentiality was not established until 1926 and it was only in 1932 that zinc deficiency was first identified under field conditions (in Californian apple orchards and South Australian citrus trees) In the time since 1932, zinc has been found to be a vitally important micronutrient in crop production and deficiencies of this element have been shown to be more widespread throughout the world than those of any other micronutrient Although more than 70 metalloenzymes containing zinc have been identified, these only account for a relatively small proportion of the total zinc in a plant (Brown *et al*, 1993) The metabolic functions of zinc are based on its strong tendency to form tetrahedral complexes with N-, O- and particularly S-ligands and it thereby plays both a functional (catalytic) and a structural role in enzyme reactions (Marschner, 1995)

In plants, zinc does not undergo valency changes and its predominant forms are low molecular weight complexes, storage metalloproteins, free ions and insoluble forms associated with the cell walls Zinc can become inactivated within cells by the formation of complexes with organic ligands or by complexation with phosphorus Depending on the plant species, between 58% and 91% of the zinc in a plant can be in a water-soluble form (low molecular weight complexes and free ions) This water-soluble fraction is widely considered to be the most physiologically active and is regarded as a better indicator of plant zinc status than total zinc contents The low molecular weight complexes are normally the most abundant soluble form of zinc and are probably the most active form of the metal (Brown *et al*, 1993)

Root exudates as an indicator of root plasma membrane integrity and found greater leakage of the 32P phosphorus isotope out of roots of zinc-deficient wheat than from zinc-sufficient roots (Welch *et al*, 1982) Potassium leakage was significantly higher from the roots of zinc-deficient cotton, wheat and tomato plants, but this leakage could be mitigated by supplying zinc for 12 hours (Cakmak and Marschner, 1998)

Flowering and seed production are severely depressed in zinc-deficient plants Zinc deficiency in maize severely retarded the development of tassles, anthers and pollen grains They stated that the decrease in pollen production by the anthers and in the pollen fertility of low-zinc plants indicated that zinc deficiency suppressed male sexuality in maize (Sharma *et al* 1990)

2.3.2. Zinc availability in soil

The range of zinc in soils of 10-300 mg/kg with a mean of 50 mg Zn per kg Low concentrations in sandy soils and higher zinc concentrations in soils with larger clay contents (Kickens, 1995). The range of zinc in India under oxisol condition is 24-30 mg kg ^{1}(Allowey, 2001)

The mean deposition of zinc onto agricultural land in England and Wales, based on 42 months of monitoring at 34 sites, was 221 g ha ^{1} yr ^{1} (Nicholson *et al*, 2003) Zinc in soils occurs in the following forms i) Free ions (Zn^{2+} and $ZnOH^{+}$) and organically complexed zinc in solution, ii) Adsorbed and exchangeable zinc held on surfaces of the colloidal fraction in the soil, comprising clay particles, humic compounds and iron and aluminium hydrated oxides,iii) Secondary minerals and insoluble complexes in the solid phase of the soil (Kiekens, 1995).

The concentration of soluble zinc in soils ranged from 4-270 µg/l which is very low compared with average total concentrations of around 50-80 mg/kg However, in very acid soils, soluble concentrations of 7137 µg/l have been found, indicating that solubility is strongly, but inversely linked to soil pH Zinc forms soluble complexes with chloride, phosphate,nitrate and sulphate ions (Kabata and Pendias, 1992)

The organic ligands reduced the amounts of zinc adsorbed onto an oxisol soil and that the effect was most pronounced with those ligands, including humic acids, that complexed zinc most strongly Soluble forms of organically complexed zinc can result in zinc becoming increasingly mobile and plant available in soils (Barrow, 1993) Kiekens in 1995 stated that there appeared to be two different mechanisms involved in the adsorption of zinc by clays and organic matter One mechanism operates mainly in acid conditions and is closely related to cation exchange, and the other mechanism operates in alkaline conditions and mainly involves chemisorption and complexation by organic ligands

2.3.3. Interaction zinc and other plant nutrients

2.3.3.1. Zinc – Nitrogen interaction

Nitrogen appears to affect the zinc status of crops by both promoting plant growth and by changing the pH of the root environment In many soils, nitrogen is the chief factor limiting growth and yield and therefore, not surprisingly, improvements in yield have been found through positive interactions by applying nitrogen and zinc fertilizers Nitrogen promoted growth can cause a dilution in copper concentration which is then exacerbated by applied zinc This problem is really a zinc-copper interaction exacerbated by nitrogen Nitrogen fertilisers such as ammonium sulphate [$(NH4)_2SO_4$] can have a marked acidifying effect on soils and so lead to an increase in the availability of zinc to crops in soils of relatively high pH status (Kirk *et al* , 1995)

2.3.3.2. Zinc - Phosphorus interaction

High soil phosphate levels are one of the most common causes of zinc deficiency in crops encountered around the world However, although this interaction with phosphate has been recognized for many years, the actual mechanisms responsible are still not completely understood In general, plant uptake of zinc decreases sharply, often beyond a level which can be attributed to dilution effects due to growth enhancement, with an increase in the soil content or supply of fertilizer phosphorus In acid tropical soils, the risk of phosphorus induced zinc deficiency increases when phosphorus application is accompanied by liming Liming will overcome aluminium toxicity and thereby increase root growth but the sharp decrease in zinc concentrations in the soil solution combined with higher zinc requirements due to enhanced shoot growth requires the additional supply of zinc to prevent a reduction in growth with high phosphorus and lime supply (Marschner, 1993)

2.3.3.3. Interactions of Zinc with other Macronutrients

Several macronutrient elements, including calcium, magnesium, potassium and sodium are known to inhibit the absorption of zinc by plant roots in solution culture experiments, but in soils their main effect seems to be through their influence on soil pH Potassium and magnesium have been shown to inhibit zinc absorption in solutions with low levels of calcium, but once the calcium concentration was increased, the effects disappeared In the dry season, rice in the Philippines has been found to respond to zinc combined with potassium at some sites, but only responses to potassium were found in the wet season (Ramon and villemin, 1989)

2.3.3.4. Interactions of Zinc with other Micronutrients

Zinc is known to interact with copper, iron, manganese and boron a) Zinc-copper interactions can occur through i) Competitive inhibition of absorption (due to copper and zinc sharing a common site for root absorption), ii) Copper nutrition affects the redistribution of zinc within plants b) Iron-zinc interactions appear to be just as complex as those between zinc and phosphorus, but they have not attracted so much attention Increasing zinc supplies to plants have been observed to increase the iron status, to decrease it, and to have no effect on it Zinc deficient plants can absorb high concentrations of boron in a similar way to zinc deficiency enhancing phosphorus toxicity in crops and this is probably due to impaired membrane function in the root (Loneragan *et al* , 1993)

Materials and Methods

3. MATERIALS AND METHODS

An investigation was carried out at College of Agriculture, Padannakkad and Research farm of RARS, Pilicode to study the effect of silicon, boron and zinc nutrition on bitter gourd (*Momordica charantia* L) var Preethi in oxisols

The whole investigation was carried out as two experiments, a pot culture experiment at College of Agriculture, Padannakkad and a field experiment in RARS, Nileshwar farm

The investigation include

- Collection of soil samples and analysis for physical and chemical properties
- Standardizing the dose and method of application of Si, B and Zn fertilizers to bitter gourd crop
- Pot culture experiment and field experiment to evaluate the effect of Si, B and Zn on available nutrient status of soil and yield of bitter gourd

The experiment details with special reference to the materials used and methods adopted are discussed in this chapter

3 1 COLLECTION OF SOIL SAMPLES

Soil sample for initial analysis were collected from the land prepared for field experiment and from the same field where soil was collected for pot culture experiment Soil sample were drawn from surface 15 cm from 10 different locations of the field The bulk sample was pooled, reduced to required quantity and dried The air dried soil sample were ground and passed through 2 mm sieve and stored in air tight containers

The sample were analyzed for pH, EC, organic carbon, available nutrients such as N, P, K, Ca, Mg, S, Cu, Zn, Si and B following standard procedures given in Table 1 The soil analysis data is presented in Table 2

Table 1. Analytical methods followed in soil analysis

S No	Parameter	Method	Reference
1	Electrical conductivity	Conductivity meter	Jackson (1958)
2	pH	pH meter	Jackson (1958)
3	Organic carbon	Chromic acid wet digestion method	Walkley and Black (1934)
4	Available N	Alkaline Permanganate method	Subbaiah and Asija(1956)
5	Available P	Bray extraction and photoelectric colorimetry	Jackson (1958)
6	Available K	Flame photometry	Pratt (1965)
7	Available Ca	Atomic absorption spectroscopy	Jackson (1958)
8	Available Mg	Atomic absorption spectroscopy	Jackson (1958)
9	Available S	Photoelectric colorimetry	Massoumi and Cornfield (1963)
10	Available Fe	Atomic absorption spectroscopy	Sims and Johnson (1991)
11	Available Mn	Atomic absorption spectroscopy	Sims and Johnson (1991)
12	Available Zn	Atomic absorption spectroscopy	Emmel *et al.* (1977)
13	Available Si	Photoelectric colorimetry	Korndorfer *et al* (2001)
14	Availabe B	Photoelectric colorimetry	Gupta (1967)

Table 2. Physico-chemical properties of the initial soil sample

S No	Parameter	Pot culture experiment	Field experiment
1	pH	6 20	6 35
2	Electrical Conductivity (dsm ^{1})	0 16	0 12
4	Organic carbon (%)	0 24	0 37
6	Available Nitrogen (kg ha^{-1})	230 25	243 53
7	Available Phosphorus (kg ha ^{1})	24 37	27 10
8	Available Potassium (kg ha ^{1})	150 43	175 02
9	Available Calcium (mg kg ^{1})	1589 60	1736 00
10	Available Magnesium (mg kg ^{1})	48 83	57 67
11	Available Sulphur (mg kg ^{1})	28 89	31 780
12	Available Iron (mg kg ^{1})	80 4	115 7
13	Available Manganese (mg kg^{-1})	12 5	20 6
14	Available Silicon (mg kg^{-1})	27 47	30 68
15	Available Boron (mg kg$^{-1)}$	0 36	0 49
16	Available Zinc(mg kg ^{1})	2 59	3 54

3 2 POT CULTURE EXPERIMENT

A pot culture experiment was conducted at College of Agriculture, Padannakkad to standardize the dose and method of application of Si, B and Zn to bitter gourd crop in oxisols, and its effect on available nutrient status of soil and yield

3.2.1.Experimental details

The details of experiment are presented below,

Number of treatment 19

T1 B -0 2% foliar+ Zn-0 2% foliar + Si-20 ppm in soil

T2 B-0 2% foliar + Zn-0 2% foliar + Si + 40 ppm in soil

T3 - B-0 2% foliar + Zn-0 4% foliar + Si-20 ppm in soil

T4 B-0 2% foliar + Zn-0 4% foliar + Si-40 ppm in soil

T5 B-0 2% foliar + Zn-0 6% foliar + Si-20 ppm in soil

T6 B-0 2% foliar + Zn-0 6% foliar + Si-40 ppm in soil

T7 B-0 4% foliar + Zn-0 2% foliar + Si-20 ppm in soil

T8 B-0 4% foliar + Zn-0 2% foliar + Si-40 ppm in soil

T9 B-0 4% foliar + Zn-0 4% foliar + Si-20 ppm in soil

T10 B-0 4% foliar + Zn-0 4% foliar + Si-40 ppm in soil

T11 B-0 4% foliar + Zn-0 6% foliar + Si-20 ppm in soil

T12 B 0 4% foliar + Zn-0 6% foliar + Si-40 ppm in soil

T13 B-0 6% foliar + Zn-0 2% foliar + Si-20 ppm in soil

T14 B-0 6% foliar + Zn-0 2% foliar + Si-40 ppm in soil

T15 B-0 6% foliar + Zn-0 4% foliar + Si-20 ppm m soil

T16 B-0 6% foliar + Zn-0 4% foliar + Si-40 ppm in soil

T17 B-0 6% foliar + Zn-0 6% foliar + Si-20 ppm in soil

T18 B-0 6% foliar + Zn-0 6% foliar + Si-40 ppm in soil.

T19 Control (No Zn, B and Si, only Package of Practices)

Replication – 3

Desighn RBD

Variety Preethi

Composition of Si, B and Zn sources used are detailed below

Calcium silicate- 19% Si, 20 2% Ca

Borax- 11% B

Zinc sulphate- 40% Zn

The layout of the pot culture experiment is shown in Fig 1

3.2.2. Soil

Soil for pot culture experiment was collected from RARS, Nileswar farm where field experiment was carried out 8 kg soil was taken and filled in each pot for conducting pot culture experiment The experimental soil was red soil with pH 6 3 belonging to the taxonomical order oxisols

Fig.1 Layout of the pot culture experiment

T9R1		T16R2		T6R3
T1R1		T5R2		T1R3
T4R1		T2R2		T17R3
T2R1		T9R2		T15R3
T12R1		T15R2		T5R3
T16R1		T13R2		T4R3
T10R1		T6R2		T18R3
T14R1		T18R2		T9R3
T3R1		T4R2		T19R3
T5R1		T12R2		T10R3
T11R1		T17R2		T7R3
T6R1		T11R2		T3R3
T18R1		T3R2		T13R3
T8R1		T10R2		T2R3
T13R1		T1R2		T14R3
T15R1		T19R2		T8R3
T7R1		T14R2		T11R3
T19R1		T8R2		T16R3
T17R1		T7R2		T12R3

3.2.3. Fertilizer application

Fertilizer were applied as per package of practices recommendations (POP) of KAU (2011) FYM @ 20- 25 t/ha as basal dose along with half dose of N (35 kg) and full dose of P_2O_5 (25 kg) and K_2O (25 kg/ha) The remaining dose N (35 kg) was applied in two equal split doses at the time of vining and at the time of full blooming The other cultural practices were adopted as per POP, KAU, 2011

3.2.4. Collection of plant samples for analysis

The fully matured leaves and fruits are collected from mature plants by cutting Fruits were cut in to small pieces and dried Fresh fruit is used for Vit C analysis To minimize soil contamination, leaves were washed in 0 2 % detergent, and thoroughly rinsed with distilled water (Wallace *et al*, 1980) prior to oven drying (70° C, 24 h) Dried tissue sample were ground and passed through a 20-mesh screen Ground sample were re-dried for 48 h (70° C) and placed in snap-cap vials, then stored in desiccators until use

3.2.5 Analysis for plant samples

Plant samples were collected at harvest stage and analyzed for different macro and micro nutrients *viz*, N, P, K,Ca, Mg, Fe, Mn, Si, Zn ,B ,Fe and Vit C content by standard procedure given in Table 3

3.2.6. Chemical analysis for soil sample

Soil samples from each treatment was collected from surface 15 cm in plastic bags, air dried, sieved with 2 mm sieve and stored in air tight container in laboratory until analysis Soil sample were analyzed for available nutrients such as N, P, K, Ca, Mg, S, Fe, Mn, Si, B, and Zn by standard procedures which have been shown in Table 1

Table 3. Analytical method followed for plant analysis

S No	Parameter	Method	Reference
1	Total N	Modified kjeldahl method	Jackson (1958)
2	Total P	Vanodo molybdate yellow colour method	Piper (1966)
3	Total K	Flame photometry	Jackson (1958)
4	Total Ca and Mg	Atomic Absorption Spectoscopy	Issac and Kerber (1971)
5	Total S	Turbidimetric method	Bhargava and Raghupathi (1995)
6	Total Zn	Atomic Absorption Spectoscopy	Emmel *et al* (1977)
7	Total B	Azomethane –H colorimetric method	Bingaham (1982)
8	Total Si	Blue silicomolybdous acid method	Ma *et al* (2002)

3.2.7. Biometric observations

The following biometric observations are made in both pot culture and field experiment

3.2.7.1. Number of branches

Number of branches counted after reaching the harvesting time

3.2.7.2. Plant height

Plant height was measured from the base of the stem to the tip of the youngest leaf using a meter scale and expressed in cm Plant height was noted at 45^{th} day after planting

3.2.7.3. Days for flowering

Number of days taken for first male and female flower is noted from date of planting

3.2.7.4. Days for first harvest

Number of days taken to first harvest is noted from date of planting

3.2.7.5. Number of fruits

Number of fruits per plant was recorded at harvesting stage

3.2.7.6. Average fruits breadth, length and weight

Average breadth, length and weight of the fruits are taken from each plants

3.2.7.7. Percentage of marketable fruits

Number of fruits with good appearance for marketing is counted from total fruits and percentage is calculated

3.2.7.8. Keeping quality of fruits at ambient conditions

Mature harvested fruits are kept under room condition and notice the days taken for decaying

3.2.7.9. Incidents of pest and diseases

Pest and disease damage were evaluated through out the crop period and the incidents of pest attack and disease were noted

3.4. DETERMINATION OF SILICON IN SOIL AND PLANT SAMPLES

3.4.1. Detrmination of silicon in soil sample

3.4.1.1. Extraction of silicon in soils

5g soil was weighed in plastic centrifuge tube, and 12 5 ml of 0 5 M Acetic acid (1 2 5 ratio) was added (Korndorfer *et al*,1999) After shaking continuously for a period of one hour, it was centrifuged at 3000 rpm for 3 minutes and then filtered Silicon in the extract was determined by adopting the procedure of Korndorfer *et al* (2001)

3.4.1.2. Estimation of silicon in soils

Silicon in the extract was determined by transfering 0 25 ml of filtrate into plastic centrifuge tube followed by the addition of 10 5 ml of distilled water, 0 25 ml of 1 1 HCl and 0 5 ml of 10% ammonium molybdate solution (pH 7-8) After 5 minutes 0 5 ml of 20% tartaric acid solution was added, and after another 2 minutes 0 5 ml reducing agent ANSA (Ammonium Naphthol Sulphonic Acid) was added and colour was developed Absorbance was measured at 630 nm using UV visible spectrometer after 5 minutes Simultaneously silicon standards (0 2, 0 4, 0 8 and 1 2 mg/l) were prepared, color was developed and measured using UV visible spectrometer (Korndrofer *et al* ,2001)

3.4.2. Determination silicon in plant sample

3.4.2.1. Plant sample digestion

Powdered leaves samples dried in an oven at 70°C for 2 days prior to analysis The sample (0 5 g) was digested in a mixture of 3 ml each of HNO_3 (62 %) and H_2O_2 (30%) and 2 ml of HF (46 %) using microwave digester (milestone MLS 1200) with following steps 250 watts for 5 minutes, 500 watts 5 minutes and venting for 5 minutes Then the digested samples were diluted to 50 ml with 4% boric acid (Ma *et al* , 2003)

3.4.2.2. Estimation of silicon in digested plant samples

Silicon concentration in the digested solution was determined as described below

Digested 0 5 ml aliquot was transferred to plastic centrifuge tube To this 3 75 ml of 0 2N HCl, 0 5 ml of 10% ammonium molybdate solution, 0 5ml of 20% tartaric acid solution and 0 5 ml reducing agent ANSA (Ammonium Naphthol Sulphonic Acid) were added and the volume was make up to 12 5 ml with distilled water After 1 hour the absorbance was measured at 600 nm using UV visible spectrometer

Simultaneously silicon standards (0, 0 2, 0 4, 0 8 and 1 2 ppm) were prepared in the same matrix and measured using UV visible spectrometer

3.5. DETERMINATION OF BORON IN SOIL AND PLANT SAMPLES

3.5.1. Extraction and estimation of boron in soils

Crop response to boron was assayed by hot water extraction method as followed by Gupta (1967)

20g of sieved air dried soil sample was weighed in a 250 ml of boron free conical flask, 40ml distilled water and 0 5 g of activated charcoal added and boiled on hot plate for 5 minutes The contents was filtered immediately through Whatman no 42 filter paper and cooled to room temperature. 1ml aliquot was transferred to 10ml polypropylene tubes, 2ml of buffer and 2ml of azomethine-H reagent mix added and the absorbance was read at 420 nm after 30 minutes on a spectrometer

Similarly standard B concentrations (0 1, 0 2, 0 4, 0 6, 0 8 and 1 ppm) were read using the same procedure.

3.5.2. Determination of boron in plant sample

3.5.2.1. Ashing and extraction of the plant sample

Boron in plant sample was determined by ashing method followed by Gain and Michel(1979)

0 5g air dried plant sample was weighed in a glazed paper, 0 1g calcium oxide powder added, mixed well and transferred to porcelain crucible and placed in a muffle furnace The temperature of the furnace was raised slowly to a maximum of 550°C and the contents ignite completely,cooled with water and covered with watch glass 3ml of dilute HCl (1 1) was added and heated on a water bath for 20 minutes Finally the contents were transferred to 25ml volumetric flask and volume was made up

3.5.2.2. Estimation of boron in the plant digests

1ml of made up digest was transferred in to polypropylene tubes and 2ml of buffer and 2ml of azomethine-H reagent mix was added and the absorbance was measured after 30 minutes at 420 nm on a spectrometer (Binghum, 1982)

Similarly standard B concentration (0 1, 0 2, 0 4, 0 6, 0 8 and 1 ppm) were measured using same procedure

3.6. DETERMINATION OF Zn IN SOIL AND PLANT SAMPLES

3.6.1. Extraction and estimation of Zn soils

Available Zn was extracted by Eve (1955) by shaking 2g of soil with 20 ml of 0 1 M HCl for 5 minutes Filter through Whatsman No 42 filter paper Collect the filtrate and estimate the content of Zn using atomic absorption spectrophotometer

3.6.2. Determination of Zn in plant sample

3.6.2.1. Ashing and extraction of the plant sample

Zinc is estimated in plant digest obtained from dry ashing or from wet digestion by HNO_3 and $HClO_4$ Triacid digestion (HNO_3 H_2SO_4 $HClO_4$ – 9 4 1) and digestion of plant samples with H_2SO_4 and H_2O_2 is avoided for this estimation because H_2SO_4 used in digestion can contribute some micronutrients and heavy metals

3.6.2.2. . Estimation of zinc in the plant digests

Zinc in the digested aliquot is estimated by atomic absorption spectrophotometer

3.7. STATISTICAL ANALYSIS

The data obtained from pot culture and field experiments was subjected to statistical analysis using statistical analysis software (SAS) (Hatcher, 2003)

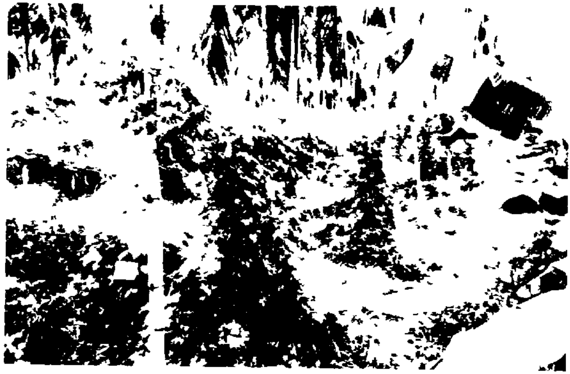

Plate 1: View of field experiment at RARS, Nileswar after 2 months

Plate 2: View of field experiment at the time of harvest

Results

4. RESULTS

The results obtained from the pot culture experiment and field experiments are presented in this chapter

4 1 POT CULTURE EXPERIMENT

A pot culture experiment was conducted at College of Agriculture, Padannakkad, to standardize the dose and method of application of silicon, boron and zinc to bitter gourd in laterite soils, its effect on available nutrient status of soil,yield and quality parameters The results of biometric observations, soil characteristics and leaf analysis of pot culture are given below

4.1.1 BIOMETRIC OBSERVATIONS

4.1.1.1Number of branches

The data on number of branches is presented in Table 4. There were significant differences among the treatments Among treatments T_{11}(10 67) and T_1(10 34) recorded maximum number of branches and minimum was recorded in T_6 (5 67)and T_{17} (5 67)

4.1.1.2. Plant height at 45 days after planting

The plant height at 45 days after planting was revealed in Table 4 The treatments T_3, T_7, T_9, T_{10}, T_{11}, T_{15} and T_{16} have remarkable effect on plant height Maximum plant height was recorded in T_7 (1 08 m) and lowest height in control (0.78)

4.1.1.3. Days for female flowering

The days for female flowering results are illustrated in Table 4 The treatment T_1 (38 days) caused earliest days taken for flowering T_8, T_{14} and T_{15} were also showing earliest flowering (38 84 days) T_3 and control were recorded longest days (41 67 days) All other treatments were on par with control

4.1.1.4. Days for first harvest

There was significant variation between treatments on days for first harvest (Table 4) Treatments T_1 and T_{10}recorded earliest days for first harvest (73.67 days) Control showing maximum days (83 days) There is 10 days difference among control and T1

4.1.1.5.Number of fruits

The data in Table 5 revealed that treatment T_8 (10 67) recorded maximum number of fruits per plant which was on par with T_2(10 34) and significantly higher than T_{12} (6 67), T_7 (6 34), T_{15} (6.00) and control (5 34)

4.1.1.5. Fruit length

The fruit length results are illustrated in Table 5. There was notable difference in fruit length between treatments. Treatment T_{14} (20 40 cm) recorded maximum fruit length which was on par with treatments T_{10} and T_{18} and Control recorded minimum fruit length (15 50 cm)

4.1.1.6. Fruit breadth

There was significant difference between treatments with respect to fruit breadth (Table 5) The treatment T_{14} (6.98 cm) which was on par with T_8 (6 67cm) and T_{14} (6.57 cm) and control recorded minimum fruit breadth (4 84) All other treatments notably reduced the fruit breadth

4.1.1.7. Fruit weight

The data on fruit weight is abridged in Table 5 The application of treatment T_{14} recorded highest fruit weight (257 33 g) which was superior to all other treatments Control showing lowest fruit weight (122 56)

4.1.1.8. Keeping quality of fruits at ambient condition

The result on keeping quality of fruits is illustrated in Table 5 There was a notable increase in keeping quality of fruits Maximum days recorded in T_{14} (6 33 days) and T_{16}(5 days) shows second most keeping quality T_9 (2 33 days) recorded minimum days for keeping There were 4 days difference between T_{14} and T_9

Table 4 Effect of silicon, boron and zinc on growth parameters of bitter gourd

Treatments	Number of branches	Plant height (m)	Days for female flowering	Days for first harvest
T1	10 34	0 97	38 00	73.67
T2	8 34	0 85	41 00	75.67
T3	5 67	1 05	41 67	75 67
T4	7 67	0.87	39.00	78 00
T5	7 34	0.97	40.34	74.67
T6	5 67	0 99	39 67	76 33
T7	6 34	1 08	40 67	75.67
T8	8 00	0 85	38 34	81 33
T9	6.67	1 02	40 34	75 33
T10	7.34	1.03	40.34	73 67
T11	10.67	1.01	39 67	76 33
T12	9 34	0.87	39 00	75 00
T13	8 00	0 99	39 34	77 00
T14	8 67	0 85	38 34	75 00
T15	9 67	1 06	38.34	78 33
T16	7 00	1 04	39.00	76 00
T17	5 67	0 83	38 67	78 00
T18	8.00	0 99	38 67	75 33
T19	7.00	0.78	41 67	83 00
Average	7 8	0.96	39 47	76 17
CD(5%)	2.94	NS	NS	3 69
SE	-	0 15	2 02	-

Table 5 Effect of silicon, boron and zinc on yield and yield characteristics of bitter gourd

Treatments	Number of fruits	Fruit length (cm)	Fruit breadth (cm)	Fruit weight (g)	Keeping quality	Yied/plant (kg)
T1	9 00	18 10	5 70	196 78	3 67	1 77
T2	10 34	18 97	5 65	197 22	3 33	2 04
T3	7.00	18 00	5 72	170 33	4 33	1 19
T4	8 34	19 50	5 33	163 56	3 33	1 36
T5	9.67	19 60	5 17	155 89	3 00	1 51
T6	7.00	17 97	5 56	169 78	3 67	1 19
T7	6 34	18 30	6 50	254 78	3 33	1 62
T8	10 67	19 70	6 67	212.89	4 00	2 27
T9	7 00	17 03	6 02	179 78	2.33	1 26
T10	9.10	20 34	6 06	173 78	3.33	1 58
T11	7 67	18 30	5 22	144 89	3 67	1.11
T12	6 67	19 03	6 57	138 22	4 00	0 92
T13	7 00	18 13	5 60	169 22	3 00	1 18
T14	8 67	20 40	6 98	257 33	6 33	2 57
T15	9 67	19 83	6 46	208 33	4 67	1 24
T16	7.00	16 80	5.93	155.67	5 00	1 35
T17	5 67	14 33	6 18	137 33	3 67	1 09
T18	8 00	20 27	6 08	192 67	3 67	1 86
T19	7 00	15 50	4 84	122 56	3	0 65
Average	8 04	18 59	5 97	182.13	3 79	1 5
CD(5%)	2.94	3 33	0 92	36 56	1.41	2 57
SE	-	-	-	-	-	-

4.1.1.9. Yield per plant

The data on fruit yield are presented in Table 6 The application of B-0.4% foliar + Zn-0 2% foliar + Si-40 ppm in soil (T_{14})recorded highest fruit yield of 2 57 kg/plant which was superior to all other treatments This was followed by T_2 (2 04 kg/plant) and T8 (2 27 kg/ha) and minimum was recorded in control (0 65 kg)

4.1.1.10. Vitamin C content in fruit

The result of Vitamin C content is shown in Table 6 Vitamin C content of the fruits were measured in the pulp and compared There were significant differences among treatments when compared to control Among the treatments T_{14} (75 14 mg/100g) recorded highest amount of vitamin C The treatment T15(72 17 mg/100g) shows second most highest value and minimum was recorded in control (53 33 mg/100g) Treatments which were given third level of B (0 6% foliar) shows notable increase in vitamin C content.

4.1.1.11. Iron content of fruit

The influence of Si, B and Zn application on iron content of fruits are illustrated in Table 6 The iron content of fruits are found to be significantly influenced by treatments The treatment T_9 (69 57 ppm) which was superior to all other treatments This was followed by T11 (66 00 ppm) and T6 (66 10 ppm) which wasshowed second and third superior treatments and control showed lowest (47 27 ppm)

4.1.1.12. Incidence of pest and disease

Effect of treatment applications on incidence of pest and disease in bitter gourd fruits are presented in Table 6 The observation were made on the incidence of pest and diseases Although we could not find any significant differences among treatment the pest and disease infestation was found highest (3.54) in control

4.1.1.13. Percentage of marketable fruits

Perusal of the data in Table 6 revealed that application of varied levels of Si, B and Zn had significant influence on percentage of marketable fruits T_{13}(88 33%) shows maximum percentage of marketable fruits while T_9(73 19%) shows minimum percentage There is 8 33% increase in T_{13} when compare to control.

Table 6. Effect of silicon, boron and zinc on vitamin C, iron content of fruits, percentage of marketable fruits and incidence of pest and diseases

Treatments	Vitamin C	Iron	Percentage of marketable fruits	Pest and disease incidence
T1	59 00	60 07	77 26	2 73
T2	63 53	53 77	73 82	1 84
T3	61 42	64 97	75 32	2 59
T4	65 94	51.63	85 63	2 56
T5	65 24	63.00	74 59	2 25
T6	55 62	66.10	84 33	1 86
T7	62 16	56 00	75.65	2.38
T8	63 24	62 42	74 82	2 95
T9	57 99	69 57	73 19	2 76
T10	64 12	62 43	82 61	1 88
T11	65 18	66 00	86 24	1 97
T12	61 90	56 27	85 77	2 34
T13	59 00	60 07	88 33	2 87
T14	75 14	59 23	83 42	1.67
T15	72 17	59 70	83.44	2 14
T16	62 10	61 80	79 00	1 79
T17	62.70	64 48	86.07	2 43
T18	64 57	58 57	87 29	2 12
T19	53 33	47 27	80 12	3 54
CD(5%)	8 53	7 40	3 66	NS
SE	-	-	-	0 74

4.1.2. SOIL CHARACTERISTICS

4.1.2.1. pH

The result of soil pH, EC and OC examined for pots which received various treatment combinations are presented in table 7 The effect of treatment application on soil pH was statistically significant Highest pH is recorded in pots receiving T_8 (6.45) and lowest was recorded in control (5 95).

4.1.2.2. EC

Effect of treatments on soil EC is presented in Table 7 Treatment application has significant effect on the electrical conductivity of soil Average EC in the treatment pots were 0 42 dS/m compared to 0.34dS/m in control Highest EC was found in T_1(0 61 dS/m) and lowest was found in T_8(0 26 dS/m)

4.1.2.3. Organic carbon content

From Table 7, it was found that the organic carbon(OC) content of soil is significantly influenced by application of Si, B and Zn OC varies between 0 42% (T_{11}) to 0.20% (T_2) In control OC content was slightly higher (0.31%) than rest of treatment average (0 29%)

4.1.2.4. Available Nitrogen

Table 8 shows the values of available N, P and K status in post harvest soil and expressed in mg/kg of pots.The effect of Si, B and Zn was found to be non significant in the case of available N Highest N content was observed in T_{11}(114 40 mg/kg) and lowest was observed in control (102.84 mg/kg) pot

4.1.2.5. Available Phosphorus

The effect of P_2O_5 content in post harvestsoil are presented in table 8 The effect of treatment application was non significant in case of available P_2O_5 The P content in the pot is varied from 14 74 mg/kg in $T_{12}$to 10 75 mg/kg in control However there was no significant difference observed between treatments and control

4.1.2.6. Available Potassium

The data with respect to K_2O content in pot soil is shown in Table 8 Application of varied levels of Si, B and Zn has significantly influenced available K_2O content Highest K_2O content was observed in pots receiving B- % foliar + Zn- % foliar+ Si- 20 ppm in soil T_{11} and control shows lowest K_2O content (62 30 mg/kg)

Table 7: Effect of sılıcon, boron and zinc applıcation on soil pH, EC and OC

Treatments	pH	EC(dS/m)	OC (%)
T1	6 27	0.61	0 28
T2	6 26	0 46	0 20
T3	6 27	0.45	0.34
T4	6.27	0 57	0 24
T5	6 23	0 48	0 21
T6	6.26	0 35	0 37
T7	6 35	0 42	0.37
T8	6 45	0 26	0.24
T9	6 35	0 38	0.23
T10	6 43	0 29	0.38
T11	5.93	0.43	0 42
T12	6.15	0 29	0 21
T13	6 27	0 46	0 28
T14	6.15	0.39	0 33
T15	6.10	0 52	0 41
T16	6.11	0 45	0.18
T17	6 10	0 41	0.29
T18	6 14	0 36	0.33
T19	5 95	0 34	0 31
CD(5%)	0.199	0 25	0 123

Table 8· Effect of sılıcon, boron and zinc applicatıon on avaılable N, P, and K content of soıl

Treatments	Avaılable N (mg/kg)	Avaılable P_2O_5 (mg/kg)	Avaılable K_2O (mg/kg)
T1	105 77	10 95	96 98
T2	109 33	13 22	78.92
T3	106 44	13 34	79.55
T4	107 49	11 66	68 37
T5	104 65	13 39	90 40
T6	107 37	11.07	118 40
T7	107 77	11.87	111 51
T8	105 19	11.71	111.27
T9	108 15	12 31	122.37
T10	108 12	12.10	111 20
T11	114 40	11 39	124.07
T12	105 27	14.74	75.10
T13	104 95	12 10	98.84
T14	105 85	13 03	106 77
T15	106 68	12 55	83 39
T16	107.33	10.83	90 77
T17	105 47	13 09	92 28
T18	107.49	11.57	97 53
T19	102 84	10 75	62.30
CD(5%)	NS	NS	35 73
SE	6 74	2 98	106.77

4.1.2.7. Available Calcium

The data on effect of treatment application on the available Ca content inpost harvested soil are presented in table 9 Application of Si, B and Zn significantly influenced the available Ca content A high variation occured among treatments It varies from T_{11}(7705 47 ppm) to T_4 (1565 87 ppm) Average Ca content is 2158 37 ppm in treatments and 1683 17 ppm in control

4.1.2.8. Available Magnesium

The data pertaining to Mg content of soils are presented in Table 9 The treatments are found significantly differed with applications of varied levels of Si, B and Zn Mg content in soil ranged from64 42 ppm (T_7) to40 92 ppm (T_1) At the same time average Mg content 56 74 ppm in treatments and 42 00 ppm in contol Foliar application of 0 4% boron solution resulted inhigh Mg content in soil.

4.1.2.9. Available Sulphur

The effect of Si, B and Zn on available sulphur content in soil is illustrated in Table 9 The effect of treatments was found to be non significant in the case of available S The available sulphur content was highest in T_{11}(33 55 ppm) which is on par with T_1(30 00 ppm), T_3(30 52 ppm), T_4(31 33 ppm), T_5 (30 89 ppm), T_6(30 89 ppm) and T_9 (31 78 ppm) and the lowest was found in control (25 36 ppm)

Table 9: Effect of silicon, boron and zinc on available Ca, Mg and S content in soil

Treatments	Available Ca (ppm)	Available Mg (ppm)	Available S (ppm)
T1	1707.63	40.92	30.00
T2	1725.90	52.42	26.89
T3	1633.77	57.67	30.52
T4	1565.87	48.83	31.33
T5	1589.60	61.00	30.89
T6	1629.23	53.92	30.89
T7	2074.47	64.42	30.18
T8	2046.17	64.08	28.89
T9	1609.87	54.17	31.78
T10	1801.53	56.33	28.58
T11	7705.47	58.25	33.55
T12	1736.00	56.92	30.55
T13	1810.10	55.92	28.18
T14	1980.63	63.83	32.99
T15	2135.57	55.33	30.89
T16	1901.13	57.17	30.15
T17	2421.93	57.50	30.67
T18	1775.87	62.58	28.94
T19	1683.17	42.00	25.36
CD(5%)	96.54	10.46	NS
SE	-	-	4.46

4.1.2.10. Available Silicon

Effect of Si, B and Zn application on available Si content inpost harvest soil is presented in Table10. Si content in soil significantly differed with the application of different levels of Si, B and Zn. Highest silicon content was found in T_{10}(33 ppm) and lowest was found in T_1(22.52 ppm). T_{12}(32.97 ppm) is on par with T_{10}. T10 (B-0.4% foliar + Zn-0.4% foliar + Si-40 ppm in soil) and T12 (B-0.4% foliar + Zn-0.6% foliar + Si-40 ppm in soil) are found to be superior compare to other treatments. The average Si content in treatments soils were28.86 ppm.

4.1.2.11. Available Boron

The effect of treatment application on available boron content of the post harvest soil is presented in Table 10. All the treatments are superior to control. T_{15}(0.84 ppm) recorded highest boron content and control (0.15 ppm) recorded lowest. The average boron content of the treatments is 0.46 ppm. T15 having boron at third level (B-0.6% foliar). Treatments were different significantly when compare to control.

4.1.2.12. Availble Zinc

The effect of treatments on available zinc content in post harvest soil is presented in table 10. The data Significantly differed were observed in available Zn content of post harvest soil with the application of Si, B and Zn. Highest Zn content was recorded in T_{13}(4.82 ppm) which was on par with treatment T_7 and T_{11}. Lowest was recorded in control that is 1.96 ppm.

Table 10: Effect of silicon, boron and zinc on a available micronutrient content of soil

Treatments	Silicon (ppm)	Boron (ppm)	Zinc (ppm)
T1	22.52	0.19	2.55
T2	28.63	0.61	3.54
T3	31.03	0.35	2.52
T4	29.19	0.31	3.40
T5	27.28	0.49	2.77
T6	31.26	0.16	2.59
T7	27.47	0.36	4.02
T8	30.66	0.25	3.50
T9	25.73	0.65	2.77
T10	33.00	0.36	3.48
T11	29.49	0.38	4.05
T12	32.97	0.48	3.24
T13	26.03	0.51	4.82
T14	28.77	1.02	3.64
T15	30.52	0.84	2.87
T16	27.47	0.69	2.70
T17	28.45	0.41	3.32
T18	29.11	0.19	4.71
T19	25.310	0.15	1.96
CD(5%)	3.460	0.06	0.64
SE	-	-	-

4.1.3. Leaf analysis

The chemical analysis of bitter gourd leaf sample was conducted in order to examine the plant nutrient status. Leaf samples were collected at the time of harvest, dried in oven and were powdered and analysed using standard analytical procedure explained in the materials and methods. The results obtained after statistical analysis are presented in table 11 and12.

4.1.3.1. Nitrogen

The effect of Si, B and Zn application on nitrogen (N) content in leaf is illustrated in Table 11. Nitrogen content of the leaf is significantly influenced by treatments. The plants receiving B-0.4% foliar + Zn-0.6% foliar + Si- 20 ppm in soil(T11) recorded highest N content(2.50%) which is on par with T_{10} and T_{12}(2.40 %) whereas T_1(1.30%) recorded lowest N content in the leaves. The average N content of treatments was1.98 %.

4.1.3.2. Phosphorus

The data with respect to phosphorus content in leaves is illustrated in Table 11. There was statistical difference on effect of treatment application in leaf P content.The average P content of treatments are 0.41% while control have 0.44%. Highest P content was recorded in T_{15}(0.78%) and lowest was recorded in T_5 and T_7 (0.09%).

4.1.3.3. Potassium

Effect of Si, B and Zn application on K content in leaf is shown in Table 11. Significant differences were observed in K content of leaf as a result of treatment application. In the case of K, the treatment T_{15}(B-0.6% foliar + Zn-0.4% foliar + Si-20 ppm in soil) had significantly higher value of 2.25%.All the treatments are found to be superior to control (0.87%).

Table 11: Effect of silicon, boron and zinc application on N, P and K content of bitter gourd leaf

Treatments	N(%)	P(%)	K(%)
T1	1.30	0.33	1.20
T2	1.70	0.40	1.54
T3	1.90	0.52	2.01
T4	1.90	0.19	1.25
T5	2.10	0.09	0.99
T6	2.30	0.35	2.04
T7	1.90	0.09	0.92
T8	1.80	0.36	1.50
T9	2.20	0.47	2.09
T10	2.40	0.38	1.38
T11	2.50	0.47	0.99
T12	2.40	0.37	2.23
T13	1.40	0.34	1.21
T14	2.2	0.69	1.06
T15	1.80	0.78	2.25
T16	1.70	0.56	1.46
T17	1.90	0.59	2.37
T18	2.20	0.35	0.98
T19	1.60	0.44	0.87
CD(5%)	0.57	0.13	0.21
SE	-	-	-

4.1.3.4 Silicon

The Si content of leaves analyzed at harvest stage is shown in Table 12. The effect of silicon content in leaves as influenced by different treatments showed statistically significant differences. The Si content of leaves is varied from 10.65 ppm in T_8 to 3.10 ppm in T_{17} which is same ofcontrol.The treatment T_8 receives second level of silicon (40 ppm) where T_{17} receives first level of silicon (20 ppm). The average Si content of the treatments is 6.41 ppm.

4.1.3.5 Boron

The effect of silicon, boron anc zinc application on the leaf B content of bitter gourd is presented in table 12. There was significant difference among boron content of the leaves as influenced by treatments. There is a drastic variation in boron content of treatments. It ranges from 92.48 ppm in case of $T_{13}$to 36.96 ppm in control. The highest value is in T_{13}(92.48 ppm) which is on par with T4(85.16 ppm) and T6(81.48 ppm).There was steady increase of boron content in leaves after treatments

4.1.3.6. Zinc

The data with respect to zinc content in the leaf is presented in Table 12. Zn content of the leaves were found to be significant. Zn content ranges from 81.86 ppm in T_{12} to 58.97 ppm in T_{14}. Control shows superior to T_{14} that is 59.43 ppm. $T_{14}$is the treatment combination of B-0.6% foliar + Zn-0.2% foliar + Si-40 ppm in soil. T12 is on par with T6 (80.87 ppm).

Table 12: Effect of silicon, boron and zinc application on available micronutrient content of bitter gourd leaves

Treatments	Silicon (ppm)	Boron (ppm)	Zinc (ppm)
T1	3.65	48.21	75.433
T2	6.32	73.55	66.567
T3	6.27	58.47	59.600
T4	6.22	85.16	73.633
T5	5.73	60.25	74.933
T6	8.35	81.48	80.867
T7	6.43	65.62	79.887
T8	10.65	39.14	63.000
T9	8.11	59.81	71.333
T10	6.96	59.17	74.600
T11	6.72	62.85	75.533
T12	6.05	49.17	81.867
T13	6.11	92.48	62.300
T14	8.13	74.51	58.97
T15	6.21	57.72	65.10
T16	4.97	74.26	75.73
T17	3.10	45.14	79.47
T18	5.41	48.62	78.70
T19	3.10	36.96	59.43
CD(5%)	1.05	14.75	7.30
SE	-	-	-

4.2. FIELD EXPERIMENT

The field experiment was conducted at Regional Agricultural Research Station farm at Nileswar to study the effect of silicon, boron and zinc nutrition in bitter gourd. Results of various biometric observation as well as detailed soil, leaf and fruit analysis were done. The parameters of observations are same as pot culture. The data were subjected to statistical analysis and the results are presented below.

4.2.1. BIOMETRIC OBSERVATIONS

4.2.1.1. Number of branches

The number of branches per plant is revealed in Table 13. Number of branches per plant was recorded and the data were tabulated and subjected to statistical analysis.There were significant differences among the treatments. Treatment T_1 (12.54) recorded maximum number of branches per plant and T_3(6.78) shows minimum number of branches and control shows 7.56 branches.

4.2.1.2.Plant height at 45 days after planting

The data with respect to plant height is illustrated in Table 13.The effect of treatment application found to be non significant. At 45 DAP the highest plant height was observred in T_1(1.13 m) which is on par with T11(11.76 m) and T15(11.43 m)and minimum was recored in T_8 and control, that is 0.80 m.

4.2.1.3. Days for female flowering

The results of days taken for female flower is presented in Table 13.The treatment T_1 (36.33 days) showed earliest flowering. T_7 (36.67 days) is on par with that. Control were recorded longest days (41.67 days).

4.2.1.4. Days for first harvest

Effect of treatments on days for first harvest is presented in Table. All the treatments are performed well compared to control. Treatments T_5 recorded minimum number of days (73.00 days). There is 12 days of difference between T_5 and control. It was observed in delayed harvest in control plants (82.00 days).

4.2.1.5. Number of fruits

The data in Table 14 revealed the effect of treatment on number of fruits per plant. There was significant differences among the treatments. Treatment T_3 (17.78) recorded maximum number of fruits per plant which was on par with T_{10} (17.34) and T_{15}(10.45) recorded minimum fruits numbers. Average number of fruits in treated plants is 13.64.

4.2.1.6. Fruit length

The fruit length differed significantly with the application of varied levels of Si, B and Zn and illustrated in Table 14. There were drastic difference among treatments. Treatment T_{14} (22.17 cm) recorded maximum fruit length which was on par withT_{18} (21.10 cm). Control plants recorded minimum fruit length (14.80 cm).

4.2.1.7. Fruit breadth

The data on fruit breadth is presented in Table 14.Treatments are significantly superior to control except T_6 and T_{11} .Maximum fruit breadth is recorded in T_{14} (8 cm) which was on par with T_7 (7 cm)and control recorded minimum fruit breadth (4.53).

4.2.1.8. Fruit weight

The effect of Si, B and Zn on fruit weight is shown in Table 14. Treatments are found to be significant with respect to control. T_{14} (300 g) showing maximum fruit weight and control showing lowest fruit weight (116.67 g). The average weight of treatments is 179.41 g.

4.2.1.9. Keeping quality of fruits at ambient condition

The result on keeping quality of fruits is illustrated in Table 14. There is notable increase occur in keeping quality of fruits. Maximum days recorded in T_{14} (6.70 days) and T_4, T_9(2.40 days) shows minimum days for keeping. There is almost 4 days difference between T_{14} and T_9.

Table 13: Effect of silicon, boron and zinc application growth parameters of bitter gourd

Treatments	Number of branches	Plant height (m)	Days for female flowering	Days for first harvest
T1	12.54	1.13	36.33	74.67
T2	9.23	0.81	38.67	75.67
T3	6.78	1.01	38.67	75.67
T4	8.57	0.96	38.67	75.67
T5	8.54	0.95	39.00	73.00
T6	7.89	0.96	37.67	76.67
T7	8.65	1.04	36.67	75.67
T8	9.67	0.80	38.33	79.33
T9	7.76	1.01	38.33	74.00
T10	8.65	0.94	39.00	74.00
T11	11.76	0.97	38.33	75.67
T12	10.45	0.82	39.00	75.67
T13	9.67	0.98	38.67	76.67
T14	10.76	0.90	38.67	74.00
T15	11.43	1.04	38.00	78.33
T16	9.14	0.92	38.67	74.00
T17	8.73	0.89	39.67	75.67
T18	9.45	1.01	38.67	74.00
T19	7.56	0.80	42.00	82.00
CD(5%)	2.35	NS	2.04	3.52
SE	-	0.17	-	-

Table 14 : Effect of silicon, boron and zinc on yield and yield characteristic of bitter gourd

Treatments	Number of fruits	Fruit length (cm)	Fruit breadth (cm)	Fruit weight (g)	Keeping quality	Yied/plant (kg)
T1	15.23	19.50	6.00	215.33	4	3.28
T2	12.56	20.00	6.17	201.67	3.7	2.53
T3	17.78	20.67	6.37	165	3.4	2.94
T4	10.67	20.33	6.00	151.67	2.4	1.62
T5	16.45	20.17	5.00	156.67	2.7	2.57
T6	15.34	18.00	5.27	158.33	4	2.43
T7	11.89	18.00	7.00	278.33	3	3.31
T8	12.45	19.00	6.43	178.33	2.7	2.82
T9	12.78	17.83	6.07	163.33	2.4	2.08
T10	17.34	21.00	6.67	226.67	2.7	3.09
T11	15.78	17.00	5.17	126.67	3.7	1.99
T12	13.56	20.00	6.50	130.67	3.4	1.77
T13	12.12	20.67	6.00	156.67	3	1.89
T14	11.45	22.17	8.00	300	6.7	3.44
T15	10.45	19.00	6.97	200	4.4	2.09
T16	14.34	18.67	6.50	130	3.7	1.86
T17	12.45	16.33	6.13	120	3.4	1.49
T18	12.89	21.10	6.13	170	3.4	2.19
T19	10.56	14.80	4.53	116.67	3.1	1.23
CD(5%)	3.21	3.45	0.96	32.58	1.56	1.69
SE	-	-	-	-	-	-

4.2.1.10. Yield per plant

Effect of Si, B and Zn application on yield per plant is presented in table 14. All treatments are superior to control. The combined application of B-0.4% foliar + Zn-0.2% foliar + Si-40 ppm is recorded highest fruit yield of 3.44 kg/plant and minimum was recorded in control (1.23 kg).

4.2.1.11. Vitamin C content of fruit

The result of vitamin C content is shown in Table 15.There were significant differences among treatments when compared to control. Among the treatments T_{14} (80.23 mg/100g) recorded highest content of vitamin C which was on par with T13(76.00 mg/100g) and minimum was recorded in control plants (52.37 mg/100g).

4.2.1.12. Iron content of fruit

The influence of Si, B and Zn appliacation on iron content in fruits are illustrated in Table 15. Treatments are found to be significantly influence the iron content of fruits. The treatment T_9 (68 ppm) shows highest iron content and control showed lowest (46.50 ppm). The average iron content among treatments is 58.4 ppm.

4.2.1.13. Incidence of pest and disease

The majour problem notices was fruit fly attack. Control measures were taken uniformly for that, after recording the number of affected fruits per plant. Although we could not find any significant differences among treatments, the pest and disease infestation was found highest (3.54) in control. The mean of the infested leaves per plant were taken and where statistically analysed.

4.2.1.14. Percentage of marketable fruits

The data on percentage of marketable fruits is presented in Table 15. All treatments are differed significantly. T_{11}(89.56 %) shows maximum percentage of marketable fruits while T_9(75.23 %) shows minimum percentage.

Table 15: Effect of silicon, boron and zinc on vitamin C, iron content of fruits, percentage of marketable fruits and incidence of pest and diseases

Treatments	Vitamin C (mg /100g)	Iron (ppm)	Percentage of marketable fruits	Pest and disease incidence
T1	54.70	62.20	78.37	2.73
T2	64.50	52.83	76.42	1.84
T3	63.57	59.60	77.62	2.59
T4	66.13	45.93	83.55	2.56
T5	61.33	57.90	78.23	2.25
T6	58.67	64.20	88.36	1.86
T7	67.37	55.63	79.87	2.38
T8	66.13	57.33	76.67	2.95
T9	58.37	68.00	75.23	2.76
T10	64.77	60.97	82.61	1.88
T11	67.73	65.83	89.56	1.97
T12	60.30	56.10	84.87	2.34
T13	76.00	55.27	89.23	2.87
T14	80.23	61.03	84.55	1.67
T15	71.40	50.17	85.46	2.14
T16	69.80	58.97	80.32	1.79
T17	68.20	60.17	87.34	2.43
T18	68.30	59.07	86.25	2.12
T19	52.37	46.50	80.34	3.54
Average	65.97	58.4	82.47	2.28
CD(5%)	2.62	5.69	2.59	NS
SE	-	-	-	0.74

4.2.2. SOIL CHARACTERISTICS

4.2.2.1. pH

The result of soil pH, EC and OC examined for pots which received various treatment combinations are presented in table 16. The effect of treatment application on soil pH was statistically significant. Highest pH is recorded in pots when treatments given at B-0.4% foliar + Zn-0.2% foliar + Si-40ppm,T_8(6.45) and lowest is recorded in control (6.00).

4.2.2.2. EC

The effect of treatment on soil EC is presented in Table 16. Treatment application has significant effect on the electrical conductivity of soil. Highest EC was found in T_1(0.59 dS/m) and lowest was found in T_8(0.26 dS/m). Average EC in the treatment pots is 0.39 dS/m.

4.2.2.3. Organic carbon content

Organic carbon (OC) content of soil is significantly influenced by the application of Si, B and Zn. OC varies from 0.45% in T_{11} to 0.18% in T_6. For control it is 0.31%. On an average, OC content of treatment were 0.29%.

4.2.2.4. Available N

Table 17 shows the values of available N, P and K status plots in kg/ha. The effect of Si, B and Zn application found to be significant in the case of available N. Highest N content was found in T_9(240.87 kg/ha) and lowest was found in T_{17}(224.17 kg/ha) with a mean of 235.17 kg/ha. Control was showing 230.77 kg/ha.

4.2.2.5. Available Phosphorus

The data on available P_2O_5 content in soil is presented in Table 17. The effect of treatment application was significant in case of available P_2O_5. The P content is varied from 33.18 kg/ha in T_{12} to 19.92 kg/ha in control. The average P_2O_5 content in treatments is 26.39 kg/ha.

4.2.2.6. Available Potassium

The data with respect to K_2O content in post harvest soil is shown in Table 17. Application of Si, B and Zn have significant effect on available K_2O. Highest K_2O content was observed when B-0.4% foliar + Zn-0.6% foliar + Si-20 ppm soil is given, T_{11}(306.90 kg/ha). Control shows lowest K_2O content (135.30 kg/ha). The mean of the treatment is 230.08 kg/ha.

Table 16: Effect of silicon, boron and zinc application on soil pH, EC and OC

Treatments	pH	EC(dS/m)	OC (%)
T1	6.27	0.59	0.25
T2	6.26	0.43	0.22
T3	6.27	0.32	0.35
T4	6.25	0.45	0.24
T5	6.23	0.48	0.23
T6	6.26	0.32	0.35
T7	6.35	0.48	0.38
T8	6.45	0.26	0.25
T9	6.35	0.36	0.23
T10	6.43	0.34	0.39
T11	5.93	0.35	0.45
T12	6.15	0.29	0.23
T13	6.27	0.59	0.25
T14	6.15	0.43	0.33
T15	6.10	0.42	0.41
T16	6.11	0.35	0.18
T17	6.10	0.31	0.29
T18	6.14	0.34	0.33
T19	6.00	0.43	0.31
Average	6.2	0.39	0.29
CD(5%)	0.185	0.25	0.133
SE	-	-	-

Table 17: Effect of silicon, boron and zinc application on available N, P, and K content of soil

Treatments	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)
T1	232.63	25.03	250.06
T2	240.60	30.43	174.90
T3	233.53	28.87	173.06
T4	234.47	21.30	135.30
T5	235.77	31.27	201.67
T6	233.66	20.63	269.50
T7	236.30	24.43	286.00
T8	235.27	23.67	279.40
T9	240.87	22.93	282.70
T10	234.66	30.14	248.97
T11	234.10	21.87	306.90
T12	234.83	33.18	161.70
T13	234.67	23.86	253.37
T14	239.60	31.05	249.70
T15	238.13	27.27	176.37
T16	234.40	22.83	221.10
T17	224.17	31.87	254.10
T18	235.47	24.46	216.70
T19	230.77	19.92	138.23
Average	235.17	26.39	230.08
CD(5%)	4.41	0.92	7.32
SE	-	-	-

4.2.2.7. Available Calcium

The data on effect of treatment application on the available Ca status of soil is presented in table 18. Application of Si, B and Zn significantly influenced the soil available Ca content. Significant difference was found among the treatments. It varied from T_{17} (2465.53 ppm) to T_4 (1381.17 ppm) with a mean of 1825.64 ppm.

4.2.2.8. Available Magnesium

The data pertaining to Mg content of soils are illustrated in Table 18. The treatments are found significantly differed. Highest Mg content was found in T_8 (69.98 ppm) and the lowest is recorded in control (44.37 ppm). While the average is 58.74 ppm. Foliar application of 0.4% foliar shows superior in Mg content in soil.

4.2.2.9. Available Sulphur

The effect of Si, B and Zn on available sulphur content in soil is illustrated in Table 18. The effect of treatments was found to be significant in the case of available S. Highest S content was found in T_{15} (31.13 ppm)which is on par with T_{10} (30.68 ppm) and the lowest was foun in control (28.22 ppm). The average of treatments is 29.76 ppm.

Table 18: Effect of silicon, boron and zinc on available Ca, Mg and S content in soil

Treatments	Available Ca (ppm)	Available Mg (ppm)	Available S (ppm)
T1	1860.37	49.28	29.67
T2	1719.33	57.68	30.23
T3	1676.03	60.00	30.20
T4	1381.17	48.97	28.99
T5	1586.37	59.40	30.55
T6	1656.90	51.18	29.35
T7	2045.43	69.48	30.42
T8	2040.73	69.98	28.76
T9	1643.37	55.90	28.54
T10	1529.50	67.07	30.68
T11	1562.90	52.92	29.96
T12	1452.13	63.58	28.60
T13	1951.97	55.25	29.97
T14	2176.33	66.47	29.16
T15	2389.97	59.37	31.13
T16	1849.40	55.83	29.95
T17	2465.53	51.97	29.60
T18	1874.03	63.02	29.75
T19	1627.42	44.37	28.22
Average	1825.64	58.74	29.76
CD(5%)	97.38	1.15	0.72
SE	-	-	-

4.2.2.10. Available Silicon

Effect of Si, B and Zn application on available Si content in field soil is presented in Table 19. Treatments are found to be significantly differed. Highest silicon content was found in T_{10} (32.73 ppm) and lowest was found in control (23.50 ppm). T_{10} (B-0.4% foliar + Zn-0.4% foliar + Si-40 ppm in soil) was found to be superior compared to other treatments and control. The average Si content in treated soil was 28.62 ppm.

4.2.2.11. Available Boron

The effect of treatment application on available boron content of the field soil is presented in Table 19. All the treatments are superior to control. Available boron content of the soil was found to be significant. T_{15}(0.89 ppm) recorded highest boron content and control (0.12 ppm) recorded lowest. The mean of the treated soil is 0.44 ppm.

4.2.2.12. Available Zinc

The effect of Si, B and Zn application on available Zn content in field soil is illustrated in Table 19. Significant differences were observed in available Zn content of soil as a result of treatment application. Highest Zn content was recorded in B-0.6% + Zn-0.2% + Si-20 ppm,T_{13}(5.79 ppm) which was on par with treatment T_{18} (5.11 ppm). Lowest was recorded in control that is 1.80 ppm.

Table 19: Effect of silicon, boron and zinc on available micronutrient content of soil

Treatments	Silicon (ppm)	Boron (ppm)	Zinc (ppm)
T1	25.23	0.18	2.86
T2	32.13	0.56	3.27
T3	26.76	0.32	2.99
T4	30.06	0.31	3.43
T5	24.56	0.46	3.05
T6	30.60	0.15	3.09
T7	25.80	0.35	4.89
T8	29.70	0.22	2.89
T9	24.73	0.64	3.47
T10	32.73	0.34	3.47
T11	28.70	0.33	4.87
T12	30.60	0.42	3.47
T13	26.90	0.52	5.79
T14	30.83	1.01	3.61
T15	26.80	0.89	3.52
T16	29.81	0.68	3.21
T17	28.13	0.40	3.02
T18	31.10	0.16	5.11
T19	23.50	0.12	1.80
Average	28.62	0.44	3.66
CD(5%)	1.35	0.05	0.62
SE	-	-	-

4.2.3. Leaf analysis

The chemical analysis of bitter gourd leaf sample was conducted in order to examine the plant nutrient status. Leaf samples were collected at the time of harvest, dried in oven and were powdered and analysed using standard analytical procedure explained in the materials and methods. The result obtained after statistical analysis are presented in table 20 and 21 below.

4.2.3.1. Nitrogen

The data with respect to nitrogen content in leaves is presented in Table 20. Nitrogen content of the leaf is significantly influenced by treatments. T_{11} recorded highest N content (2.80%) whereas T_1 recorded lowest N content in the leaves (1.30%). The average N content of treatment was 2.06%.

4.2.3.2. Phosphorus

The effect of Si, B and Zn application on P content in leaves is illustrated in Table 20. There was statistical difference on effect of treatment application leaf P content. Highest P content was recorded in T_{15}(0.82%) and lowest was recorded in T_5 (0.09%) with a mean of 0.43%. Control is showing 0.44%.

4.2.3.3. Potassium

The effect of treatment application on K content in leaf is shown in Table 20. Significant differences were observed in K content of leaf as a result of treatment application. All the treatments are found to be superior to control. Maximum K content was recorded in T_{17}(B-0.6% foliar + Zn-0.6% foliar + Si- 20 ppm in soil) that is 2.37% and the minimum was recorded in control (0.79%).

Table 20: Effect of silicon, boron and zinc application on N, P and K content of bitter gourd leaf

Treatments	N(%)	P(%)	K(%)
T1	1.33	0.33	1.2
T2	1.74	0.40	1.54
T3	2.12	0.52	2.01
T4	2.34	0.49	1.25
T5	2.10	0.09	0.99
T6	2.37	0.35	2.04
T7	1.94	0.13	0.92
T8	1.84	0.36	1.5
T9	2.22	0.47	2.09
T10	2.48	0.38	1.38
T11	2.83	0.47	0.99
T12	2.45	0.37	2.23
T13	1.33	0.33	1.2
T14	2.26	0.69	1.06
T15	1.85	0.82	2.25
T16	1.77	0.56	1.46
T17	1.94	0.59	2.37
T18	2.26	0.35	0.98
T19	1.66	0.44	0.79
Average	2.06	0.43	1.53
CD(5%)	0.59	0.23	0.28
SE	-	-	-

4.1.3.4 Silicon

The effect of silicon content in leaves as influenced by different treatments is shownin Table 21. Treatments are found to be statistically significant differences. Theranges of Si content is varied from 11.72 ppm in T_{10} to 2.69 ppm in control. T_{10} receives second level of silicon (40 ppm). The average Si content in treated leaves is 6.73 ppm.

4.1.3.5 Boron

The effect of silicon, boron anc zinc application on the leaf B content of bitter gourd is presented in table 21. There was significant difference among boron content of the leaves as influenced by treatments. It ranges from 102.83 ppm in case of $T_{13}$to 27.53 ppm in control. The highest B content was shown when treatment applies at B-0.6% foliar + Zn -0.2% foliar + Si-20 ppm in soil.

4.1.3.6. Zinc

The data with respect to zinc content in the leaf is presented in Table 21. The treatments among Zn content of the leaves were found to be significant. Zn content ranges from 83.10 ppm in T_{18} to 57.30 ppm in control. The average Zn content of treated leaves is 73.12 ppm. T_{18} is the treatment combination of B-0.6% foliar + Zn-0.6% foliar + Si-40 ppm in soil.

Table 21: Effect of silicon, boron and zinc application on available micronutrient content of bitter gourd leaves

Treatments	Silicon (ppm)	Boron (ppm)	Zinc (ppm)
T1	4.69	45	78.9
T2	10.76	86.60	61.7
T3	3.51	41.90	56.8
T4	7.05	97.70	75.9
T5	6.46	44.95	74.8
T6	6.12	69.60	81.6
T7	5.15	60.97	82.66
T8	9.23	29	59
T9	6.37	58.67	76
T10	11.72	52.27	74.8
T11	7.68	56.97	81.6
T12	6.55	42.87	82.6
T13	6.69	102.83	58.9
T14	5.67	65.33	59.9
T15	5.52	53.80	73.3
T16	8.63	77.00	73.2
T17	5.72	34.30	81.4
T18	3.60	48.63	83.1
T19	2.69	27.53	57.3
Average	6.73	59.36	73.12
CD(5%)	0.32	12.05	1.19
SE	-	-	-

Plate 3: Fruit characteristics of best treatments vs control (T_{19})

Plate 4: Best treatment

Discussion

5. DISCUSSION

Discussion of the results of investigation carried out at College of Agriculture, Padanakkad and Regional Agricultural Research Station farm of Nileswar to study the effect of silicon, boron and zinc nutrition in bitter gourd var. Preethi is presented below. The investigation comprised of pot culture and field experiments. Zinc and boron were given as foliar spray while silicon was applied to the soil.

5.1 POT CULTURE STUDIES

5.1.1. Effect on plant growth parameters

Foliar application of B, Zn and soil application of Si were found to be non significant in the case of plant growth characteristics like plant height and days for first male flowering. While number of branches, days for first female flowering and days for first harvest were found to be influenced significantly (Table 4) by the treatment. Increases were also recorded in fruit characteristics like number of fruits, fruit length, fruit breadth, fruit weight, keeping quality and overall yield in treatments receiving Zn, B and Si. This promoting effects in treatments receiving these nutrient combinations in one level or other showed superiority over control. However, significantly better values for each parameters were different for different treatments and these might be due to the beneficial effect of B, Zn and Si. Bitter gourd is sensitive to lack of micronutrient and the micronutrients are often incorporated to improve the growth as reported by Njoroge and Van Lujik (2004).

Gregam *et al.* (1998) had observed that application of boron 2, 4 and 6 ppm in bitter gourd increased fruit and seed yield and fruit maturity was earliest due to the application of B at 4 ppm. Fruit yield was also highest in this treatment. In this present study the results indicated that the application of foliar B (0.6%) is enhanced the fruit yield.

While assessing the quality of fruits a notable observation is that, compared to control, vitamin C and Fe content of fruits were high in plants which received these nutrients (Table 6). Nutritionally bitter gourd fruit ranks first among the cucurbits in respect of iron and ascorbic acid (vit. C). Application of B increased vit. C content in bitter gourd (Verma *et al*, 1984). Among the cucurbits, it is considered a prized vegetable because of its high nutritive value especially with high ascorbic acid and iron (Behera *et al.*, 2004)

5.1.2. Effect on soil nutrient status

The effect of Si, B and Zn application on the soil nutrient status were studied and there was significant effect of treatment on soil parameters like pH, EC, OC, K, Ca, Mg, Si, B and Zn. But the treatments did not influenced N, P and S status of the soil.

pH of the soil receiving the treatments were higher than that of control. This may be the beneficial effect of Ca, because Si is applied as calcium silicate to soil. Excess uptake of anions over cations leads to the net removal of protons in the soil and causes an increase in soil pH.

Organic carbon of the soils was significantly influenced by the treatments application. On an average, OC content of the treatments were found to be higher than that of control. But the OC content of the soil was generally very low. The increase may be due the beneficial effect of higher nutrition.

The treatments did not show any significant effect on available N and P in soil in the case of pot culture experiments. This may be due to the positive effect of Si and B on N uptake since in the present study, appreciable increase in available B and Si content of soil was evidenced for the application of calcium silicate and foliar sprays of B. Similar results have been reported by Ho *et al.* (1980) and Barman *et al.* (2014). Zinc and phosphorus have antagonistic effect in soil as well as plant systems.

The available K content in soil was influenced by the treatments (table 8). The increase in K availability may be due to the avoidance of leaching loss of K as a result of Si application. Similar observations were also made by Lalithya *et al.* (2014) and Mongia *et al.* (2003). Matichenkov and Bocharnikova (2010) have also reported that soil application of Si amendments can help in reducing the leaching loss of K. Increase in K availability of soil due to B application was also reported by Barman *et al.*, (2014).

Ca and Mg status of the soils were found to be significantly influenced by the treatment applications. Ca content of the soils increased with levels of Si, B and Zn. S content of the soils was found to be non significant. However, S status in the treatment applied plots were marginally higher than that of control.

The Si availability showed a concomittant increase with application of Si as calcium silicate. But as indicated in leaf Si content the available Si in soil registered low values in the treatments. This decrease may be due to increased absorption of Si by the enhanced vegetative and reproductive growth of the plants receiving the treatments.

B and Zn levels in the soil were found to be higher in the soils which received foliar sprays. Thus may be due to the washing and by draining the fertilizer solution from leaves to the soil surface as reported by Nomura *et al.* (2011).

5.1.3. Effect of treatments on leaf nutrient status

After application of the treatments, leaf samples were taken from the plants at harvest stage and analyzed for nutrients. The effect of Si, B and Zn nutrition showed significant differences in the leaf nutrient status of N, P, K as well as Si, B and Zn on the leaf nutrient status.

Treatment application caused an increase in the N and K content of the leaves compared to control. P content in the leaves show lower value compared to control. This might be the antagonistic effect of Zn on P.

Significant different in Si, B and Zn concentration of the leaves was noticed. The Si nutrition of bitter gourd evaluated in terms of concentration and uptake was naturally influenced by Si fertilization as calcium silicate (soil application). With respect to content and uptake of Si, in the pot culture experiment application of calcium silicate (40 ppm) with zinc sulphate (0.2%) and borax (0.6%) was significantly superior to other treatments.

B nutrition of bitter gourd showed a promising improvement due to the application of borax both as soil treatment and as foliar spray. Increased concentration of B from first to third level increased the B levels in leaves. Highest B content was observed when B was applied at 0.6%.

5.2. Field Experiment

Similar experiment as in the case of pot culture with same treatment combinations was also carried in field conditions. It was found that soil application of Si and foliar application of B and Zn significantly enhanced the vegetative characters like number of branches, plant height, days for first flowering and yield characters like number of fruits per plant and yield per plant. Vitamin C and Fe content of the fruits also exhibited significant difference among the treatments.

5.2.1. Effect on plant growth parameters

The effect of Si, B and Zn nutrition made substantial effect on the growth parameters. B and Zn fertilization through foliar and soil application of Si has accomplished significant variation in plant growth parameters like plant height, number of branches and days taken for flowering. In field experiment also, the treatment receiving B (0.6%) foliar spray + Zn (0.2%) foliar spray + Si (40 ppm) on soil basis showed best results. This can be attributed to the significant increase in available silicon and boron to the plants in the treatment and positive influence on the availability and uptake of other macro and micro nutrients as influenced by this treatment combination. Similar reports were made by Debnath *et al.* (2009), Gholami and Falah (2013) and Ahmad *et al.* (2013). Number of branches was higher in treatments when compared to control. This is because Zn is important for enzyme activity. More than 70 metalloenzymes containing Zn have been identified, these only account for a relatively small proportion of the total Zn in a plant (Brown *et al.*,1993). Zinc deficient plants have been reported to leak more root exudates resulting in more diseases and poor performance (Welch *et al.*, 1982).

5.2.2. Effect of Si, B and Zn on yield

The effects of these nutrients on yield are shown in table 5. Highest yield was observed when Si is given at higher level (40 ppm). Cucurbits need Si as a beneficial element and in bitter gourd silicon help in production of fruits with good colour and sturdy spines which will not break away on packing and transport (Iwasaki and Matsumura, 1999). The role of Si in plants are enhancement of growth and yield, resistance against lodging, enhances photosynthesis, resistance against disease causing organism (Epstein, 2001).

In the case of B, there is not much variation between treatments among yield. But the application is necessary because a commendable increase in yield was noticed when compared to control. Similar results were observed by Gedam *et al.* (1998), who reported that the application of boron 2, 4, and 4 ppm in bitter gourd increased fruit and seed yield and fruit maturity was earliest due to the application of boron at 4 ppm.

Highest yield was noticed when Zn applied at lower dose (0.2%). The finding indicated the level of Zn were found significant on fruit yield (kg/plant). The increase in yield of bitter gourd is due to micronutrients may be due to the higher rate of photosynthesis and sugar formation due to enhanced chlorophyll synthesis and enzyme activity which lead to translocation of more photosynthates to growing fruits which ultimately leads to higher production of dry matter and consequently more yield. Also various reactions in plant metabolism are catalyzed by micronutrients. Zn is an essential catalyst in the synthesis of auxin from tryptophan would have encouraged the auxin biosynthesis in the active sinks which would have led to higher transport and accumulation of photosynthates in these sinks in fruits and hence, improving yield. These results are in conformity with those of Dongre *et al.* (2000) for yield per plant, yield per plot and yield per hectare in chilli, Nusin (1991) and Ingel *et al*, (1993) for fruit diameter, length of fruit and fresh green chillies per plot and Ravichandran *et al.* (1995) in brinjal. Effect of treatment combinations are depicted in figure 2.

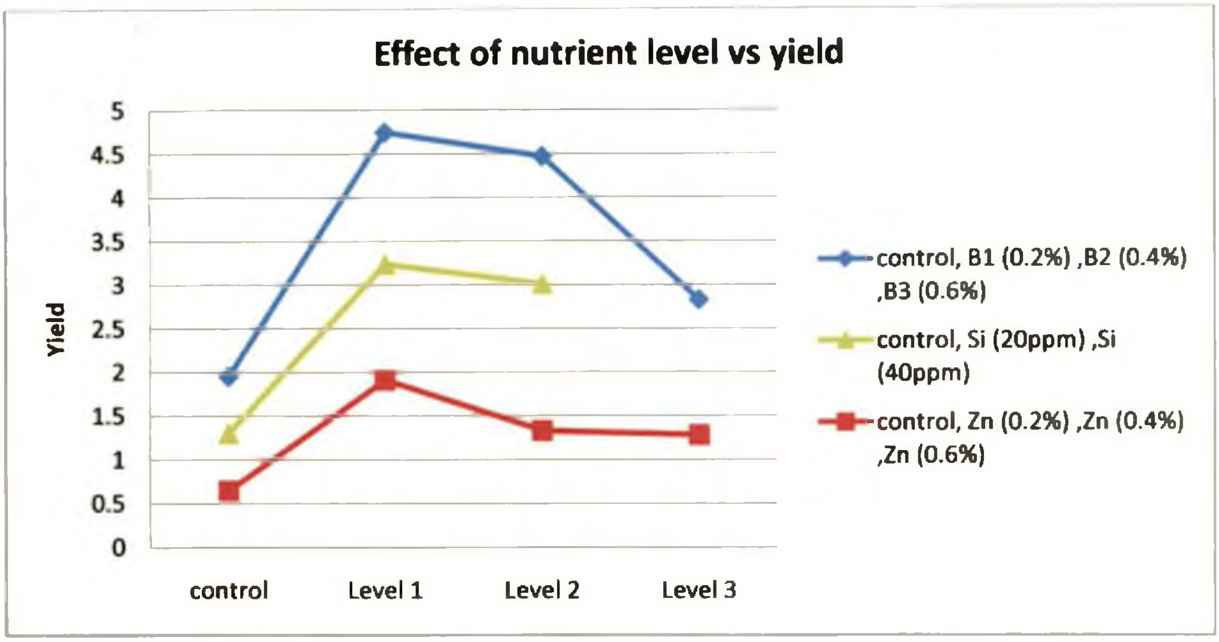

Figure 2: Effect of nutrient levels on bitter gourd yield

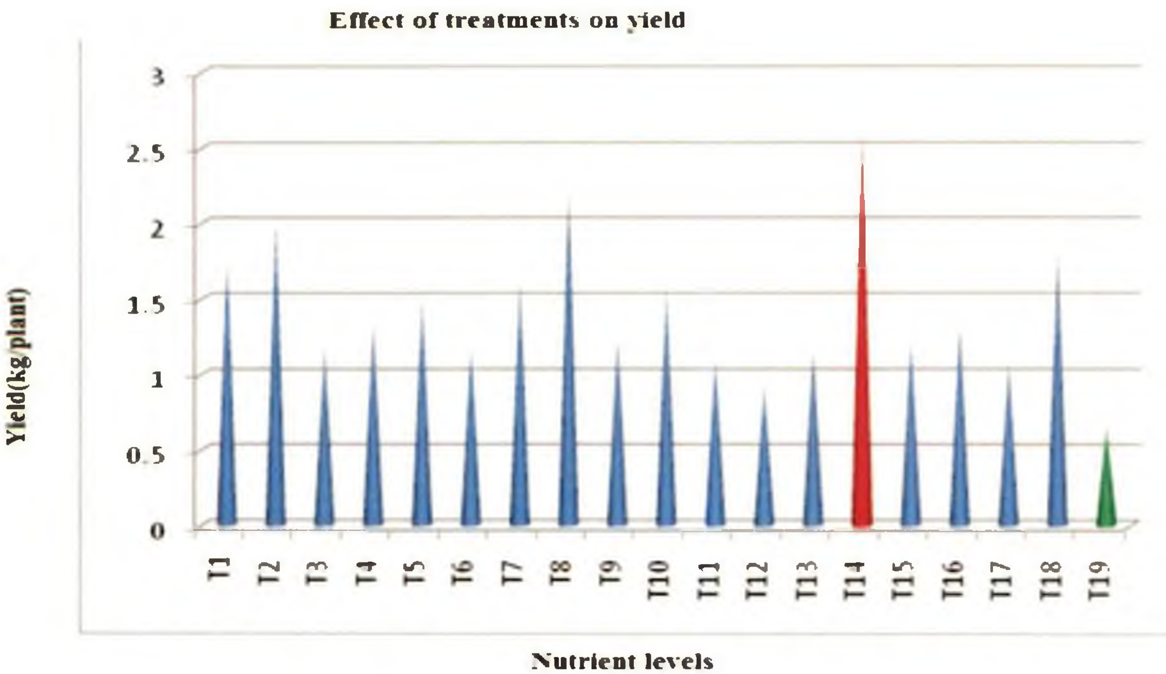

Figure 3: Effect of treatments on bitter gourd yield

5.2.3. Effect on soil nutrient status

The treatments shows significant effect on available N, P_2O_5 and K_2O content in soil in the case of field experiments. This may be due to the positive effect of Si and B on N availability since in the present study, appreciable increase in available B and Si content of soil was evidenced for the application of potassium silicate and borax as foliar spray. Similar results have been made by Ho *et al.* (1980) and Barman *et al.* (2014). Available P_2O_5 content in soil was significantly higher in the case of treatment application. This might be due to the fact that the anion monosilicic acid $[Si(OH)_3]^-$ can replace the phosphate anion $[HPO_4]^{2-}$ from aluminum and iron phosphates there by increasing the solubility of P. In the case of field experiment, application of calcium silicate @ 100 kg Si ha^{-1} + borax @ 10 kg ha^{-1} showed similar results. Similar results have been reported by Subramanian and Gopalswamy (1990); Matinchav *et al.* (2000).

The available K content in soil was influenced by the treatments in both pot and field experiments. The increase in K availability may be due to the avoidance of leaching loss of K as a result of Si application. Similar observations were also made by Lalithya *et al.* (2014) and Mongia *et al.* (2003). Matichenkov and Bocharnikova (2010) have also reported that soil application of Si amendments can help in reducing the leaching loss of K. Increase in K availability of soil due to B application was also reported by Barman *et al.*, (2014). This may be also due to the production of hydrogen ions during reduction of Fe and Al toxicity which would have helped in the release of K from the exchange sites or from the fixed pool to the soil solution. Similar results were reported by Patrick and Mikkelsen (1971).

Ca, Mg and S status of the soils were found to be significantly influenced by the treatments applications. This may be due to the application of Si as calcium silicate on soil basis. Si, B and Zn status of soil found to be significantly different compared to control. Si content is affect due t the application of calcium silicate on soil. B and Zn content in soil is affected because of washing out of foliar residues.

5.2.3. Effect on leaf nutrient status

The treatment application showed a notable differences in leaf nutrient status of N, P, K, Si, B and Zn. The content of N in leaf was conspicuously higher for the treatments receiving foliar application of B and Zn and soil application of Si. If the soil have higher alkaline $KMnO_4$-N content then this might have naturally resulted in enhanced absorption of N by the crop leading to higher N content and uptake. Similar results have been reported by Sing *et al.* (2006) and Barman *et al.* (2014). Application of B-0.6% foliar + Zn-0.4% foliar + Si- 20 ppm on soil is registered highest P content in leaf. The available P in the soil was also high in the above treatments owing to the phosphate anions released from Fe and Al phosphate by monosilicic acid anions produced by the treatments. This would have resulted in better absorption of P by plant which has reflected in better content and uptake of P.

Similar results were reported by Ma and Takahashi (1990). Increased K concentration in soil would have contributed to greater K absorption by plant which has reflected in higher content in straw, grain and total uptake. Liang (1999) reported similar results.

The Si nutrition of bitter gourd is evaluated in terms of concentration and uptake was naturally influenced by Si fertilization as calcium silicate (soil application). With respect to content and uptake of Si, in the field experiment application of B-0.4% foliar + Zn 0.4% foliar + Si-40 ppm on soil basis was significantly superior to other treatments. Soil application of calcium silicate reflected significantly higher content and uptake of Si in plant. These findings are in line with those reported by Singh *et al.* (2006). Boron nutrition of course as one could expect showed a promising improvement due to application of borax as foliar spray. Similar results were reported by Gupta and Cutcliffe (1978) and Rakshit *et al.* (2002). Zn content was found to be in the medium range in leaves. This might be because Zn deficient plants can absorb high concentrations of B in a similar way to Zn deficiency enhancing phosphorus toxicity in crops and this is probably due to impaired membrane function in the root (Alloway, 2008).

Summary

6. SUMMARY

The salient findings of the present study entitled "Silicon, boron and zinc nutrition of bitter gourd (*Momordica charantia* L.) var. Preethi" are summarized in this chapter.

Investigation was carried out at College of agriculture, Padannakkad and Regional Agricultural Station farm of Nileswar during April 2014 to August 2014 with the objective to standardize dose and method of application of silicon, boron and zinc in red loam soils. The whole study consists of two parts – pot culture and field experiments.

The pot culture sturdy was conducted at COA, Padannakkad. The experiment was carried out in RBD taking into consideration of the varying light intensity at the site of pot culture area. The treatments were applied with three levels of each zinc and boron (0.2, 0.4 and 0.6%) respectively and two levels of silicon (20 and 40 ppm) on soil basis. There were eighteen treatment combinations and one control with three replications. The soil taken from the field of RARS, Nileswar was uniformly filled in pots arranged in three blocks and then plants was raised in that. Five seed were sown in each plot then thinned to single plant. Silicon is applied as calcium silicate to soil at the time of planting. Boron and zinc are applied as foliar with borax and zinc sulphate respectively, biometric and yield data were collected. Significant differences among the treatments were observed in the biometric characteristics of plants and for yield, T_{14} (B-0.6% foliar + Zn-0.2% foliar + Si-40 ppm in soil) recorded highest fruit length, breadth, weight and vitamin C content.

The field experiment with same treatments was also carried in RARS farm, Nileswar in RBD with nineteen treatment and three replications. Three plants were maintained in each pit and each of the plot have four such pits. Major nutrients *viz,* N, P, K application and other cultural practices were uniformly followed for all plants as per Package of Practices, KAU (2011). Method of application and level of application of silicon, boron and zinc were same as that of pot culture experiment. Foliar application are done at 30^{th}, 40^{th} and 60^{th} days after planting. Soil application of silicon at two levels was done at the time of planting.

The result of field experiment showed that treatment application significantly enhanced the number of fruits, fruit length, fruit breadth and fruit weight. Highest viamin C was found in T_{14}(B-0.6% foliar + Zn-0.2% foliar + Si-40 ppm in soil). It also showed highest fruit length, breadth, weight and yield. While in the case of Fe content of fruits T_9(B-0.4% foliar + Zn-0.4% foliar + Si-20 ppm in soil) recorded highest concentration in fruits.

Maximum number of fruits was observed in T_3 (B-0.% foliar + Zn-0.4% foliar + Si-20 ppm in soil), minimum number of days taken for female flower as well as for first harvest is recorded in T_5(B-0.2% foliar + Zn-0.6% foliar + Si-20 ppm in soil). Number of branches is highest in T_1(B-0.2% foliar + Zn-0.2% foliar + Si-20 ppm in soil). Eventhough statistically non significant control plants shows greater degrees of fruit fly attack compared to treatments.

The effect of silicon, boron and zinc application on soil nutrient status of N, P, K, Ca, Mg, S, Si, B, Zn, pH, EC and OC was found to be significant.

The average pH value of the soil in treatment plots were higher than that of control plot. Highest pH (6.45) was found in T_8 (B-0.4% foliar + Zn-0.2% foliar + Si-40 ppm in soil). Electrical conductivity of the soils exhibited significant differences among the treatments and average EC of the treatment plots were higher than that of control plot. Highest EC was found in T_1(B-0.2% foliar + Zn-0.2% foliar + Si-20 ppm in soil) while lowest was in T_8(B-0.4% foliar + Zn-0.2% foliar + Si-40 ppm in soil). Organic carbon content of the soils was also significantly influenced by treatment applications. Highest OC was found in T_{11} (B-0.4% foliar + Zn-0.6% foliar + Si-20 ppm in soil).

Available N content of soil was significantly affected by treatment application. Highest available N was recorded in T_9. Treatment application significantly influenced soil P_2O_5 and K_2O content.Highest available P_2O_5 and K_2O found in T_{12} (B-0.4% foliar + Zn-0.6% foliar + Si-40 ppm in soil) and T_{11} (B-0.4% foliar + Zn-0.6% foliar + Si-20 ppm in soil)

N, P and K content of leaves found to be significantly affected. By treatments. N content is highest when treatments are given B-0.4% foliar + Zn-0.6% foliar + Si-20 ppm. Si, B and Zn cont also found significantly affected by treatments.

The results of the field experiment showed that treatment application significantly enhanced the fruit weight, length, breadth, vit. C and Fe contents of fruits. The highest fruit weight and vit. C content were recorded in T_{14}(B-0.6% foliar + Zn-0.2% foliar + Si-40 ppm in soil). Minimum days taken for female flowering was recorded in T_5 (B-0.2% foliar + Zn-0.6% foliar + Si-20 ppm in soil). The same treatment recorded minimum days for first harvest.

The effect of Si, B and Zn nutrition on soil nutrient status of N, P, K, Ca, Mg and S was found to be significant.

Available N content of the soil was significantly influenced by treatment application. Highest available N was recorded in T9. Increasing level of Zn decreased the P levels in soil. K level in soil increased with increasing level of B. Available K is highest in T_{11}(B-0.4% foliar + Zn-0.6% foliar + Si-20 ppm in soil).

As the leaf nutrient concentration of bitter gourd is concerned significant influence of treatment application of Si, B and Zn status of leaves. Highest Si content was recorded when treatment is given with a combination of (B-0.4% foliar + Zn-0.4% foliar + Si-40 ppm in soil). B content is ranges from 102.83 ppm to 27.23 pmm.

Benefit cost ratio of the best treatment (T_{14}) found to be 2.13 (@Rs 30/kg of fruit). So this shows that the treatment is promising higher returns to the farmers.

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SILICON, BORON AND ZINC NUTRITION OF BITTER GOURD (*Momordica charantia* L.) Var. PREETHI

by

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ABSTRACT

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ABSTRACT

The experiment entitled "Silicon, boron and zinc nutrition in bitter gourd (*Momordica charantia* L.) var.Preethi" was carried out with the objective to standardize the dose and method of application of silicon, boron and zinc red loam soils. The investigation was carried out at College of Agriculture (COA), Padannakkad and RARS farm at Nileswar during April 2014 to August 2014. The whole study consisted of two parts- pot culture and field experiments.

The pot culture study was conducted at COA, padanakkad. The experiment was carried out in RBD taking into consideration of varying light intensity at the site of pot culture area. The treatments applied with three levels each of zinc and boron (0.2, 0.4 and 0.6%) respectively and two levels of silicon (20 and 40 ppm) on soil basis. There were eighteen treatment combinations and one control with three replications. The soil taken from the field of RARS, Nileswar and uniformly filled in pots arranged in three blocks and then plants was raised in that. Five seed were sown in each pot then thinned to single plant. Silicon is applied as calcium silicate to soil at the time of planting. Boron and zinc are applied as foliar with borax and zinc sulphate respectively, biomtric yield data were collected. Significant differences among the treatments were observed in the biometrics characteristics of plants and for yield. T_{14} (B-0.6% foliar + Zn-0.2% foliar + Si-40 ppm in soil) recorded highest fruit length, breadth, weight and vitamin C content.

Another experiment with same treatments was also carried in RARS farm, Nileswar in RBD with nineteen treatment and three replications. Three plants were maintained in each pit and each of the plot have four such pits. Majour nutrients *viz,* N, P, K application and other cultural practices were uniformly followed for all plants as Package of practices, KAU (2011). Method of application and level of application of silicon, boron and zinc were same as that of pot culture experiment. Foliar application are done at 30th , 40th , 60th days after planting. Soil application of silicon at two levels was done at the time of planting.

The result of field experiment revealed that, yield and quality parameters differed significantly with the application of varied levels of Si, B and Zn. Highest vitamin C was found in T_{14} (B-0.6% foliar + Zn-0.2% foliar + Si-40 ppm in soil). It also showed highest fruit

length, breadth, weight and yield. While in the case of Fe content of fruits T_9(B-0.4% foliar + Zn-0.4% foliar + Si- 20 ppm in soil) recorded highest concentration in fruits.

After the harvest, the effect of these treatments on soil nutrient availability was studied. The results showed that available N, P, K, Ca, Mg, S, Si, B and Zn status in treated plot were improved significantly when compared to control. Similarly, leaf nutrient analysis at the time of harvest revealed that N, P, K, Si, B and Zn were showed significant differences among treatments.

Both pot culture and field experiment indicated th effect of silicon and boron are more important than zinc in bitter gourd. T_{14} (B-0.6% foliar + Zn-0.2% foliar + Si-40 ppm in soil) found to be performing well under pot culture and field conditions respectively.