"IMPACT OF FOLIAR SPRAY OF MICRO-NUTRIENTS ON GROWTH, YIELD AND QUALITY OF BROCCOLI (*Brassica oleracea* L. *var. Italica*) UNDER POLY HOUSE CONDITION"

M.Sc. (Hort.) Thesis

by

Alka Minz

DEPARTMENT OF VEGETABLE SCIENCE

COLLEGE OF AGRICULTURE

FACULTY OF HORTICULTURE

INDIRA GANDHI KRISHI VISHWAVIDYALAYA

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"IMPACT OF FOLIAR SPRAY OF MICRO-NUTRIENTS ON GROWTH, YIELD AND QUALITY OF BROCCOLI (*Brassica oleracea* L. *var. Italica*) UNDER POLY HOUSE CONDITION"

Thesis

Submitted to the

Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.)

by

Alka Minz

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

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CERTIFICATE –I

This is to certify that the thesis entitled "**Impact of foliar spray of micro-nutrients on growth, yield and quality of Broccoli (*Brassica oleracea L. var. Italica*) under poly house condition**" submitted in partial fulfillment of the requirements for the degree of **Master of Science in Horticulture (Vegetable Science)** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) is a record of the bonafide research work carried out by **Alka Minz** under my/our guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma or has been published/published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been duly acknowledged by her.

Chairman

Date: 7-10-2021

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMTTEE

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Member	(Dr. H. K. Panigrahi)	
Member	(Dr. S. S. Porte)	
Member	(Dr. R.R. Saxena)	

CERTIFICATE – II

This is to certify that the thesis entitled **"Impact of foliar spray of micro-nutrients on growth, yield and quality of Broccoli *(Brassica oleracea L. var. Italica)* under poly house condition"** submitted by **Alka minz** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) in partial fulfillment of the requirements for the degree of **Master of Science in Horticulture (Vegetable Science)** in the **Department of Vegetable Science** has been approved by the external examiner and Student's Advisory Committee after oral examination, the chairmanship of head of the Department.

Signature of Head of the Department

(Name Dr. Neeraj Shukla)

Date: 23-10-2021

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Faculty Dean _____ 23.11.21

Approved/Not approved

Director of Instruction _____

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LIST OF SYMBOLS/NOTATIONS

NOTATIONS	Full form
%	Per cent
@	At the rate
^{0}C	Degree Celsius
et al.	And others/ and co-workers
etc.	And so on; other people/ things
Fig.	Figure
i.e.	That is
$Plant^{-1}$	Per plant
viz.	Namely
Var.	Variety
Avg.	Average
S. No.	Serial Number
Temp.	Temperature
Ha	Hectare
max.	Maximum
min.	Minimum
Cm	Centimeter
T	Treatment
Mm	Millimeter
G	Gram
$Kg\ plot^{-1}$	Kilogram per plot
Mg	Milligram
qha^{-1}	quintal per hectare
Min	Minute
S	Second
No.	Number
L^{-1}	Per liter

LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
CD	Critical Difference
DAT	Days After Transplanting
FYM	Farm Yard Manure
SE(m)	Standard error of mean
RDF	Recommended dose of fertilizer
CV.	Cultivar
B:C	Benefit cost ratio
IGKV	Indira Gandhi Krishi Vishwavidyalaya
NPK	Nitrogen, Phosphorus, Potassium
MOP	Muriate of Potassium
RF	Rain Fall
RH	Relative Humidity
Ppm	Parts per Million
B	Boron
S	Sulphur
Cu	Copper
Zn	Zinc
$ZnSO_4$	Zinc sulphate
H_3BO_3	Boric acid
$CuSO_4$	Copper sulphate
R	Replication

THESIS ABSTRACT

a)	Title of the Thesis	:	"Impact of foliar spray of micro-nutrients on growth, yield and quality of Broccoli (*Brassica oleracea L. var Italica*) under poly house condition"
b)	Full Name of the Student	:	Alka minz
c)	Major Subject	:	Vegetable Science
d)	Name and Address of the Major Advisor	:	Mrs. Nisha Jangre (Assistant Professor) Department of Vegetable Science, College of Agriculture, Raipur (C.G.)
e)	Degree to be Awarded	:	M.Sc. (Hort.) Vegetable Science

Signature of the Student

Signature of Major advisor

Date- 7-10-2021

Signature of Head of the Department

ABSTRACT

The Present investigation entitled "Impact of foliar spray of micro-nutrients on growth, yield and quality of Broccoli (*Brassica oleraceae L. var. italica*) under poly house condition" was conducted during *Rabi* season 2020-21 under department of Vegetable Science at "Center of Excellence on Protected Cultivation and Precision Farming", IGKV, Raipur (C.G.). The experiment consisting of 10 treatments viz., copper sulphate @ 0.20 %, copper sulphate @ 0.40 %, copper sulphate @ 0.60 %, boric acid @ 0.20 %, boric acid @ 0.40 %, boric acid @ 0.60%, zinc sulphate @ 0.20 %, zinc sulphate @ 0.40 % and zinc sulphate @ 0.60 %.

Experiment was carried out with Completely randomized design with ten treatments and three replications. All the treatments exhibited superior growth, yield and quality of broccoli. Treatments T_9 -zinc sulphate @ 0.60% found highly effective for growth and quality parameter as it showed greatest plant height (66.81cm), no. of leaves (26.47), stalk length (18.22 cm), root length (16.06 cm), ascorbic acid content (86.44 mg) and total soluble solid (7.74%) while T_5- boric acid @ 0.40% was found superior to days to first curd induction, 50% maturity and harvest of curd.

The T_5- boric acid @ 0.40% was found highly effective for yield attributing as it showed highest curd yield plant^{-1} (326.46 g), yield plot-^{1} (6.29 kg), yield ha^{-1} (157.24 q), curd diameter (17.57 cm), fresh weight of plant (901.98 g), dry weight of plant (104.22 g), fresh weight of curd (326.46 g) and dry weight of curd (36.51g). Economic study of broccoli showed that highest cost of cultivation (Rs 180735 ha^{-1}) with T_3-copper sulphate @ 0.60% while maximum gross income (Rs 471720 ha^{-1}), net income (Rs 292325 ha^{-1}) and B:C ratio (2.62) was observed with T_5- boric acid @ 0.40%.

शोध सारांश

अ.) शोध ग्रंथ का शीर्षक	:	"पॉलीहाऊस परिस्थिति के तहत सूक्ष्म पोषक तत्वो के पर्णीय छिड़काव का ब्रोकली (*ब्रेसिका ओलेरसिया* वर. इटालिका एल.) के वृद्वि, उपज और गुणवत्ता पर पड़ने वाले प्रभाव का मूल्यांकन"
ब.) छात्रा का पूरा नाम	:	अल्का मिंज
स.) प्रमुख विषय	:	सब्जी विज्ञान
द.) प्रमुख सलाहकार का नाम एवं पता	:	श्रीमति निशा जांगडे, सहायक प्रध्यापक, सब्जी विज्ञान विभाग, कृषि महाविद्यालय , इं.गां.कृ.वि.वि., रायपुर , (छ.ग.)
इ.) सम्मानित की जाने वाली उपाधि	:	एम.एस.सी. (उद्यानिकी) सब्जी विज्ञान

छात्रा के हस्ताक्षर

प्रमुख सलाहकार के हस्ताक्षर

दिनांक 7-10-2021

विभागाध्यक्ष का हस्ताक्षर

सारांश

वर्तमान जांच ''पॉलीहाऊस परिस्थिति के तहत सूक्ष्म पोषक तत्वो के पर्णीय छिड़काव का ब्रोकली (ब्रेसिका ओलेरसिया वर. इटालिका एल.) के वृद्वि, उपज और गुणवत्ता पर पड़ने वाले प्रभाव का मूल्यांकन'' शीर्षक से रबी सीजन 2020–21 के दौरान सब्जी विज्ञान विभाग के तहत ''सेंटर ऑफ एक्सेलेंस ऑन प्रोटेक्टेड कल्टीवेशन एंड प्रिसिजन फार्मिंग'' इं.गां.कृ.वि.वि , रायपुर (छ.ग.) पर आयोजित की गइ। प्रयोग में 10 उपचार शामिल हैं, जैसे कॉपर सल्फेट @ 0.20 %, कॉपर सल्फेट @ 0.40 %, कॉपर सल्फेट @ 0.60 %, बोरिक एसिड @ 0.20 %, बोरिक एसिड @ 0.40 %, बोरिक एसिड @ 0.60 %, जिंक सल्फेट @ 0.20 %, जिंक सल्फेट @ 0.40 % और जिंक सल्फेट @ 0.60 %।

दस उपचारों और तीन पुनरावृत्ति के साथ कम्प्लीटली रेंडमाइज्ड़ ब्लॉक डिजाइन का प्रयोग किया गया । सभी उपचारों ने ब्रोकली की बेहतर वृद्धि, उपज और गुणवत्ता का प्रदर्शन किया। उपचार टी 9–जिंक सल्फेट @ 0.60 % वृद्धि और गुणवत्ता पैरामीटर के लिए अत्यधिक प्रभावी पाया गया क्योंकि यह सबसे बड़ी पौधे की ऊंचाई (66.81 सेमी), पत्तों की संख्या (26.47), डंठल की लंबाई (18.22 सेमी), जड़ की लंबाई (16. 06 सेमी), एस्कॉर्बिक एसिड सामग्री (86.44 मिलीग्राम) और कुल घुलनशील ठोस (7.74 %) जबकि टी 5 – बोरिक एसिड @ 0.40% पहली कर्ड उत्पादित करने के लिय दिनों की संख्या, 50% कर्ड परिपक्वता होने के लिय दिनों की संख्या और कर्ड की कटाई के लिय दिनों की संख्या।

टी 5– बोरिक एसिड @ 0.40 % उपजा के लिए अत्यधिक प्रभावी पाया गया क्योंकि इनमें उच्चतम कर्ड उपज (326.46 ग्राम), उपज प्लॉट$^{-1}$ (6.29 किलोग्राम), उपज हेक्टेयर$^{-1}$ (157.24 क्विंटल), कर्ड व्यास (17.57 सेमी) दिखाया। , पौधे का ताजा वजन (1567.84 ग्राम), पौधे का सूखा वजन (104.22 ग्राम), कर्ड का ताजा वजन (326.46 ग्राम) और कर्ड का सूखा वजन (36.51 ग्राम)। ब्रोकोली के आर्थिक अध्ययन से पता चला है कि टी 3–कॉपर सल्फेट @ 0.60% खेती की उच्चतम लागत (180735 रूपये हेक्टेयर$^{-1}$) और टी 5– बोरिक एसिड @ 0.40% के साथ अधिकतम सकल आय (471720 रूपये हेक्टेयर$^{-1}$), शुद्ध आय (292325रूपये हेक्टेयर$^{-1}$) और बीः सी अनुपात (2.62) पाया गया।

CHAPTER I

INTRODUCTION

Cole group of vegetables are important among all winter vegetables. The group ‘cole crop’ is said to be derived from the wild cabbage, "cole warts" (*Brassica oleracea var. sylvestris*). Broccoli (*Brassica oleracea var. italica*) belongs to the genus Brassica and the family Brassicaceae, chromosome no. (2n=18) which comprises a diverse variety of crop plants originated from the Mediterranean Sea and changed over time by selection and breeding (Decoteau,2000). Vegetables, which are classified as herbaceous plants from which a portion is eaten cooked or raw during the main course of a meal, are an essential part of our agricultural system. After China, India is the world's second-largest producer of vegetables (Thamburaj and Singh, 2001).

Nutritionally, it contains vitamin A (9000 mg/100 g), vitamin B_1 (0.05 mg/100 g), vitamin B_2 (0.12 mg/100g), vitamin C (137 mg/100 g), minerals viz; calcium (1.29 %), phosphorus (0.79 %), potassium (3.5 %), sulphur (1.26 %), iron (205 ppm), iodine (1.965 ppm), copper (24 ppm), protein (3.3 %), total carbohydrates (5.5 %), fat (0.2 %), water (89.9 %) and calories (36/100 g) (Thamburaj and Singh, 2001). Nutritional composition of broccoli resembles that of cauliflower. It has about 130 times more vitamin A contents than cauliflower and 22 times more than cabbage. The unique combination of anti-oxidant, anti-inflamatory and pro-detoxification components in broccoli make its unique food items (Mateljan, 2009).

Its medicinal properties are steadily gaining more importance in the world. Broccoli's health advantages are attributed in part to secondary plant chemicals having antioxidant properties (Jones *et al*., 2006). Broccoli is also high in glucosinolates, which are the precursors to the chemoprotective isothiocyanate, a compound linked to cancer prevention (Aires *et al.,* 2006). Antifungal, bactericidal, nematicidal and alleopathic characteristics are associated with glucosinolates and their breakdown products (Fahey *et al.,* 2002). Broccoli is often high in sulphoraphane, has been linked to reduce the risk of lung and postrate cancer (Joseph et al., 2004). Broccoli is also high in vitamins C, which function as anti-carcinogens and lower the risk of cardiovascular disease. It is required for growth and repair of

body tissue. It aids the body's production of collagen, a tissue required for the health of bones, teeth, gums, and blood vessels (Anon 2007).

India is the world's second largest producer of vegetables, after China with an annual production of approximately 162.187 (million tonnes) from 92.05 (million hectare) of land, (Anon, 2013). India ranks second in terms of area and production of cauliflower and broccoli. In 2019, global production of broccoli (combined for production reports with cauliflowers) was 27 million tonnes, where as China and India together contribute for 73% of the world total. In India (2019) the production of broccoli was 9.1 million tonnes. Major broccoli producing growing states of India are West Bengal, Bihar, Odisha, Madhya Pradesh, Haryana, Gujarat and Jharkhand (FAO, 2019). However, this production does not meet the requirement of 300g of vegetables per capita per day. As a result, India's vegetable production must be greatly increased.

Morphologically, it resembles to cauliflower although the plant produces heads rather than curds, with green buds and thick fleshy flowering stalks. It has a large, generally green flower head arranged in a tree-like pattern on branches that grow from a thick, edible stem. Broccoli is green in colour due to the presence of chlorophyll in the sepals of the floral buds, which are cultivated as annual buds for the mature flower buds. Broccoli is dicotyledonous biennial herbaceous for seed production and considered as annual when harvested for fresh consumption. The temperature of 20^0C to 25^0C is optimum for its growth while 15^0C to 20^0C for its heading stage.

Horticultural crops suffer widely in zinc deficiency followed by boron, manganese, copper, iron and molybdenum deficiencies. The most appropriate method to overcome such deficiencies in crops is foliar spray of nutrients such as boron, copper, and zinc for growth and metabolism. Foliar application of micronutrients has different advantageous over soil application, in that nutrients are given and taken up directly by the target organs, resulting quick response. They are a vital component of the enzyme system and play an important part in the creation of chlorophyll, protein synthesis, and as an oxidation-reduction agent in biological systems (Kaya and Higgs, 2002).

Micronutrients, which include boron, chlorine, copper, iron, manganese, molybdenum, nickel and zinc, are required in small amounts than the other essential nutrients. They are essential for healthy plant growth and profitable crop production. Micronutrients provide an economical source for correcting nutrients deficiencies and improving plant health. Micronutrients can be used as both soil and foliar application.

Zinc is another essential micronutrient, highly essential for most of the Crucifers, specifically for broccoli. It was reported that zinc is a co-factor of broccoli myrosinase and promotes the synthesis of sulphoraphane during the first reaction. Zinc also dramatically regulates the plant growth and activates enzymes, so it's essential for plants as well, interveinal chlorosis, which causes stunted shoot growth and internode shortening, as well as mottled leaf and little leaf, is an indication of zinc deficiency in early plants (Liang *et al*., 2006).

Boron is important in glucose translocation, cell wall construction, and RNA synthesis, and it regulates these processes (Narayanamma *et al*., 2007). Boron is a critical micronutrient for a variety of plant activities, including providing structural stability and functional integrity to biological membranes, and facilitating the movement of sugar or energy into different growing sections of plants. It also aids pollination and seed germination (Hakala *et al.,* 2006). Boron deficiency in brassica plants results in severe symptoms such as head browning, cubical or transverse cracking, and discoloration.

Copper is a component of enzymes and serves as a catalyst for respiration. Copper is found in large amounts in enzyme proteins, which control the rate of a number of biochemical reactions in plants. Copper is a required non-mobile element for plant development and activation of various enzyme in carbohydrate and nitrogen metabolism, as well as lignin synthesis. Copper shortage can result in stem and twig dieback, leaf yellowing, and impaired plant development.

Looking to the above facts, the present investigation, entitled **"Impact of foliar spray of micro-nutrients on growth, yield and quality of Broccoli (*Brassica oleracea L. var. italica*) under poly house condition**" will be undertaken with the following objectives:

1. To find out most effective micro-nutrients and their optimum dose for growth and yield parameters of broccoli.
2. To study the effect of different micro-nutrients on qualitative parameters of broccoli.
3. To estimate the benefit – cost ratio of broccoli cultivation under different treatments.

CHAPTER II

REVIEW OF LITERATURE

Broccoli is one of the vegetable species most widely grown and consumed in the world (Pizetta *et al.* 2005). Macro-nutrients play a crucial part in the growth and development process of plant. Similarly, micro-nutrients are essential, since they are required for vital growth processes (Ali *et al.* 2008). Micro-nutrients can be provided to deficient soils through soil application, foliar spray or seed treatment to increase yield, nutritional value and nutrient usage efficiency (Malakouti 2009).

For optimum development it's essential to adopt the right fertiliser dose, as both rapid and slow growth are undesirable. Slow growth diminishes yield whereas rapid growth causes the bud clusters to become loose and hollow-stemmed (Chadha 2003).

Broccoli is a new crop grown in the tropical climate of Chhattisgarh. As a result, no previous research on broccoli had been done in tropical conditions, especially in Chhattisgarh. However, since it is close to cabbage and cauliflower, the work performed on those vegetables is also discussed here.

Effect of micronutrients on

2.1. Vegetative growth parameters

2.2. Yield attributing parameters

2.3. Quality aspect of broccoli

2.4. Economics

2.1. Effect of micronutrients on vegetative growth parameters

Bhagavatagoudra and Rokhade (2001) observed that there was a significant increase in plant height, dry matter accumulation and dry weight of nodules in cabbage when sulphur was applied @ 40 kg ha^{-1}.

Singh (2003) reported that in cauliflower cv. Pusa Synthetic, boron treatment led to significant improvements in cauliflower growth characteristics. At 45 DAT and 60 DAT, Borax applies at 5 kg ha^{-1} as soil application + 0.25% as foliar spraying, obtained maximum number of leaves (17.4) and leaf area (374.6cm).

Prasad and Yadav (2003) studied that the experiment in cauliflower cv. Snowball-16 that better performance was recorded due to the application of Boron

(0.3%) and molybdenum (0.3%) each individually as well as in the combination over the control, which were recorded in terms of vegetative parameters (i. e. number of leaves plant^{-1}, leaf width, plant height, stem diameter, length of stem and root length).

Adhikary *et al.* (2004) revealed that when the crop was treated with the application of borax @ 10 kg ha^{-1} results the greatest number of leaves plant^{-1} (12.73) and maximum height of plant (24.05 cm) was found when the crop was applied with borax 25 kg ha^{-1} in cauliflower.

Meena (2004) reported that the different doses of Nitrogen and Sulphur dramatically which improved the growth attributes. With 180 and 60 kg ha^{-1} nitrogen and sulphur, respectively, obtained the highest number of leaves (26.6 and 23.43), leaf area (1874.00 and 1784.00 cm^2) and plant height (56.09 and 50.09 cm), were recorded in sprouting broccoli.

Mahmud *et al.* (2005) determined that the influence of sulphur on the growth of cauliflower viz. number of leaves plant$^{-1,}$ Plant height, stalk length leaf width and leaf length. Different combination of boron, sulphur and molybdenum gave the statistically significant growth parameter. Better results were obtained by all the parameters in T_5 treatment (sulphur @ 30kg/h, Boron @ 1kg/h, Molybdenum @ 0.5kg/ha).

Zhi *et al.* (2005) reported that in both seasons, the activation of micronutrients in foliar spray achieved the highest values of vegetative growth expressed in broccoli as plant height (67.00 cm and 67.33 cm), leaves number (20.67 and 20.67), total plant fresh weight (1173.28 and 1125.02 g/ plant) and total plant dry matter (22.60 g and 23.18 g) were recorded by plants when supplied with Mix (zinc+ boron at 200 ppm from each).

Saha *et al*. (2006) revealed that in sprouting broccoli, increasing amount of borax from 15 to 21 kg ha^{-1} resulted in significant increasing plant height (58.66 cm), while increasing levels of ammonium molybdate from 1.2 to 1.8 kg ha-1 gradually increased plant height (56.54 cm).

Kanujia *et al.* (2006) found that research into the effects of micronutrients on cabbage vegetative development and yield revealed that, the foliar spraying of Zn

@100ppm gives highest plant height (40.8 cm), maximum leaf length (30.9 cm) and plant spread (44.4 cm^2) in cabbage variety Golden Acre.

Moniruzzaman *et al.* (2007) reported that in sprouting broccoli the maximum plant height (76.10 cm in 2004-05 and 78.12 cm in 2005-06) was produce at 1.5 kg B/ha + 200 kg N/ha ($B_{1.5}N_{200}$) closely followed by 1.5 kg B/ha + 100 kg N/ha ($B_{1.5}N_{100}$). The combination of 2.0 kg B and 200 kg N/ha (B_2N_{200}) produced maximum number of leaves $plant^{-1}$, plant spread and length leaf that were statistically at par with $B_{1.5}N_{200}$ and $B_{1.5}N_{100}$ treatment combinations.

Yadav *et al.* (2009) studied that the use of integrated micro-nutrient of ferrous sulphate (0.5%), zinc sulphate (0.5%), and boric acid (0.5%) gave higher plant height (45.20 cm), leaf length (32.40 cm), leaf width (24.20 cm) and days for initiation of heads (62.20) in cabbage.

Jamre *et al.* (2010) reported that sulphur and zinc application had an important impact on cauliflower growth and yield. Increases in number of leaves $plant^{-1}$, plant spread and plant height; as well as the application of zinc, had a major impact on cauliflower growth and yield.

Shah *et al.* (2010) observed that, boron application had a significant effect on stem length, stem diameter, and leaf width in sprouting broccoli, and spraying of borax @ 0.3 % at 30 and 45 DAT, it gives maximum stem length (45.57 cm), stem diameter (2.56 cm) and leaf width (15.62 cm).

Ahmed *et al.* (2011) recorded that the foliar application of molybdenum @ 45 µg per liter gave an average height of plant (88.69 cm) over control (84.73 cm) and number of leaves per plant (19.07) over control (18.20) in cauliflower.

Sitapara *et al.* (2011) observed that during the Rabi seasons investigated the effects of growth promoters (GA3 and NAA) and micronutrients (boron) on the cauliflower cv. Snowball-16 the foliar application of two spray (at 15 DAT and 30 DAT) of gibberellic acid @ 100ppm and boric acid at 0.2 % were obtained good for growth parameters (viz. number of leaves, leaf length plant height, stalk length and stem diameter etc).

Devi *et al.* (2012) has been noticed that the influence of application of foliar spray of borax @ (0.1 %) as on cabbage and the results are considerable and were

recorded that plant height, number of leaves per plant, root fresh weight, shoot fresh weight, dry weight and yield were enhanced significantly.

Kumar *et al.* (2012) revealed that, the integrated foliar application of boron 100 ppm and molybdenum 50 ppm gave highest plant height (57.27 cm), number of leaves (16.69), leaves length (48.99 cm), leaves width (18.95 cm), fresh weight of leaves (840.40 g), total weight of plant (1.69 kg), and desire maximum (73.33) days taken for curd maturity in the cauliflower.

Kumar *et al.* (2012) reported that the influence of foliar sprays of urea (1%), micronutrients (B, Zn, Mn, Cu, and Fe, each 0.2%), and GA3 (0.01%) on production productivity, earliness in curd production, and quality of broccoli cv. FIESTA. The urea 1% spray had the maximum ultimate plant spread in both the E-W and N-S directions (54.63 and 51.92 cm), whereas the boric acid 0.2 % spray had the significant increases in leaf number (16.79). However, GA3 0.01 % and zinc sulphate 0.2 % exceeded other treatments and controls in terms of stalk length (16.03 cm) and root length (15.07 cm), respectively, during harvesting.

Hassan *et al*. (2013) found that, the combined application of (Zn 2.48 %+ Fe 7.5% + Mn 3.5% + Cu 1% + B 0.65% + Mo 0.3%) in broccoli gave highest plant height (46.10 cm), number of leaves (17.16), leaf area (419.17 cm^2), shoot fresh weight (603.50 g), and shoot dry weight (14.69 g) and maintains superiority over other treatments.

Abd El-All (2014) studied that, all fertilisation treatments enhanced all vegetative growth parameters of broccoli, as evaluate by number of leaves per plants, leaf area, fresh weight of leaves and plant height, compared to the control. High levels of S (150 kg/fed) or Zn (200ppm), on the other hand, were responsible for the highest averages.

Lal *et al.* (2015) reported that Plant height (26.20 at 40 DAT and 50.58 at 60 DAT) and number of leaves per plant increased substantially when zinc levels were increased up to 30 kg/ha (29.09). Chlorophyll content (903.13 mg/100 g) and leaf area (2.46 cm^2), on the other hand, increased dramatically with rising zinc levels up to 20 kg/ha.

Singh *et al.* (2015) observed that there was a substantial response on broccoli growth for various treatments while sprouting broccoli. 120 kg N, 60 kg P_2O_5, 40 kg

K_2O_5, and 15 kg B are applied per hectare, highest plant height (65.33cm), number of leaves per plant (18.26), longest leaf length (52.99cm), longest leaf width (17.98cm), plant spread (55.53cm), and stem diameter (4.47cm).

Verma and Nawange (2015) was identified that the effect of varied quantities of nitrogen (N) and sulphur (S) on cabbage growth, yield and quality. Nitrogen application of 150 kg/ha and sulphur application of 60 kg/ha resulted in considerably higher plant height, plant spread, stem diameter, head diameter, head weight, and yield in cabbage.

Ain *et al.* (2016) reported that at 0.5 % Zn, maximum plant height (40.49 cm) and number of leaves per plant (13.08) were recorded, while at 1 % Zn, maximum leaf weight (9.66 g) and number of curds per plant (9.17) were observed in broccoli. With 0.25 % boron, the maximum plant height (39.31 cm) was observed, while the minimum plant height (32.30 cm) was observed in plants sprayed with 1 % boron. In broccoli, B @ 0.5 % resulted in the highest number of leaves per plant (12.83) and highest leaf weight (10.17 g), while 1 % boron resulted in the highest number of curds per plant (8.41).

Chaudhari *et al.* (2017) observed that spraying of micronutrients T8 (Fe 2.0 %, Mn 0.5 %, Zn 4.0 %, Cu 0.3 % and B 0.5 %) +(Ammonium molybdate) which shown significantly maximum on growth characters viz. plant height (74.93 cm), Length of stalk (16.59 cm), Number of leaves per plant (23.39) and Plant spread (N-S: 76.81 cm and E-W: 77.79 cm).

Singh *et al.* (2017) reported that micronutrients (B, Mo, Mn, and Zn) add @ 2 kg (B), 0.5 kg (Mo), 2.5 kg (Mn), 3 kg (Zn) per hectare significantly increased plant height (51.30 cm), number of leaves (22.92 cm), plant spread (52.83 cm), and bud or head diameter (16.90 cm) in broccoli.

Shivran *et al.* (2017) found that applying 30 kg zinc ha^{-1} to sprouting broccoli resulted in the highest and slightly more values of growth and yield attributes such as plant height (29.75 cm and 55.16 cm at 30 and 60 DAT) and number of leaves per plant (7.91 and 16.90 at 30 and 60 DAT), stem diameter (1.38 cm and 2.62 cm at 30 and 60 DAT) and plant spread (1.38 cm and 2.62 cm at 30 and 60 DAT).

Singh *et al*. (2018) reported that the plant height, no. of leaves and plant spread was highest in T6 (Boron + Manganese + Zinc) followed by T8 (B + Mo + Mn + Zn) at 20,40 and 60 DAT.

Singh *et al*. (2018) reported that on broccoli the result clearly indicated that the treatment zinc sulphate @ 0.60% exhibited highest plant height (63.29 cm), leaf length (43.63 cm), leaf width (22.60 cm), fresh plant weight (1908.83 g) and phenol content (8.86%).

Chowdhury and Sikder (2019) reported that tallest plant (61.32 cm) was recorded in combination of 0.05% Mo, 0.25% S and 1% Zn. Again, the combined treatment of 0.03% Mo, 0.05% S and 1.5% Zn showed significant maximum positive effect on head length (29.36 cm) and head diameter (30.22 cm) indicated that this combination treatment might be very effective in sprouting broccoli and the maximum leaf length and leaf width were recorded to be significantly highest at combined treatment of 0.05% Mo+ 0.05% S + 1.5% Zn i.e., 41.58 cm, and 29.35 cm.

Bairwa *et al.* (2020) revealed that in cauliflower the maximum number of leaves plant^{-1} (22.74 and 21.96), width of leaves (22.77 cm and 21.87), Length of leaves (45.62 cm and 44.28 cm), plant height (63.22 cm and 61.75 cm), length of root (23.67 cm and 22.36 cm), highest stem length (12.46 cm and 11.84 cm), maximum stem diameter (4.52 cm and 4.21 cm), earliest days to first curd initiation 43.75 days and 45.14 days, earliest 50% curd maturity 60.27 days and 61.44 day were recorded from treatment T5 (100% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + ZnSO4 @ 25 kg ha^{-1}) during both season (2017-18) and (2018-19).

2.2. Effect of micronutrients on yield attributing parameters

Hunashikatti *et al.* (2000) studied that the spraying of a combination treatment of 25 kg S and 1 kg Mo per ha led to a significant increase cabbage quality and yield (63.19 t/ha).

Yang *et al*. (2000) observed that the effect of eight B-Mo treatments on broccoli curd yield and active oxygen metabolism was studied, according to the study. B and Mo increased superoxide dismutase (SOD), peroxidase (POD) and nitrate reductase (NR) activity, decreased malondialdehyde content and

antioxidation rate, inhibited membrane lipid peroxidation, and increased curd yield, respectively, at 6 and 5 g/litre.

Bhagavatagoudra and Rokhade (2001) studied applying 40 kg S ha^{-1} gave highest yield of 45.74 t ha-^{1}, followed by 20 kg S ha^{-1} (39.74 t ha^{-1}) and (36.13 t ha^{-1}). As compared to the control, the head has a slightly higher weight (772.38 g), number of inner leaves (38.6), surface area (7.914 cm^2), and diameter (15.80 cm) in cabbage.

Rhoads and Olson (2001) reported 45 kg S ha^{-1} in cabbage was clearly excessive, as the highest yields were consistently achieved with 22 kg S ha^{-1}.

Sanderson and Tremblay (2003) revealed that sulphur and calcium affected the output of broccoli and cauliflower and discovered that sulphur enhanced broccoli output by up to 14% (as potassium sulphate) and cauliflower production by 25%. (as gypsum).

Prasad and Yadav (2003) observed that in cauliflower cv. Snowball-16 was recorded due to the application of Boron (0.3%) and molybdenum (0.3%) each individually as well as in the combination over the control, which were recorded in terms of yield attributing parameter (i.e. curd width, curd depth and curd weight).

Singh (2003) studied that in cauliflower cv. Pusa Synthetic, consequential enhanced yield of cauliflower was noticed due to application of Boron. Borax applies at 5 kg/ha as soil application + 0.25% as foliar spraying at 45, 60 DAT, obtained in the maximum weight of curd (510.0 g), diameter of curd (15.68 cm), depth of curd (8.48 cm), yield $plot^{-1}$ (16.23 kg), yield ha^{-1} (140.86 q).

Adhikary *et al.* (2004) found that the maximum weight of curd (10.9 Mt/ha) and diameter of the curd (10.28 cm) was obtained when the crop was supplied with borax @ 25 kg per ha in cauliflower.

Chhipa (2005) determined that the application of Zn 40 kg and sulphur 40 kg ha^{-1}, respectively, highest curd yield (286.23q/ha and 285.95 q/ha) and net return (Rs. 84132 and Rs. 83888) in cauliflower.

Pizetta *et al*. (2005) revealed that the yield intervals for broccoli, cauliflower, and cabbage were 16.9 to 20.5 t ha^{-1}, 21.6 to 29.6 t $ha^{-1,}$ and 40.5 to 46.3 t $ha^{-1,}$ respectively. Broccoli and cabbage yields increased in a linear relationship with boron levels, but cauliflower yields increased in a quadratic relationship.

Zhi *et al.* (2005) reported that responded of micronutrients in foliar spary supplied with Mix2 (200ppm zinc + 200 ppm boron) gave the highest head height (19.33cm and 21.00cm), head diameter (21.67cm and 20.67cm), number of stalks per head (16.33 and 16.00) and head fresh (941.61g and 953.55g) and dry weights (20.69g and 19.90g) in both seasons.

Bhat *et al.* (2006) studied that the application of boron @ 0.5 ppm increased the yield of cauliflower curd to the maximum level (25.50 Mt/ha).

Narayanamma *et al*. (2007) reported that the boric acid application @ 100 ppm resulted in head weight (1.80kg), head diameter (16.30 cm) and highest yield (39.70 Mt/ha), while application of ammonium molybdate @50 ppm produced head weight (1.37 kg), Head diameter (14.70 cm) and yield of head (33.10 Mt ha^{-1}) and application of zinc sulphate @ 100 ppm obtained weight of head (1.55 kg) and diameter of head (15.80 cm) and yield of head (8.10 Mt ha^{-1}) in cabbage.

Moniruzzaman *et al*. (2007) reported that yield attributes (diameter of head, main head weight and secondary shoot weight) and yield $plant^{-1}$ were also found highest from B_2N_{200} which was statistically identical to $B_{1.5}N_{200}$ and $B_{1.5}N_{100}$. With B_2N_{200}, the maximum head yields of 15.67 and 16.81 tonnes $hectare^{-1}$.

Lashkari *et al.* (2008) found that the application of ZnSo4 @ 0.5 per cent gave maximum marketable yield of curd (33.70 Mt/ha) over control (22.36 Mt/ha) in cauliflower cv. Snowball-16.

Firoz *et al*. (2008) reported that at 1.0 kg B/ha gives the highest yield (512.30 g/plant) was recorded. The highest weight of curd (294.60 g) was achieved in broccoli when boron was applied at 1.0 kg/ha. Curd weight and yield per plant vary significantly between cultivars in terms of varietal influence. The Green Harmony variety produced the best results (606.20 g/plant).

Nandi and Nayak (2008) observed that the effectiveness of micronutrients boron, zinc, molybdenum, copper, iron, and manganese alone and in combination as foliar sprays on hybrid cabbage. With 100 ppm as zinc sulphate sprayed thrice at 10-day intervals, the head weight (1.50 kg) was the maximum.

Dhakal *et al.* (2009) reported that the boron (B) and phosphorus (P) effect on soil nutrient status, plant nutrient uptake, and cauliflower (*Brassica oleracea var. botrytis* L.) variety Snowball-16 yield were investigated. Four levels of boron (0,

0.65, 1.3, 1.95 kg boron/ha) and four levels of phosphorus (0, 30, 60, 90 kg P_2O_5/ha) were included in the sixteen treatment combinations. Due to which application of 1.3 kg boron (B) with 60 kg P_2O_5/ha gives maximum curd yield.

Bhat *et al*. (2010) reported that applying boron as boric acid at 0.5 ppm improves cabbage and cauliflower yields (34.76 $Mtha^{-1}$ and 25.50 Mt/ha, respectively).

Shah *et al.* (2010) revealed the results show a significant impact on sprouting broccoli output, quality, and growth. The highest overall head yield (13.37 tones/ha) and protein content (3.24 g/100g) were obtained by spraying 0.3 percent borax at 30+45 DAT. It also produced the maximum diameter of central head (10.01 cm).

Shah *et al.* (2010) reported that with the application of boron and zinc @ 15 kg ha^{-1} each, the largest volume of knob (294.79 cc) was noticed in knol-khol.

Jamre *et al.* (2010) reported sulphur application had an enormous effect on cauliflower growth and yield. Increases in dry matter content, yield of curd, fresh weight of curd and dry weight of curd per 100 g of fresh weight, as well as the use of zinc, had a major impact on cauliflower growth and yield. Dry matter content, yield of curd, fresh weight of curd, and dry weight of curd per 100 g of fresh weight all increased significantly.

Sitapara *et al.* (2011) reported the growth promoters (GA_3 and NAA) as well as micronutrients (boron) on cauliflower cv. Snowball-16 obtained highest yield attributes (viz. curd diameter, curd depth, curd weight) and finally highest the curd yield of cauliflower.

Hussain *et al*. (2012) reported that the output of broccoli was dramatically boosted with boron application up to 1.0 kg ha^{-1}. As a result, this rate had a considerable impact on the reduction of hollow stem condition. A slightly higher level of B (1.0 kg ha^{-1}) resulted in the lowest incidence of hollow stem disorder, with a hollow stem index of 1.0, compared to a maximum of 1.16 when no B was applied.

Kumar *et al.* (2014) studied that, foliar spraying of boron 0.5% in cauliflower was the best treatment for maximum weight of curd (930.50g) and highest (310.70q/ha) marketable yield.

Abd El-All (2014) reported that apart from secondary curd yield character, which reached 2.940 ton/fed, it was concluded 2.830 ton/fed in the second season

because to excessive potassium levels. The highest yield; either primary or secondary, and total yield/fed for sulphur high rate. In both seasons, the use of a high rate of sulphur (150 kg/fed.) resulted in the largest percent increase in total yield, except for the 2.940 ton/fed secondary curd yield feature.

Islam *et al.* (2015) reported that when boron was applied @ 2 kg/ha.it gives highest yield (32.19 t/ha) of genotype Early Green variety of broccoli.

Lal *et al.* (2015) studied that the results indicate increasing the amount of zinc applied up to 30 kg/ha enhanced the average weight of central head, secondary head plant^{-1}, and central head volume (313.45g, 187.92g and 108.73cc). Biological production per plant (1.65 kg), total head production per plot (7.23 kg), per hectare (223.40q), and total number of secondary heads (8.67) all improved significantly as zinc levels were increased up to 20 kg ha^{-1}.

Singh *et al.* (2015) revealed that observations of sprouting broccoli demonstrated a substantial effect on broccoli yield for various treatments. With the application of 120 kg N+ 60 kg P_2O_5+ 40 kg K_2O_5+ 15 kg B ha^{-1}, gave the maximum length of curd (16.33cm), curd diameter (13.69cm), curd weight plant^{-1} (286.89g), weight of sprout plant-^{1} (126.89g), and total yield curd and sprout (148.51 q per ha) were attained.

Verma and Nawange (2015) found that the different doses of nitrogen and sulphur affected cabbage development, quality and yield. Determined that providing 150 kg of nitrogen ha^{-1} and 60 kg of sulphur ha^{-1} resulted in improved head width, head weight per plant, and cabbage production. The maximum yield was achieved when the treatment combination of 150 kg N/ha and 60 kg S/ha was used.

Ain *et al.* (2016) observed that 1 % boron was found in broccoli number of curds per plant (8.41). Zinc and boron levels of 0.5 % used in different treatments, produced better results in most of the growth and yield parameters.

Chaudhari *et al.* (2017) observed that application of micronutrients T_8 (Fe 2.0%, Mn 0.5%, Zn 4.0%, Cu 0.3% and B 0.5 %) + (Ammonium molybdate) which shown significantly higher on yield parameter viz. marketable curd yield (28.64 t/ha), curd width (19.16 cm), Gross weight (2.65 kg plant^{-1}) and Net weight (883.33 g plant^{-1}).

Choudhary and Paliwal (2017) reported that in sprouting broccoli, the overall head production (0.683 kg plant-1, 10.93 kg plot-1, and 337.28 q ha^{-1}) was highest when vermicompost @ 2.5 t ha^{-1} + FYM @ 5 t ha^{-1} + seedling inoculation with azosprillium + PSB culture was used in combination with S @ 40 kg ha^{-1} + Zn @ 5 kg ha^{-1} + Boron @ 1.5 kg ha^{-1}.

Singh *et al*. (2017) reported that among the treatment T_5 (B 2kg+ Mn 2.5kg+Zn 3kg) had the highest average bud weight per plant (303.69 gm), yield ha^{-1} (121.48 q), plant fresh weight (908.28 gm), dry plant matter (95.61 gm), root weight (45.02 gm), and dry weight (11.65 gm).

Shivran *et al.* (2017) found that in sprouting broccoli the curd weight (420.07 g), diameter of curd (12.72 cm), total number of secondary curd (10.14), volume of curd (113.42 cc), yield $plot^{-1}$ (4.34 kg) and yield ha^{-1} (215.05 q ha^{-1}).

Gocher *et al*. (2017) observed that when compared to control and 20 kg sulphur, the application of 40 kg S ha^{-1} dramatically improved parameters of yields such as average curd weight (g), yield $plot^{-1}$ (kg), and yield ha^{-1} (q) in cauliflower var. Pusa synthetic, but statistically equaled 60 kg sulphur ha^{-1}. With 60 kg ha^{-1}, which was statistically similar to 40 kg ha^{-1}, the maximum average weight of curd (372.05 g), yield $plot^{-1}$ (5.95 kg), and ha^{-1} (105.77 q ha^{-1}) were obtained, although the least was accomplished in cauliflower under regulation.

Singh *et al.* (2018) reported that micronutrient application had a major impact on head diameter when compared to control. T_6 (B + Mn + Zn) and T_8 (B + Mo + Mn + Zn) treatments had significantly higher yield ha^{-1} than the other treatments (121.48 q/ha and 115.04 q/ha, respectively), and bud weight was significantly affected by the various treatment combinations attempted. T_6 (B + Mn + Zn) had the maximum bud weight by a wide margin (303.69 gm).

Singh *et al.* (2018) observed that in sprouting broccoli the yield noted in (T_5) boric acid @ 0.40% (135.05 q/ha) followed by (T_{15}) zinc sulphate @ 0.60% (134.98 q/ha), (T_2) ammonium molybdate @ 0.20% (131.66 q/ha) and (T_4) boric acid @ 0.20% (131.38 q/ha).

Chowdhury and Sikder (2019) studied that the present investigation, the main head weight in the combine treatment 0.05% Mo+ 0.05% S + 1.5% Zn showed

maximum head weight (1150.54 g). However, treatment combination 0.05% Mo+ 0.5% S + 1.5% Zn was significantly at par (1149.91 g).

Bairwa *et al.* (2020) found that the curd yield of cauliflower the significantly ranged from 172.50 to 293.25 q ha^{-1} during first year and from 151.75 to 268.75 q ha^{-1} during second year. The highest curd yield viz., 293.25 q ha^{-1} during first year and 268.75 q ha^{-1} during second year was recorded in treatment T_5 {100% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + ZnSO4 @ 25 kg ha^{-1}} over and above the control.

Tudu *et al*. (2020) reported that the fresh head production of broccoli owing to B and Zn application under limed and non-limed conditions ranged from 122.78 to 136.80 q ha^{-1}. Borax @ 0.2 percent + ZnSO4 @ 0.5 percent produced the maximum yield. The mean head yield in the limed condition was 134.73 q ha^{-1}, whereas the yield in the unlimed condition was 124.06 qha^{-1}, representing an increase of 8.60 percent in yield over the unlimed condition.

2.3. Effect of micronutrients on quality parameters

Hunashikatti *et al.* (2000) found that alone sulphur @25 kg/ha and molybdenum @ 1kg/ha were produce the highest yield (58.46 t/ha) and protein content (6.83%) in cabbage heads. The highest ascorbic acid concentration (54.38 mg/100g) was observed with 50 kg S ha^{-1} and 2 kg Mo $ha^{-1.}$

Chhipa (2005) observed that significant increases in chlorophyll content (1.340 and 1.360 mg/g), protein content in curd (2.71 and 2.68 percent), S content (1.21 and 1.19 percent), and Zn content (48.37 and 49.15 ppm) were seen in cauliflower after feeding 40 kg S ha-1 and 4 kg Zn ha-1.

Aires *et al*. (2006) studied that the effect of N and S fertilisation on the glucosinolate content of the aerial component and roots of broccoli sprouts. Sulfur was measured at 0, 14.6 and 29.2 mg L1 and nitrogen was measured at 0, 45.5 and 91.0 mg L1. Total glucosinolates in the aerial component were significantly higher (P 0.001) than in the roots, according to the findings. 4-methylsulfinylbutyl and 3-methylsulfinylpropyl were the most prevalent glucosinolates in the aerial part, while 2-phenylethyl and 4-methylthiobutyl were found in the roots.

Shah *et al.* (2010) observed that spraying of borax @ 0.3 % at 30 + 45 DAT (B2) gave protein content of head (3.24 g/100g) found a significant response on quality of sprouting broccoli.

Kumar *et al.* (2012) observed in sprouting broccoli, physicochemical parameters such as TSS (10.53°brix), total sugar (2.61%), and soluble protein (40.49 mg/100g) were highest with urea 1 % spray, but ascorbic acid dropped, and zinc sulphate and boric acid 0.2 % spray were preferred, while copper sulphate 0.2 % spray had the lowest phenol.

Abd El-All (2014) reported that the high-rate treatment (150 kg/fed) had the highest % of N, P and K, as well as the highest concentration of vitamin C. Sulphur, at a rate of 150 kg/fed, was also used. In comparison to the other treatments, and Zn at 200 ppm had the highest sulforaphan (SFN) g/g concentration. Although sulforaphan content was identified in broccoli green heads and mature seeds, S in glucoraphanin only accounted for 4- 10% of total S content in broccoli heads, the previous increases might be regarded as a significant increase in S.

Lal *et al.* (2015) reported that the vitamin C content (85.55mg 100 g^{-1}), crude protein (2.15%), N (0.341%), P (0.062%), and K (0.301%) and zinc content (17.70 ppm) in head, increased significantly by the application of zinc upto 30 kg ha^{-1}.

Islam *et al*. (2015) reported that Broccoli dry matter, ascorbic acid, and potassium content increased when boron levels grew up to 2.0 kg/ha, but afterwards dropped as boron levels increased further. Iron and carotene content, on the other hand, improves as boron levels rise to 3.0 kg/ha.

Verma and Nawange (2015) During the Rabi season, researchers conducted a field experiment on sandy loam soil to observed the effect of different levels of nitrogen and sulphur affected cabbage development, yield, and quality. They found that the addition 80 kg/ha of sulphur resulted in a much greater protein content than other sulphur applications.

Choudhary and Paliwal (2017) treatment F3 (S @ 40 kg ha^{-1} + Zn @ 5 kg ha^{-1} + Boron @ 1.5 kg ha^{-1}) was found to have the highest crude protein content (2.28 percent) in the head, as well as the highest vitamin-c content (83.40 mg/100g) in the head.

Singh *et al*. (2017) reported that micronutrients (B, Mn and Zn) were applied at the rate of 2 kg (B), 2.5 kg (Mn), 3 kg (Zn) per hectare significantly increased vitamin 'C' (93.92 mg), TSS (^{0}Brix) (8.37) content in sprouting broccoli.

Shivran *et al.* (2017) observed that in sprouting broccoli the application of 30 kg zinc/ha resulted in the maximum and significantly more values of quality attributes viz. TSS (12.72^{0}Brix), Ascorbic Acid (87.31 mg/100 g), Total sugars (3.44%), Reducing sugar (2.66 %) and non-reducing sugar (0.75 %).

Slosar *et al*. (2017) Foliar zinc application dramatically increased the content of sulforaphane in broccoli florets by about 19.8-32.9 percent (Zn 0.75) and 37.2-49.3 percent (Zn 1.50) compared to the control, as well as the content of total polyphenolics (of about 9.0-12.5 percent (Zn 0.75) and 33.9-35.2 percent (Zn 1.50)) and antioxidant activity (Zn 0.75 (3.7-4.2%) and Zn 1.50 (5.3-7.0)).

Pankaj *et al.* (2018) observed that there was a noticeable difference between different treatment combinations, according to the report. T_5 (B + Mn + Zn) has the highest T.S.S (0Brix) value of 8.80, followed by T_9 (Zn) with 7.90. T0 (control) had the lowest T.S.S (0Brix) value of 6.45. T_5 (B + Mn + Zn) had the highest vitamin ‘C' mg/100gm (94.80 mg), followed by T_6 (Mo + Mn) with 88.73 mg. T_0 (control) had the lowest vitamin C level at 79.02, followed by T_2 (Mo) at 79.03. (82.23 mg).

Singh et al. (2018) found that in sprouting broccoli the foliar application of (T_5) boric acid @ 0.40% resulted non-reducing sugar (1.80 %) followed by (T_2) ammonium molybdate @ 0.40% (1.79 %), (T_{15}) zinc sulphate @ 0.60% (1.78 %) and (T_6) boric acid @ 0.60% (1.77 %) which were significantly superior to the other treatments.

Singh *et al.* (2018) observed that there had been a substantial interaction between individual treatment combinations, according to the report. T_6 (B + Mn + Zn) had the highest T.S.S (^{0}Brix) value of 8.37, as well as the highest vitamin "C" mg/100gm (93.92 mg) and the highest Tritable acidity (0.44 percent).

Chowdhury and Sikder (2019) found that the highest amount of ascorbic acid (116.70mg/100g) showed by the treatment of 0.03% Mo+ 0.5% S + 1% Zn. Maximum amount of vitamin-A (1.78 mg/100g) were observed in the combination of 0.03% Mo+ 0.5% S + 1.5% Zn in broccoli.

Tudu *et al*. (2020) studied that in broccoli the combined micronutrients are applied in foliar spray of borax @ 0.2% and ZnSO4 @ 0.5% significantly increased head quality in terms of TSS (7.03 ^{0}Brix), ascorbic acid (97.25 mg $100g^{-1}$), total sugar (1.79%), reducing sugar (1.35%), non-reducing sugar (0.42%) and crude protein (1.69%).

2.4. Effect of micronutrients on economics

Bhagavatagoudra and Rokhade (2001) revealed that the higher benefit: cost ratio (3.95) with S at 40 kg ha^{-1} was followed by 20 kg S ha^{-1} (3.8) and control in cabbage (3.64).

Singh (2003) reported that in cauliflower borax applies at 5 kg/ha as soil application + 0.25% as foliar spraying at 45 DAT and 60 DAT, the net profit (51,203rupees/ha) and benefit cost ratio (4.20).

Meena (2004) found that the treatments for sprouting broccoli included four levels of nitrogen (0, 120, 150, and 180 kg ha^{-1}) and sulphur (0, 120, 150, and 180 kg ha^{-1}) (0, 40, 50 and 60 kg ha^{-1}). The use of 150 kg N ha^{-1} and 50 kg S ha^{-1} was found to be the most cost-effective, with a net profit of Rs 176832.41 and a benefit-cost ratio of 4.33:1.

Singh and Singh (2004) studied that at 30 and 60 days after transplanting, researchers looked at the B:C ratio for cauliflower (cv. Snowball-16) treated with foliar sprays of N (0, 0.5, 1.0, 1.5 percent) and Zn (0, 10, 20, or 30 ppm). 1.0 percent N + 30ppm Zn had the maximum net profit (52628.30 rupees/ha) and B:C ratio (1:2.803), followed by 1.0 percent N + 20ppm Zn (51 447.87 rupees/ha and 1:2.743).

Yadav *et al*. (2009) reported that, in cabbage the integrated spray of Zinc sulphate (ZnSO4) 0.5%, Ferrous sulphate 0.5%, Boric acid 0.5% in cabbage gave maximum net returns (Rs/ha 36,397) and highest (1.77) B:C ratio.

Jamre *et al.* (2010) revealed that 60 kg S ha^{-1} and 6 kg Zn ha^{-1} treatments yielded the highest net returns of Rs. 94382 ha^{-1} and Rs. 94016 ha^{-1}, respectively, with profit cost ratios of 3.83 and 4.04, which were comparable to 40 kg S/ha and 4 kg Zn/ha treatments, which yielded net returns of Rs. 90458 ha^{-1} and Rs. 91010/ha, respectively, with benefit costs of 3.77 and 3.90. Because of the highest curd yield, these treatments had the highest net return and benefit: cost ratio.

Lal *et al.* (2015) reported that in broccoli the application of 20 kg zinc/ha were having significance in term of Benefit: Cost ratio (7.00:1) and net return (Rs. 3,13,335).

Choudhary and Paliwal (2017) observed in broccoli, treatments B3 (vermicompost 2.5 t ha^{-1} + 5 t ha^{-1} FYM + Azosprillium + PSB) and F3 (S @ 40 kg ha^{-1} + Zn @ 5 kg ha^{-1} + Boron @ 1.5 kg ha^{-1}) yielded the highest net returns (Rs. 460241 and Rs. 471885) and had the highest B:C ratio (7.14:1 and 7.37:1), respectively.

Gocher *et al.* (2017) reported that the application of 125 % of the necessary NPK (F3) and 60 kg S ha^{-1} (S3) yielded the highest yield of cauliflower in the var. Pusa synthetic. However, in terms of total curd yield per plot, total curd yield per ha, net return, and B:C ratio, the treatment combination of 100% recommended NPK (F2) and 40 kg S ha^{-1} (S2) produced the best results from a farmer's economic perspective (recommended point of view).

Tudu *et al.* (2020) reported that in broccoli the combined micronutrients gave the results revealed invariably better performance of combined foliar spray of 0.2% borax with 0.5% ZnSO4 (1.37 lakh ha^{-1}, 0.63 lakh ha^{-1} and 1.85), closely followed by foliar application of 0.5% ZnSO4 (1.35lakh ha^{-1}, 0.62 lakh ha^{-1} and 1.84) for gross income, net income and B:C ratio, respectively.

CHAPTER III
MATERIALS AND METHODS

The present research entitled **"Impact of foliar spray of micro-nutrients on growth, yield and quality of Broccoli (*Brassica oleraceae L. var. italica)* under poly house condition**" was carried out during the year 2020-21 at Center of Excellence on Protected Cultivation and Precision farming under polyhouse condition, College of Agriculture, IGKV, Raipur (C.G.). The details regarding materials used and various techniques applied during the course of the experimentation have been described in this chapter.

3.1 Geographical Conditions

Raipur district is established in the central part of Chhattisgarh, Agro-climatologically known as Chhattisgarh plains and lies between 21° 16' N latitude and 81° 36' E longitude with an altitude of 289.56 meters above the mean sea level.

3.2 Climate and weather

Raipur, where the experiments were conducted, is located in the dry and sub-humid zone. It is belonging to 7th Agro-climatic zone of the country, i.e., eastern plateau and hills. The average rainfall is about 1200-1400mm, with around 85% rainfall occurred between the third week of June and mid-September, whereas minimum rainfall occurred in the month of October and February. Overall, May is the hottest month (44-46°C) and December is the coldest month (8-9°C). The rainfall pattern varies from year to year, particularly during the months of June to September, with seasonal light showers during the winter and summer seasons. In the months of May and December, the highest and lowest temperatures were recorded 42.8°C and 10.1°C, respectively.

During the span of experimentation weekly average meteorological data were recorded at the Meteorological Observatory, IGKV, Raipur are given in (Appendix A)

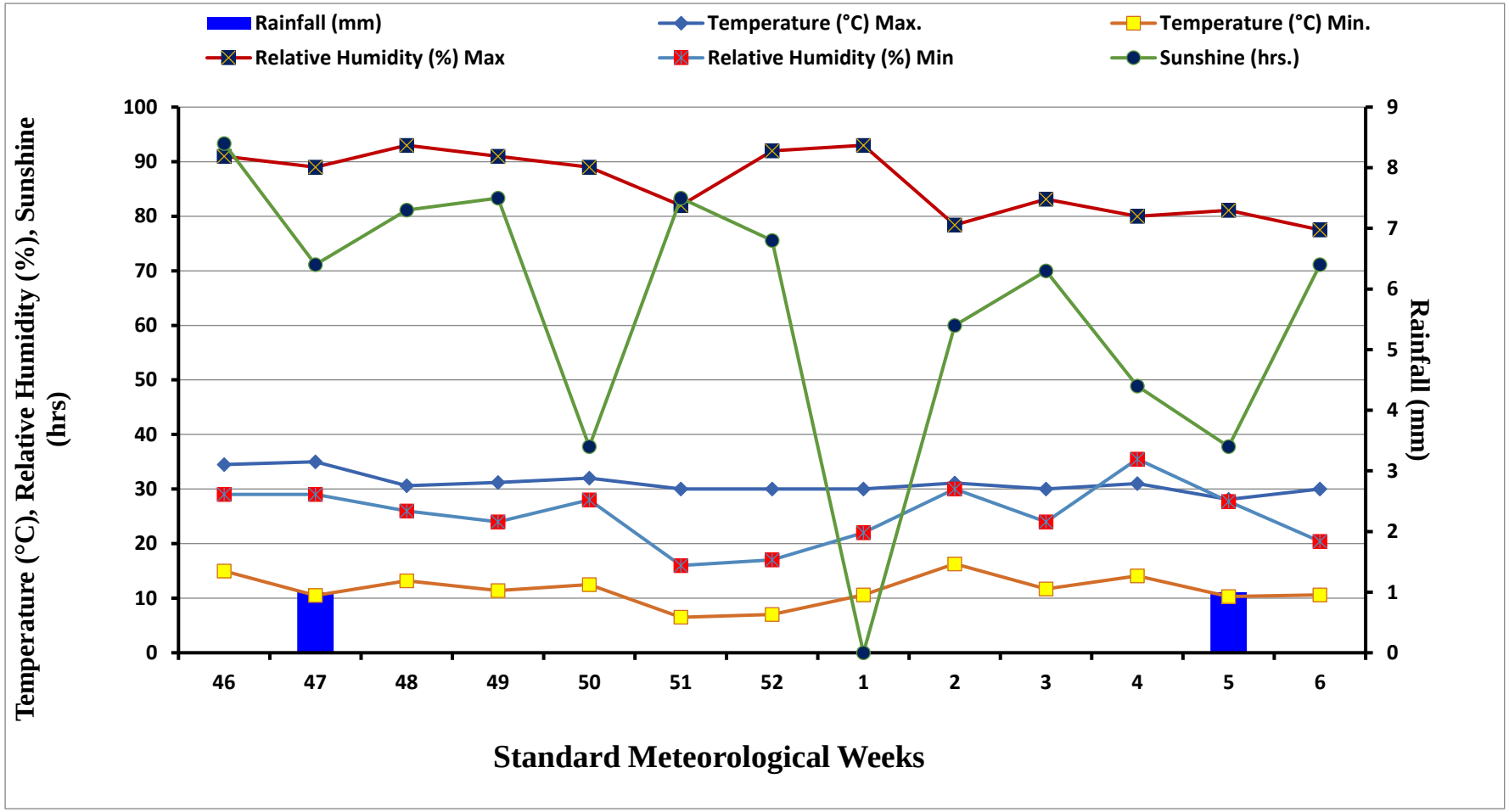

Fig 3.1 Average weekly meteorological data during cropping period (November, 2020 to February, 2021).

3.3 Experimental site

The experiment was conducted at Centre of Excellence on Protected Cultivation and Precision farming under Polyhouse condition, CoA, IGKV, Raipur (C.G.)

3.4 Choice of Variety

Green magic is one of the good variety of broccoli, it is in the mid-early maturity class with wider adaptability. Therefore, in present investigation Green magic cultivar was selected.

3.5 Experimental details:

Crop	:	Broccoli (*Brassica oleracea* var. *italica*)
Experimental design	:	Completely Randomized Design (CRD)
Season	:	Rabi 2020-21.
Spacing	:	45 cm (Row to Row) × 30 cm(Plant to Plant)
Number of Replications	:	3
Number of Treatments	:	10
Plot size	:	4m × 1m. (L×W)
Variety	:	Green Magic
Transplanting date	:	11/11/2020

3.6 Physico-chemical characteristics of the soil

Clay-loam soil was found at the research field. Prior to layout of the experiment, soil samples were randomly collected from 5 places which was taken out from 20 cm depth. The soil samples were mixed thoroughly and physio-chemical composition of the soil was determined from the given composite sample of soil. The physio-chemical analysis of soil has been presented in Table 3.1.

3.7 Preparation of Nursery

A 15-20 cm raised nursery bed of sized (3.0 m x 1.0 m) was prepared in the month of October 2020. Care must be taken while leveling, a slope of 2.0 cm was maintained from the centre to all sides for efficient drainage. The seedlings became ready for transplanting within 4-5 weeks after sowing.

Table 3.1: Physico-chemical characters of soils

Particular's classification	Analytical Values		
Physical Properties	Mechanical composition		
	Sand (%)	55.54	
	Silt (%)	18.35	Clay Loam(dorsa)
	Clay (%)	24.10	
Chemical Properties	Organic carbon (%)	0.47	Low
	Available N (kg ha^{-1})	227.78	Low
	Available P (kg ha^{-1})	19.00	Medium
	Available K (kg ha^{-1})	494.10	High
	Soil Reaction PH	7.6	Slightly alkaline
Micronutrients	Zinc (mg/kg)	0.51	Medium
	Copper (mg/kg)	0.9	High
	Boron (mg/kg)	2.0	Medium

3.8 Field preparation

Ploughing and Planking was done to obtain the experimental plot with fine tilth. Removal of unwanted plants, grasses residues and other waste materials from field was done. Broccoli seedlings were planted on raised beds of 15-20 cm in height. On 3 Nov, 2020 the experimental area laid out into ridge bed of size 4m x 1m.

3.9 Application of manure and fertilizers

FYM 25 tones/ha was added in the experimental field. Fertilizer in the form of Urea, DAP and MOP were used as the source of nitrogen, phosphorous and potassium (NPK) was applied @ 100, 80 and 80 kg/ha respectively. During crop periods, the water (H_2O) soluble fertilizers i.e., 13:00:45, 12:61:00, 17:44:00, 18:18:18, 19:19:19, and 00:00:50 were applied through fertigation to meet out the fertilizer requirement of the crops.

3.10 Transplanting of Broccoli plants

Plants with 3-4 leaf stage were transplanted on raised beds of the size 4.0 m × 1.0 m (L×W). Mulching was done to check the population of weed density and to conserve the soil moisture. On 11th November 2020, transplanting of broccoli seedling at spacing of 45 cm x 30 cm in zigzag manners was done. The soil around the plants was packed and patted firm around the base of the stem. Light irrigation was done after transplanting.

3.11 Care of experimental plants

Uniformity was maintained all over the experimental plots and same cultural practices was followed i.e., manure, fertilizations, plant protection measures during the period of the experiment. Irrigation and fertilizers had given to the broccoli plants by drip irrigation.

3.12 Preparation of solution and foliar application of micronutrients

As per schedule of treatments the required quality of micronutrients were dissolved in appropriate quantity of water and applied by foliar spraying.

Micronutrient solution. (%) = g of substance dissolve in liter of water.

Fresh solution was prepared just prior to spraying. For making 1 litre of 0.20%, 0.40% and 0.60% concentration of each micronutrient, 2g, 4g and 6g amount of each micronutrient was taken and weighed and carefully dissolved in 1litre of water. Solutions of various concentrations were uniformly spread to the plant to wet both the surfaces of leaves. Spraying of micro-nutrients was done with the help of knap sack sprayer or hand sprayer. To avoid contamination washed the sprayer thoroughly before spraying.

3.13 Treatment details

Completely randomized design (CRD) was assigned to the experiment with 3 replications. Treatments details and layout plan of the research field is presented in Table 3.2.

3.14 Time of spray

Spraying was done in the morning (about 9.30 a.m.) when the dewdrops had evaporated. The desired concentrations of micro-nutrients were prepared and first spraying was done at 15 days and 2nd at 30 days and last spraying was done at 45 days after the transplanting of broccoli crops.

Table 3.2 Treatment details

S. NO.	Notation used	Treatments
1.	T_0	Control (Water spray)
2.	T_1	Copper Sulphate (Cu) @ 0.20 %
3.	T_2	Copper Sulphate (Cu) @ 0.40 %
4.	T_3	Copper Sulphate (Cu) @ 0.60 %
5.	T_4	Boric Acid (B) @ 0.20 %
6.	T_5	Boric Acid (B) @ 0.40 %
7.	T_6	Boric Acid (B) @ 0.60 %
8.	T_7	Zinc Sulphate (Zn) @ 0.20%
9.	T_8	Zinc Sulphate (Zn) @ 0.40%
10.	T_9	Zinc Sulphate (Zn) @ 0.60%

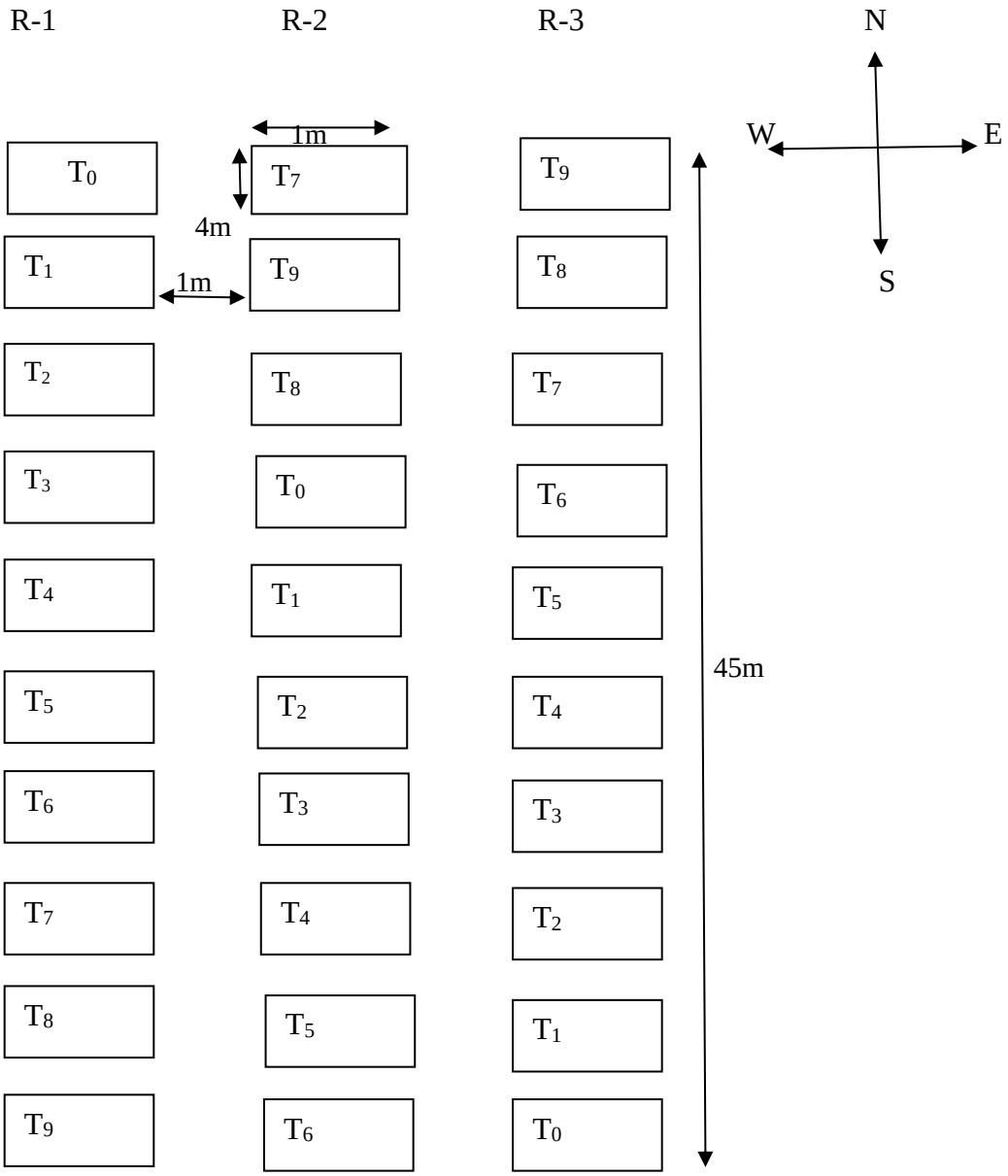

Fig.3.2 Layout plan of the research field

Table 3.3 Details of operations performed during experiments

S.NO.	OPERATIONS	DATE
1	Preparation of nursery beds	12 October
2	Seed sowing and watering	12 October
3	Layout of the field	9 November
4	Transplanting of the seedlings	11 November
5	Basal doses of NPK	11 November
6	Irrigation by drip	11 November
7	Irrigation-I	14 November
8	Gap filling	18 November
9	Irrigation-II	20 November
10	Weeding and hoeing	23 November
11	Top dressing of Nitrogen	24 November
12	Spray of micro-nutrients	26 November
13	Irrigation-III	27 November
14	Spray of insecticide (indoxacarb@500ml/hac)	28 November
15	lrrigation-IV	1 December
16	Weeding and hoeing	2 December
17	Irrigation-V	7 December
18	Top dressing of Nitrogen	11 December
19	Spray of micro-nutrients	11 December
20	Irrigation-VI	14 December
21	Insecticide spray (indoxacarb@500ml/litre)	16 December
22	Irrigation- VII	20 December
23	Weeding	24 December
24	Irrigation- VIII	25 December
25	Spray of micro- nutrients	26 December
26	Irrigation- IX	30 December
27	Irrigation-X	7 January
28	I-Picking of produce	21 January
29	Irrigation-XI	23 January
30	II-Picking of produce	24 January

31	Final picking of produce	2 February

3.15 Inter-culture operations

The following inter-cultural operations were done during the period of experimentation.

3.15.1 Gap filling

Transplanted seedlings were carefully monitored. After transplanting, only a few seedlings were injured, and these seedlings were replaced with new seedlings from the same nursery. Healthy seedlings with a ball of earth from the nursery were replaced to maintain the appropriate plant density.

3.15.2 Weeding

The experimental plots were always kept free from weeds by removing them manually. Weeding was done time to time. Broccoli roots are surface feeders; hence care was taken at the time of weeding.

3.15.3 Irrigations

Irrigation was given by drip, in the field as per the requirement of the crop in order to maintain the soil moisture because broccoli requires continuous supply of moisture. The crop was irrigated immediately after transplanting and then every 2 to 3 days until seedlings were established. After then, the crop was irrigated every 8 to 10 days at a regular interval.

3.15.4 Plant protection measurements

Required plant protection measures were taken to control the insect pest and disease by applying the accurate dose of fungicides and insecticides at proper intervals during the investigation periods.

3.16 Harvesting

The harvesting of broccoli was started from 21st January 2021 and continues up to 2nd February 2021. Broccoli was harvested when the curd attained proper size. While harvesting broccoli, care should be taken to cut the curd. During harvesting the head, cut off the stalk with a large and sharp knife.

3.17 Observations and its procedures

The observations on the growth traits that ultimately influenced the yield, i.e. plant height, number of leaves per plant, stalk length was recorded at regular intervals. The observations on the character of the head or curd as the curd diameter, the curd weight per plant, the curd yield per plot, yield per hectare, dry weight of plant, dry weight of head and root length were recorded at the time of harvesting. Five plants were selected randomly and tagged in each plot for data collection. Data were recorded from sample plants during the period of experiment. The following parameters on growth, yield and quality attributes were recorded as mentioned below.

Observations to be recorded:

Growth parameters:

Plant height (cm)

No. of leaves plant^{-1}

Stalk length (cm)

Days of first curd initiation

Days to 50% curd maturity

Days to harvest

Root length at final harvest (cm)

Quality parameters:

Ascorbic acid content (mg/100gm)

Total Soluble Solid (%)

Five plants were randomly selected in each net plot. The plants selected to record biometric observations have been labelled. The total soluble solids and ascorbic acid content has been estimated from the mature Broccoli head.

Yield attributing parameters:

Curd yield plant^{-1}

Curd yield plot^{-1}

Curd yield ha^{-1}

Curd diameter (cm)

Fresh weight of plant (g)

Dry weight of Plant (g)

Fresh weight of curd (g)

Dry weight of curd (g)

Economics:

Cost of cultivation

Gross return

Net return

B:C ratio

3.17.1 Growth parameters:

3.17.1.1 Plant height (cm)

The plant height of the five randomly selected and labelled plants per plot was measured at 20, 40 and 60 days after planting with the help of scale. The plant height was measured from ground level to the tip of the main shoot and their mean was expressed in centimeters.

3.17.1.2 Number of leaves plant^{-1}

The number of leaves of five randomly selected plants was observed at 20, 40 and 60 days after transplanting and average number of leaves per plant was calculated.

3.17.1.3 Stalk length (cm)

The stalk length of each tagged plant were observed at 20, 40 and 60 days after transplanting and measured in centimeters with the help of meter scale. The measurement was taken in term of vertical distance between the ground level and the upper part of the stalk where next tip leaf bud initiated.

3.17.1.4. Days to first bud initiation

The numbers of days taken from date of planting to date, when plant showed curd initiation were counted for each plot.

3.17.1.5. Days of 50% curd maturity

Days of 50 % curd maturity were considered as the number of days taken by crop from the date of planting till the curd reaches marketable maturity at least in the 50 percent plant.

3.17.1.6 Days to curd maturity

Date of curd maturity per replication of different treatments were recorded and average number of days to curd maturity was calculated.

3.17.1.7 Length of root (cm)

Root studies were made after the harvest of the crop. The tagged plants were uprooted with maximum possible care not to damage the roots. Roots were thoroughly washed by running water. The length of the main root under different treatments were carefully recorded.

3.17.2. Quality parameters

3.17.2.1 Ascorbic acid content (mg/100g)

Ascorbic acid content was estimated by 2,6-dichlorophenol indophenol dye method. Fruit sample (10-20 ml) is diluted to 100ml with 3% metaphosphoric acid. The juice is filtered or centrifuged to remove the fibers. Then pipette 10 ml of filtrate into a conical and titrate with standard dye to a pink end point. If a sample contain Sulphur dioxide which reduces the dye and thus interfere with ascorbic acid estimation the following procedure is followed. Take 10 ml of filtrate and add 1 ml of 40% formaldehyde and 0.1 ml od HCL and then follow to stand for 10 minutes and then titrate.

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{(Titrate value} \times \text{Dye factor} \times \text{vol. made up)}}{\text{Vol. of filterate taken} \times \text{vol. of sample taken}} \times 100$$

3.17.2.2 TSS % (Total soluble solid %)

Smaller bits of curd from each replication in each treatment were taken in a small quantity and crushed and pressed properly to extract a few drops of juice to put in prism of hand refractometer and folded back and looked through eye piece facing the light to take a reading where the shaded area boundary line intersected with unshaded area. The average TSS was calculated treatment wise.

3.17.3 Yield parameters:

3.17.3.1 Curd yield plant^{-1} (g)

To calculate the average curd yield, curds of five randomly selected plants in each plot, whole were weighed on electronic balance after cutting the leaves and stalk. Finally, average weight of curd in each plot was calculated in grams.

3.17.3.2 Curd yield (kg plot^{-1})

Curd of tagged five plants from each treatment were weighed and the average was worked out and recorded as curd yield per plant. Curd yield per plot

was obtained by multiplying plant yield with total number of plants per plot. The curd was collected when fully developed and compact. Since all the curd were not ready for harvesting at the same time, the plants were cut as they developed completely.

3.17.3.3 Curd yield (q ha^{-1})

Curd yield per hectare was calculated by using curd yield per plot and expressed in quintals. Yield per hectare was calculated on the basis of yield per plot for all the treatments.

$$\text{Curd yield (q/ha)} = \frac{\text{Weight of fruit (kg per plot)}}{\text{Net plot area } (m^2)} \times 100$$

3.17.3.4 Curd diameter (cm)

The average of the five random marketable curds at widest parts of curd was measured by scale and the average was worked out in cm.

3.17.3.5 Fresh weight of plant(g)

Freshly harvested five plants were taken in each plot and immediately measured on electronic balance. Its average was taken and expressed in gram.

3.17.3.6 Dry weight of plant (g)

Plant sample was taken from treatment and were dried at 56 ^{0}C in micro-oven for 48 hours and was weighed on electronic balance. Its average was taken and expressed in gram.

3.17.3.7 Fresh weight of curd (g)

Each tagged plant's fresh curd weight was measured in each replication of each treatment, and the average curd weight of five plants was calculated by treatment.

3.17.3.8 Dry weight of curd (g)

Curd of each tagged plant in each replication of different treatment was taken and were dried in 56 ^{0}C in micro-oven at 48hours and was weighed on electronic balance. Its average was taken and expressed in gram.

3.17.4 Economics of Cultivation

3.17.4.1. Cost of cultivation (Rs ha^{-1})

The cost of the inputs that was prevailing at the time of their use was considered (Appendix) to work out the cost of cultivation which is given in rupees per hectare.

3.17.4.2. Gross income (Rs)

The income was calculated based on the prevailing market price for the broccoli.

3.17.4.3. Net income (Rs)

The net income per hectare was calculated on the basis of gross income and cost of cultivation per hectare as follows

Net income = Gross income – Cost of cultivation.

3.17.4.4 Benefit of Cost ratio

The benefit to cost ratio was worked out by using the following formula;

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

3.18 Statistical analysis

The data collected from all the observations noted in the field and laboratory were put forth for statistical analysis for knowing the degree of variation amongst all the treatments. The analysis of variance was carried out for each character separately asper method of Panse and Sukhatme (1985). The structure of analysis of variance table is given below-

Table 3.4: ANOVA

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F cal
Treatment	(t-1)	TrSS	TrMS=TrSS/df	TrMS/ErM
Experimental Error	rt-t	ESS	EMS=ESS/df	
Total	rt-1	TSS		

Where,

r = no. of replications.

t = no. of treatments.

TrSS = Sum of squares due to treatments.

ESS = Sum of squares due to error.

TrMSS = Mean sum of square for treatments.

ErMSS = Mean sum of square for error.

Calculation of SE (m), SE(d), CD and CV:

SEm = $\sqrt{EMS}\ /r$

SEd = $\sqrt{2EMS}/r$

CD = $t_{\text{at error d.f}}$.× SEd

CV = (Gm = General mean)

Fig.3.3 Broccoli production under polyhouse

Fig.3.4. Biochemical analysis

Fig 3.5 Curd initiation stage

Fig 3.6. Harvested produces of broccoli

Zinc sulphate **Copper sulphate** **Boric acid**

Fig 3.7. Micronutrients used in the experiment.

CHAPTER IV
RESULTS AND DISCUSSION

The findings of investigation entitled "**Impact of foliar spray of micro-nutrients on growth, yield and quality of Broccoli (*Brassica oleraceae L. var. italica*) under poly house condition**" during the year 2020-21 at "Centre of Excellence on Protected Cultivation and Precision Farming", CoA, IGKV, Raipur (C.G.). The observations recorded during course of investigation were analysis statistically and represented in the form of tables and figures.

4.1 Effect of foliar spray of micro-nutrients on growth parameters

The data obtained on various growth parameters of broccoli viz. plant height (cm), no. of leaves plant^{-1}, stalk length (cm), days to first curd initiation, days to 50% curd initiation, days to curd harvest, root length (cm) were presented in table 4.1, 4.2, 4.3, 4.4, 4.5, 4.6 and 4.7 and fig. 4.1, 4.2, 4.3, 4.4, 4.5, 4.6 and 4.7 respectively.

4.1.1 Plant height (cm)

Effect of foliar spraying of the micro-nutrients which given significant variance with respect to plant height was recorded at 20, 40 and 60 days after transplanting (DAT) are presented in Table.4.1 and fig.4.1.

At 20 DAT, consequential difference was reported among the treatments with respect to plant height. The highest plant height was 21.27cm observed under the treatments T_9 {Zinc sulphate ($ZnSO_4$) @0.60%} followed by T_8 {Zinc sulphate ($ZnSO_4$) @ 0.40 %} is 20.87 cm and T_5 {Boric acid (H_3BO_3) @ 0.40%} is 20.34 cm and lowest plant height 11.59 cm was observed under T_0 (Control).

At 40 DAT, the highest plant height 36.15 cm was calculated under the T_9 {Zinc sulphate ($ZnSO_4$) 0.60%} followed by T_8 {Zinc sulphate ($ZnSO_4$) @ 0.40%} is 35.45 cm and the minimum plant height 27.34 cm was observed under T_0 (control).

At 60 DAT, the greatest plant height was recorded 66.81 cm under the T_9 {Zinc sulphate ($ZnSO_4$) 0.60%} followed by T_8 {Zinc sulphate ($ZnSO_4$) @ 0.40%} is 65.38 cm and the minimum plant height 50.42 cm were observed under the T_0 (control).

Increase in plant height is the good indicator of plant growth. The increase in vegetative growth could be related to the zinc activities in chlorophyll formation, it also influences the cell division, meristematic activity of plant tissues and expansion of cell and development of cell wall by active synthesis of amino acid i.e., tryptophan and is responsible to stimulate plant growth by the cell elongation and cell division. These results were recorded closely by Abd El-All (2014), Singh *et al.* (2017), Meena (2004) and Lal *et al.* (2015) in broccoli.

Table 4.1: Plant height (cm) as influenced by foliar spraying of micronutrients on broccoli *cv.* Green Magic under Polyhouse condition.

		Plant height (cm)		
Notations	Treatments	20 DAT	40 DAT	60 DAT
T_0	Control (Water spray)	11.59	27.34	50.42
T_1	Copper sulphate (Cu) @ 0.20%	17.64	32.12	59.61
T_2	Copper sulphate (Cu) @ 0.40%	19.82	33.56	61.44
T_3	Copper sulphate (Cu) @ 0.60%	18.60	32.34	60.15
T_4	Boric acid (B) @ 0.20%	19.74	33.30	61.07
T_5	Boric acid (B) @ 0.40%	20.34	34.47	63.39
T_6	Boric acid (B) @ 0.60%	19.12	32.88	60.33
T_7	Zinc sulphate (Zn) @ 0.20%	19.88	34.26	62.35
T_8	Zinc sulphate (Zn) @ 0.40%	20.87	35.45	65.38
T_9	Zinc sulphate (Zn) @ 0.60%	**21.27**	**36.15**	**66.81**
	SE(m)	0.35	0.55	0.68
	C.D (p = 0.05)	1.04	1.65	2.03

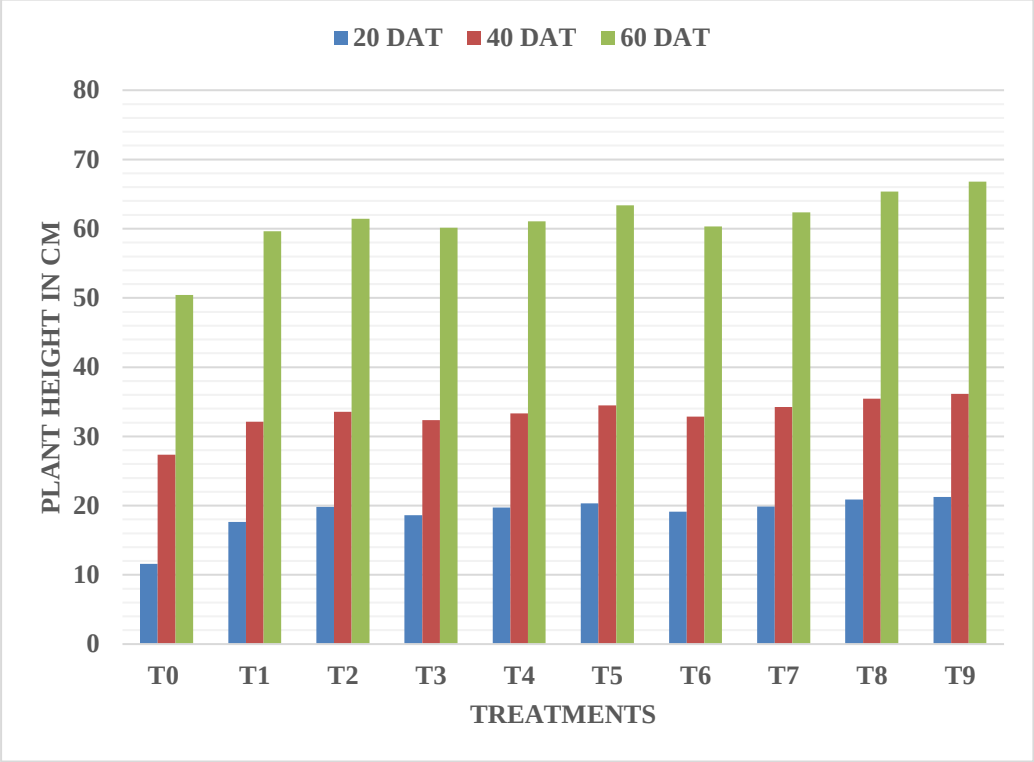

Fig.4.1: Plant height (cm) as effected by foliar of micro-nutrients *cv.* Green Magic under polyhouse condition.

4.1.2 Number of leaves plant^{-1}

Variation in number of leaves per plant reported at 20, 40 and 60 days after transplanting (DAT) showed consequential due to the application of micronutrients as represented in Table 4.2. and fig.4.2.

At 20 DAT the highest number of leaves 7.46 was noted in the treatment T_9 {Zinc sulphate ($ZnSO_4$) @ 0.60%} followed by T_5 {Boric acid(H_3BO_3) @0.40%} is 7.40. However, the lowest number of leaves plant^{-1} (5.26) in treatment T_0 (control).

At 40 DAT the highest number of leaves plant^{-1} is 13.66 noted in the treatment T_9 {Zinc Sulphate ($ZnSO_4$) @ 0.60 %} followed by T_8 {Zinc sulphate ($ZnSO_4$) @ 0.40%} is 13.23 while it was minimum 9.73 under treatment T_0 (control).

At 60 the highest number of leaves 26.47 was noted in treatment T_9 {Zinc Sulphate ($ZnSO_4$) @ 0.60 %} followed by T_8 {Zinc sulphate ($ZnSO_4$) @ 0.40%} is 25.83 while minimum number of leaves is 19.06 under the treatment T_0 (Control).

This could be the result of availability of required quantity of essential plant nutrients at various growth stages leading to hastening the metabolic processes of plant and sugar metabolism, translocation of solutes and protein synthesis that

might have the resulted in production of greater number of leaves. These results were also reported by Chaudhari *et al*, 2017 in cauliflower, Abd El-All, Lal *et al.* (2015) and Zhi *et al.* (2005) in broccoli.

Table 4.2: Number of leaves plant^{-1} as influenced by foliar spray of micro-nutrients on broccoli *cv*. Green Magic under Polyhouse condition.

		No. of leaves per plant		
Notations	Treatments	20 DAT	40 DAT	60 DAT
T_0	Control (Water spray)	5.26	9.73	19.06
T_1	Copper sulphate (Cu) @ 0.20%	5.30	10.54	20.15
T_2	Copper sulphate (Cu) @ 0.40%	6.41	11.67	23.03
T_3	Copper sulphate (Cu) @ 0.60%	5.38	10.66	21.46
T_4	Boric acid (B) @ 0.20%	5.73	11.47	22.46
T_5	Boric acid (B) @ 0.40%	7.40	12.44	24.15
T_6	Boric acid (B) @ 0.60%	5.47	10.74	21.87
T_7	Zinc sulphate (Zn) @ 0.20%	6.53	11.74	23.48
T_8	Zinc sulphate (Zn) @ 0.40%	7.13	13.23	25.83
T_9	Zinc sulphate (Zn) @ 0.60%	**7.46**	**13.66**	**26.47**
	SE(m)	0.13	0.21	0.47
	C.D (p = 0.05)	0.39	0.64	1.40

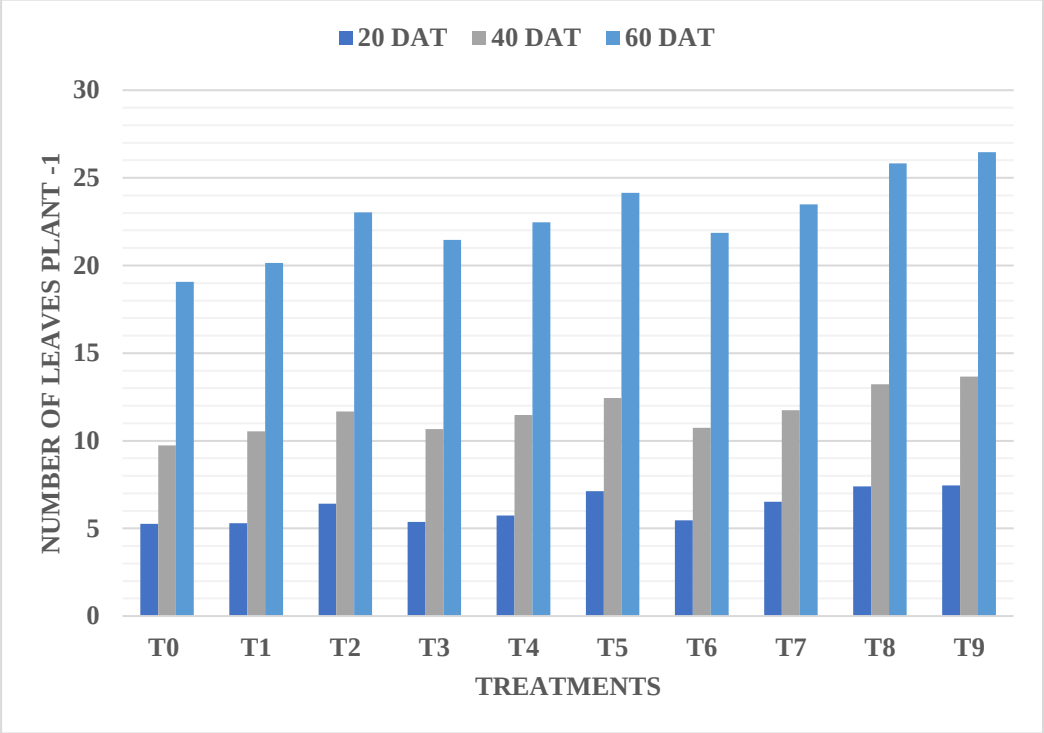

Fig.4.2. Number of leaves plant^{-1} as affect the foliar application of micronutrients *cv.* Green Magic under polyhouse condition.

4.1.3 Stalk length (cm)

Effect of foliar application of the micro-nutrients which given significant variance with respect to the length of stalk recorder at 20, 40 and 60 days after transplanting (DAT) are presented in Table 4.3. and fig. 4.3.

At 20 DAT, consequential difference was reported that the treatments with respect to the stalk length. The highest length of the stalk was observed 4.65 cm under the treatment T_9 {Zinc sulphate ($ZnSO_4$) @ 0.60%} followed by the treatment T_8 {Zinc sulphate ($ZnSO_4$) @ 0.40%} is 4.29cm and the lowest stalk length of plant 2.62 cm were observed under the treatment T_0 (control).

At 40 DAT, the highest stalk length 13.06 cm was calculated under the T_9 {Zinc sulphate ($ZnSO_4$) @ 0.60%} followed by T_8 {Zinc sulphate ($ZnSO_4$) @ 0.40%} is 11.54 cm and the minimum stalk length 7.24 cm) was observed under T_0 (Control).

At 60 DAT, the maximum stalk length 18.22 cm was reported under the T_9 {Zinc sulphate ($ZnSO_4$) 0.60%} followed by T_8 {Zinc sulphate ($ZnSO_4$) @ 0.40%}is 17.54 cm and the lowest stalk length 13.63 cm were observed under the T_0 (Control).

Various treatments of the micronutrients significant affect the growth of stalk length. All the treatments of micronutrients significantly increase the length of stalk over control. Application of the different micronutrients might have accelerated the rate of metabolic activities in the plant system that might have resulted in increasing height of the plant and stalk length. The presence of zinc activates the synthesis of tryptophan and is the precursor of IAA, it also responsible for stimulation of plant growth. These results were also observed by Singh *et al*. 2018 in broccoli and Agarwal and Ahmed (2007) in cauliflower.

Table 4.3. Stalk length as impact of foliar spray of micronutrients on broccoli *cv.* Green Magic under polyhouse condition.

		Stalk length (cm)		
Notations	Treatments	20 DAT	40 DAT	60 DAT
T_0	Control (Water spray)	2.62	7.24	13.63
T_1	Copper sulphate (Cu) @ 0.20%	3.05	9.56	14.08
T_2	Copper sulphate (Cu) @ 0.40%	3.43	11.64	14.88
T_3	Copper sulphate (Cu) @ 0.60%	3.27	10.28	14.12
T_4	Boric acid (B) @ 0.20%	3.55	10.25	15.32
T_5	Boric acid (B) @ 0.40%	4.28	11.46	16.86
T_6	Boric acid (B) @ 0.60%	3.32	10.81	15.24
T_7	Zinc sulphate (Zn) @ 0.20%	4.14	11.16	15.57
T_8	Zinc sulphate (Zn) @ 0.40%	4.29	11.54	17.54
T_9	Zinc sulphate (Zn) @ 0.60%	**4.65**	**13.06**	**18.22**
	SE(m)	0.09	0.18	0.21
	C.D (p = 0.05)	0.28	0.55	0.62

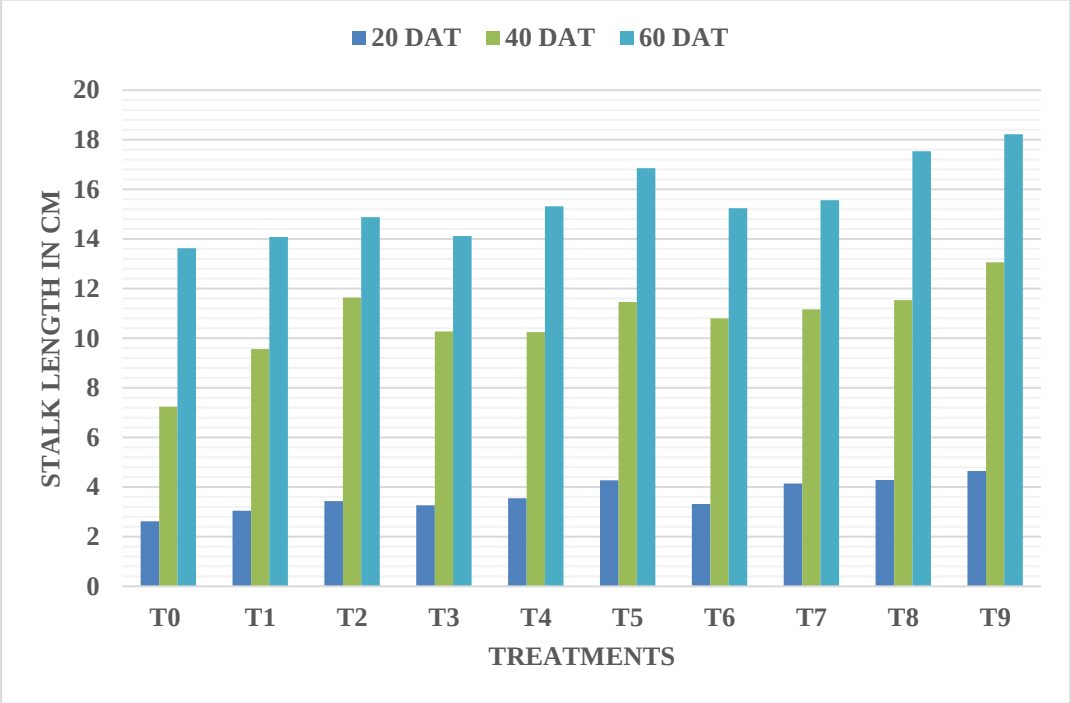

Fig.4.3. Stalk length of plant in cm as affect by foliar application of micro-nutrients *cv.* Green Magic under polyhouse condition.

4.1.4 Days to first curd initiation

Effect of foliar application of micronutrients showed that the significant differences, the different treatments of data with respect to the days to first curd initiation are presented in Table 4.4. and Fig 4.4.

As per result the maximum days to the curd initiation 57.66 days was observed under the treatment T_0 (Control) while the minimum days to curd initiation 48.66 days was observed under the treatment T_5 {Boric acid (H_3BO_3) @ 0.40%} followed by 49.66 days under T_9 {Zinc sulphate ($ZnSO_4$) @ 0.60%}.

It was observed that the curd initiation period required in plants decreased with the increasing levels of micronutrients application. This may be due to the favorable influence of micronutrient regulation on balanced nutrient absorption, which boosted physiological activities and led to the generation of endogenous growth hormone, which is responsible for the formation of early curd in plants. The present result is in agreement with the finding of Bairwa *et al.* (2020) in cauliflower. During the experiment, the effectiveness of several chemicals on the earliness of curd indicated that foliar spraying of boric acid obtains to be the most effective in

early curd commencement. The results are close to Kumar *et al*. (2012) in cauliflower and Yadav *et al.* (2009) in cabbage.

Table 4.4: Days to first curd initiation as impact by foliar spray of micro-nutrients on broccoli *cv.* Green Magic under polyhouse condition.

Notations	Treatments	Days to first curd initiation
T_0	Control (Water spray)	57.66
T_1	Copper sulphate (Cu) @ 0.20%	55.66
T_2	Copper sulphate (Cu) @ 0.40%	52.33
T_3	Copper sulphate (Cu) @ 0.60%	53.66
T_4	Boric acid (B) @ 0.20%	53.33
T_5	Boric acid (B) @ 0.40%	**48.66**
T_6	Boric acid (B) @ 0.60%	50.66
T_7	Zinc sulphate (Zn) @ 0.20%	53.00
T_8	Zinc sulphate (Zn) @ 0.40%	51.66
T_9	Zinc sulphate (Zn) @ 0.60%	49.66
	SE(m)	0.44
	C.D (p = 0.05)	1.32

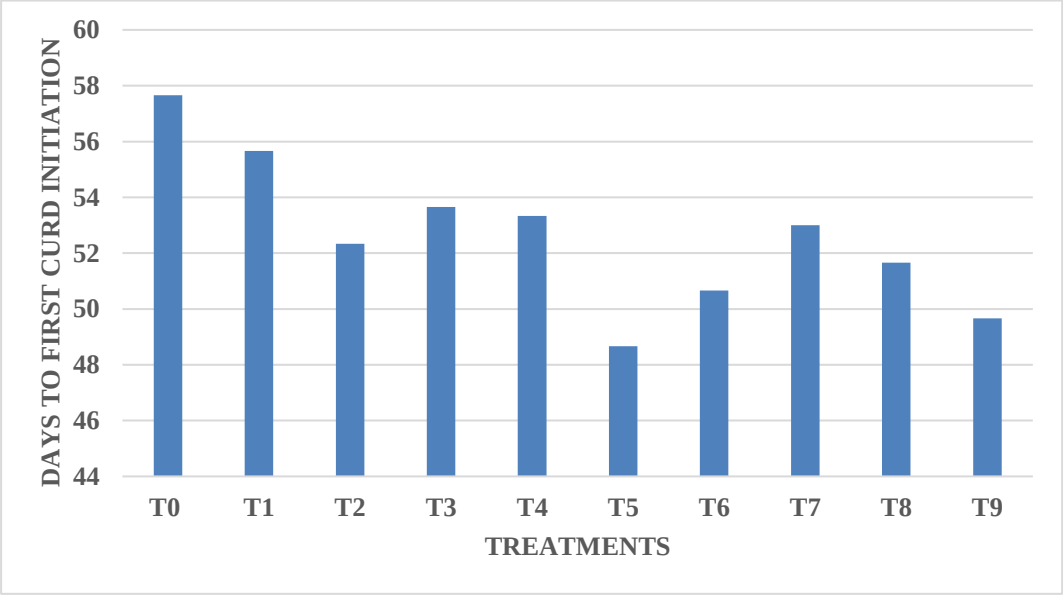

Fig.4.4 Days to first curd initiation as affected by foliar spray of micro-nutrients on broccoli *cv.* Green Magic under polyhouse condition.

4.1.5 Days to 50% curd maturity

Effect of foliar spraying of micro-nutrients recorded significant differences, the data for different treatments with the represented to days to 50% maturity of curd are shows in Table 4.5.and Fig 4.5

Treatment T_5 {Boric acid (H_3BO_3) @ 0.40%} has taken 57.46 days with the shortest period of 50% curd maturity followed by T_9 {Zinc sulphate ($ZnSO_4$) @ 0.60%}is 59.06 days whereas, the highest days to 50% curd maturity 67.28 days was observed in treatments T_0 (Control).

Boron is a crucial component in enhancing carbohydrate translocation from the point of production to the reproductive tissues in broccoli curd. Days for curd initiation and also curd maturity are reduced due to the spraying of boric acid, boron has its unique function; which resulted in the precipitation of excess cation and enhancement of conducting tissues, and also buffer action, all of which aided in the absorption of other essential nutrients. Singh (2003), Chattopadhyay and Mukhopadhyay (2003) and Chaudhari *et al.* (2017) in cauliflower.

Table 4.5: Days to 50 % maturity as impact of foliar spray of micronutrients on broccoli *cv.* Green Magic under polyhouse condition.

Notations	Treatments	Days to 50% curd maturity
T_0	Control (Water spray)	67.28
T_1	Copper sulphate (Cu) @ 0.20%	65.43
T_2	Copper sulphate (Cu) @ 0.40%	61.56
T_3	Copper sulphate (Cu) @ 0.60%	63.93
T_4	Boric acid (B) @ 0.20%	61.36
T_5	Boric acid (B) @ 0.40%	**57.46**
T_6	Boric acid (B) @ 0.60%	60.73
T_7	Zinc sulphate (Zn) @ 0.20%	62.76
T_8	Zinc sulphate (Zn) @ 0.40%	62.05
T_9	Zinc sulphate (Zn) @ 0.60%	59.06
	SE(m)	0.45
	C.D (p = 0.05)	1.33

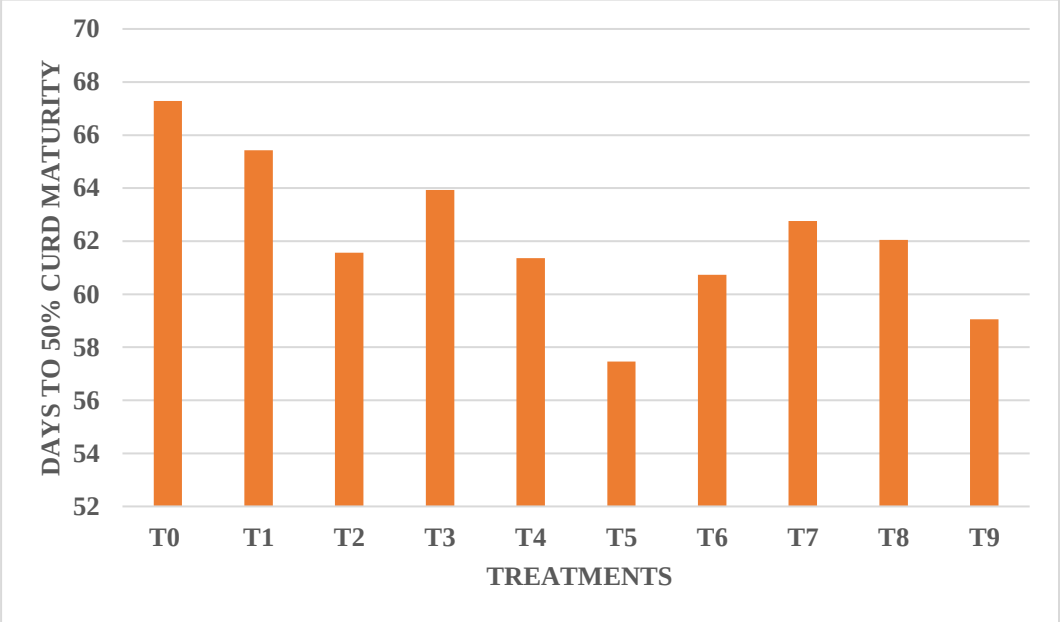

Fig 4.5 Days to 50 % maturity as affected by foliar spray of micronutrients on broccoli *cv.* Green Magic under polyhouse condition.

4.1.6 Days to curd harvest

Effect of spraying of micro-nutrients recorded significant differences; the data for different treatments with the respected to days to curd harvest are presented in Table 4.6 and Fig.4.6. T_5 {Boric acid (H_3BO_3) @ 0.40 %} has taken 68.64 days with the shortest period of curd harvest and followed by T_9 {Zinc sulphate ($ZnSO_4$) @ 0.60%} is 68.83 days whereas, the highest days to curd harvest 76.01 days was observed in treatment T_0 (Control).

The use of boric acid has an effect on the vegetative growth of broccoli, and a spraying of 0.40 percent boric acid significantly improved the vegetative properties. Boron is linked to meristematic activity, pectic and protein metabolism. It also maintaining proper plant water relations. Plant responses were most likely caused by the administration of boron in the form of boric acid. Increases in boric acid levels beyond 0.40 percent, on the other hand, resulted in significant reductions in all growth parameters. Kumar *et al.* (2012), Bairwa *et al.* (2020) in cauliflower and Moniruzzaman *et al*. (2007) in broccoli.

Table 4.6: Days to curd harvest as impact by foliar spraying of micronutrients on broccoli *cv.* Green Magic under polyhouse condition.

Notations	Treatments	Days to curd harvest
T_0	Control (Water spray)	76.01
T_1	Copper sulphate (Cu) @ 0.20%	75.74
T_2	Copper sulphate (Cu) @ 0.40%	73.86
T_3	Copper sulphate (Cu) @ 0.60%	74.70
T_4	Boric acid (B) @ 0.20%	72.61
T_5	Boric acid (B) @ 0.40%	**68.64**
T_6	Boric acid (B) @ 0.60%	71.13
T_7	Zinc sulphate (Zn) @ 0.20%	73.03
T_8	Zinc sulphate (Zn) @ 0.40%	72.34
T_9	Zinc sulphate (Zn) @ 0.60%	68.83
	SE(m)	0.48
	C.D (p = 0.05)	1.44

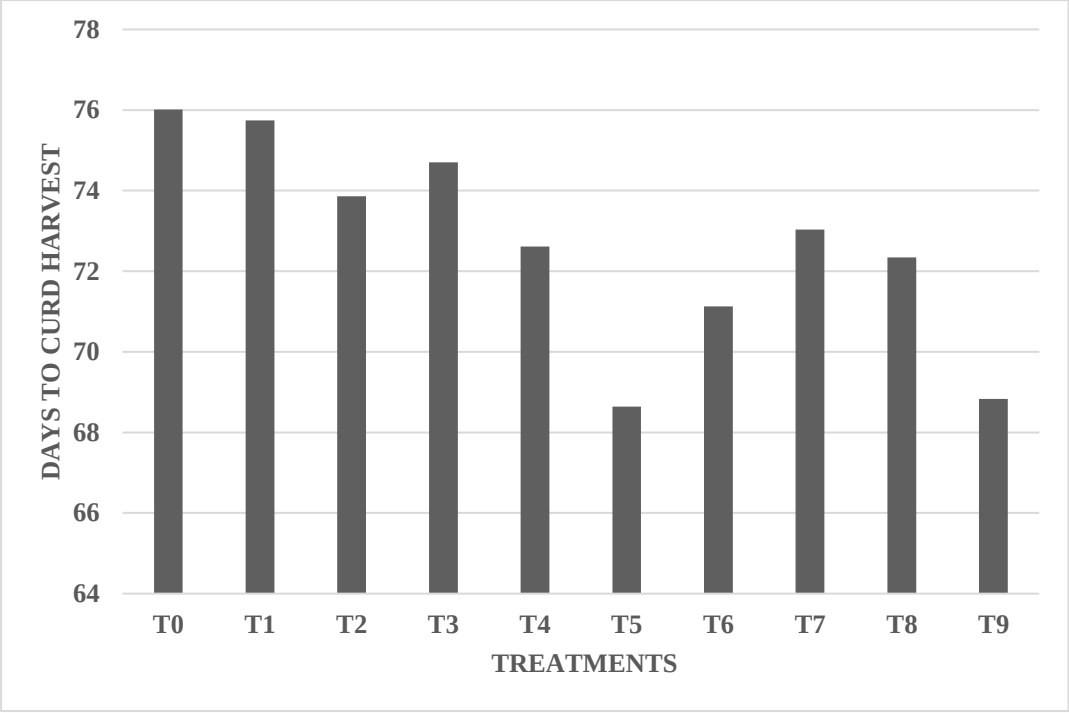

Fig 4.6. Days to curd harvest as impact of foliar spray of micronutrients on broccoli *cv.* Green Magic under polyhouse condition.

4.1.7. Root length of plant (cm)

On the Table 4.7. and fig.4.7 data are represented that the various treatments show significantly influence the root length of plant. The longest root length was noticed in the foliar spray was 16.06cm under the treatment T_9 {Zinc sulphate ($ZnSO_4$) @ 0.60%} followed by T_8 {Zinc sulphate ($ZnSO_4$) @ 0.40%} is 14.42cm and the minimum value of root length was observed 10.5 cm under T_0 (Control).

Zinc is essential for growth and development, as well involved in cell division, which promote in root elongation and shoot growth. It involved in numerous of physiological processes includes calcium metabolism, auxin synthesis, sugar metabolism translocation of solutes and protein synthesis Singh *et al*. (2017). The increase in root length connected to zinc sulphate could be owing to its direct effect on the enzymatic regulation in plants, where it acts as an activator of the enzyme involved in protein synthesis resulting in beneficial effect on root production and in expansion root system Kanujia *et al*. (2006) in cabbage, Singh *et al*. (2018), Kumar (2009) and Sharma (2012) in broccoli.

Table 4.7. Root length of plant (cm) as impact of foliar spray of micronutrients on broccoli *cv.* Green Magic under polyhouse condition.

Notations	Treatments	Root length (cm)
T_0	Control (Water spray)	10.5
T_1	Copper sulphate (Cu) @ 0.20%	11.51
T_2	Copper sulphate (Cu) @ 0.40%	12.43
T_3	Copper sulphate (Cu) @ 0.60%	11.34
T_4	Boric acid (B) @ 0.20%	13.18
T_5	Boric acid (B) @ 0.40%	13.52
T_6	Boric acid (B) @ 0.60%	12.54
T_7	Zinc sulphate (Zn) @ 0.20%	14.18
T_8	Zinc sulphate (Zn) @ 0.40%	14.42
T_9	Zinc sulphate (Zn) @ 0.60%	**16.06**
	SE(m)	0.13
	C.D (p = 0.05)	0.40

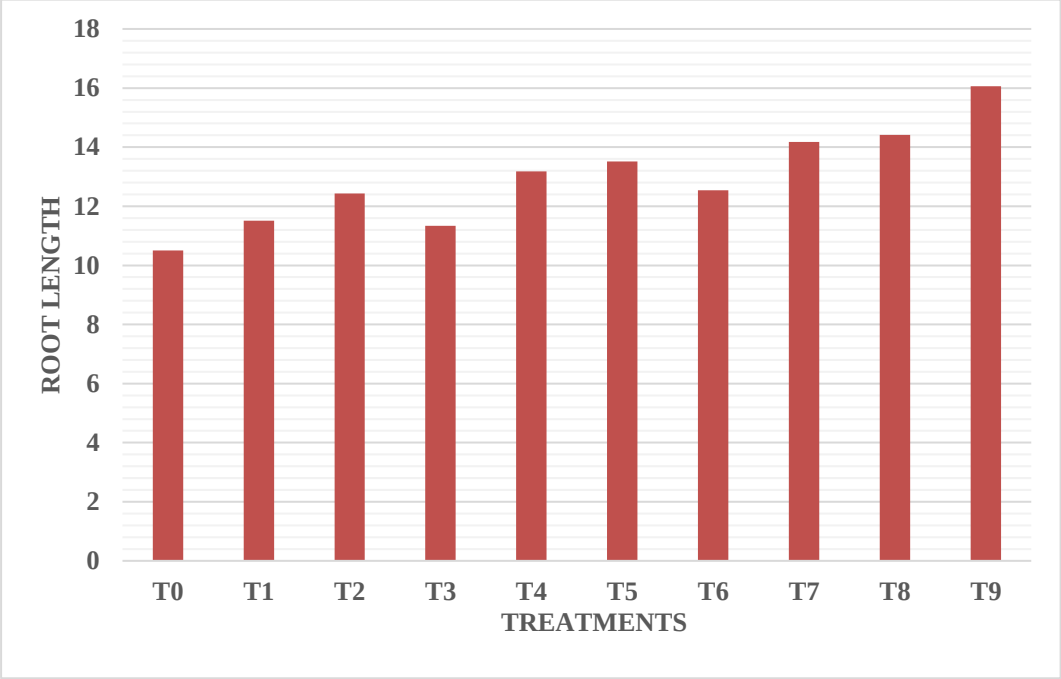

Fig. 4.7. Root length (cm) as affected by the foliar spraying of micronutrients on broccoli *cv.* Green Magic under polyhouse condition.

4.2. Effect of foliar spray of micronutrients on quality parameters

The data obtained on various quality parameters of broccoli viz. ascorbic acid (mg/100g) and Total soluble solid (%) were presented in table 4.8 and 4.9 and fig. 4.9 and 4.9 respectively.

4.2.1. Ascorbic acid (mg/100g)

There was a significant difference among the various treatments are presented on table 4.8 and fig.4.8. The highest ascorbic acid content was found 86.44mg under the treatment T_9 {Zinc sulphate ($ZnSO_4$) @ 0.60%} followed by T_5 {Boric acid (H_3BO_3) @ 0.40%} is 84.59mg and T_8 {Zinc sulphate ($ZnSO_4$) @0.40%} is 84.48mg, which were significant to the other treatments. With T_0 (Control) lowest ascorbic acid is 80.54 mg.

This could be due to influential role of zinc in ascorbic acid production. It has already been established that the zinc is helped in synthesis of tryptophan and indole acetic acid and function as an activator of number of enzymes and simultaneously assists the consumption of phosphorous and nitrogen in plants. Similar finding was obtained by Kotecha *et al*. (2016) in cabbage, Singh *et al*. (2018) and Sharma (2012) in broccoli.

Table 4.8 Ascorbic acid (mg /100g) as impact of foliar spray of micronutrients on broccoli *cv.* Green Magic under polyhouse condition.

Notations	Treatments	Ascorbic acid (mg)
T_0	Control (Water spray)	80.54
T_1	Copper sulphate (Cu) @ 0.20%	81.78
T_2	Copper sulphate (Cu) @ 0.40%	82.78
T_3	Copper sulphate (Cu) @ 0.60%	82.15
T_4	Boric acid (B) @ 0.20%	81.64
T_5	Boric acid (B) @ 0.40%	84.59
T_6	Boric acid (B) @ 0.60%	83.30
T_7	Zinc sulphate (Zn) @ 0.20%	83.24
T_8	Zinc sulphate (Zn) @ 0.40%	84.48
T_9	Zinc sulphate (Zn) @ 0.60%	**86.44**
	SE(m)	0.53
	C.D (p = 0.05)	1.59

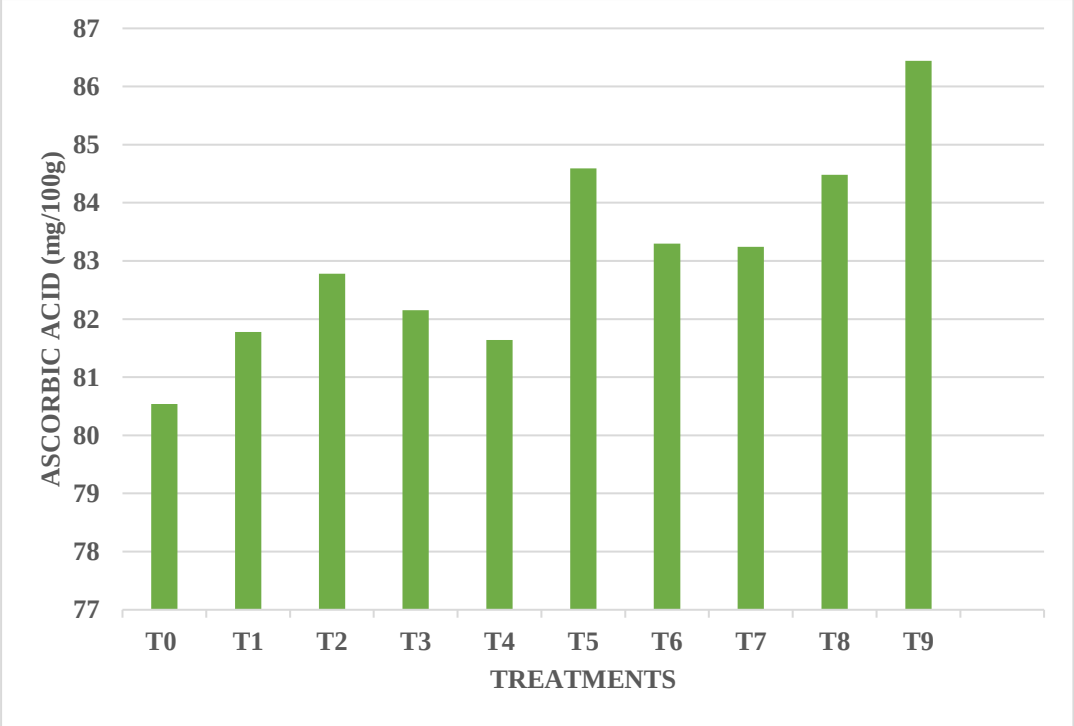

Fig.4.8. Ascorbic acid as affected by foliar spraying of micronutrients on broccoli *cv.* Green Magic under polyhouse condition.

4.2.2. Total soluble solid (%)

In Table 4.9 and fig 4.9 data are presented and showed that there was a significant difference among the various treatments. The highest TSS (%) value was found in T_9 {Zinc sulphate ($ZnSO_4$) @ 0.60%} is 7.74 followed by T_5 {Boric acid (H_3BO_3) @ 0.60%} is 7.58 and T_8 {Zinc sulphate ($ZnSO_4$) @ 0.40%} is 7.04 and the lowest TSS value was recorded in T_0 (Control) is 6.24.

The improvement in TSS content of broccoli head with the application of micronutrients might be attributed to increased metabolic activities associated with production of total soluble solids, such as carbohydrates, organic acid, amino acid and other inorganic elements, Acharya *et al*. (2015). This might be due to the increased carbohydrate production during the process of photosynthesis and photosynthetic activity of plant, Vasconcelos *et al.* (2011). Similar results were recorded by Pankaj *et al.* (2018) in broccoli.

Table 4.9 Total soluble solid (%) as impact of foliar spray of micronutrients on broccoli *cv.* Green Magic under polyhouse condition.

Notations	Treatments	Total soluble solid (%)
T_0	Control (Water spray)	6.24
T_1	Copper sulphate (Cu) @ 0.20%	6.71
T_2	Copper sulphate (Cu) @ 0.40%	7.16
T_3	Copper sulphate (Cu) @ 0.60%	6.82
T_4	Boric acid (B) @ 0.20%	6.74
T_5	Boric acid (B) @ 0.40%	7.58
T_6	Boric acid (B) @ 0.60%	7.24
T_7	Zinc sulphate (Zn) @ 0.20%	6.75
T_8	Zinc sulphate (Zn) @ 0.40%	7.04
T_9	Zinc sulphate (Zn) @ 0.60%	**7.74**
	SE(m)	0.03
	C.D (p = 0.05)	0.09

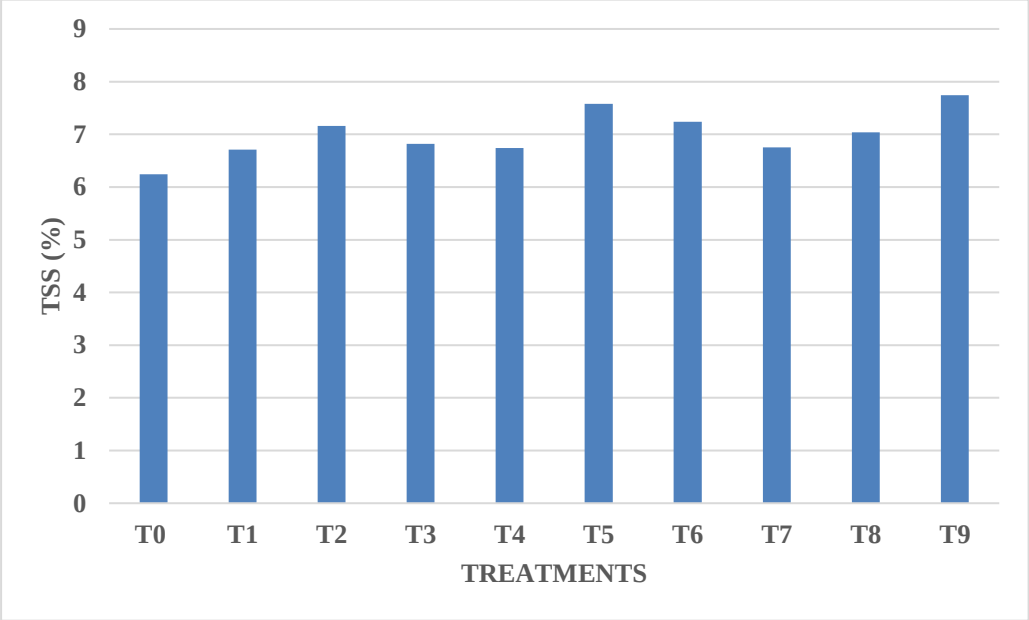

Fig.4.9. TSS (%) affected by foliar spray of micronutrient on broccoli *cv.* Green Magic under polyhouse condition.

4.3. Effect of foliar spray of micronutrients on yield attributing parameters

The data obtained on various yield attributing parameters of broccoli viz. curd yield plant^{-1}(g), curd yield plot^{-1} (kg), curd yield (q ha^{-1}), curd diameter (cm), fresh weight of plant (g), dry weight of plant (g), fresh weight of curd (g) and dry weight of curd (g) were presented in table 4.10, 4.11, 4.12, 4.13, 4.14, 4.15 and 4.16. and fig. 4.10, 4.11, 4.12, 4.13, 4.14, 4.15 and 4.16. respectively.

4.3.1. Curd yield plant^{-1} (g)

The data for different treatments with regard to the curd yield are represented in the Table 4.10. and fig.4.10. Curd range was recorded between 192.70g to 326.46g as impact of foliar application of micronutrients showed significant differences for curd yield.

The data indicated that maximum curd yield was observed 326.46g under the treatment T_5 {Boric acid (H_3BO_3) @ 0.40%} followed by T_4{Boric acid (H_3BO_3) @ 0.20%} is 318.52g and the minimum yield of curd yield 192.70g was reported in the T_0 (control).

The increment in the yield of curd might be due to physiological role of micronutrients. The favorable effects of micronutrients can be attributed to the fact

that, the element is essential in nitrogen metabolism and it also increases the synthesis of auxin which promotes the cell size. Moreover, boron acts as a catalyst in the oxidation and reduction processs and has importance in sugar metabolism, which might have increased curd weight. The current findings are consistent with previous reports of Kanujia *et al.* (2006) in cabbage, and Slosar *et al.* (2016) in broccoli and Chaudhari *et al.* (2017) in cauliflower.

Table 4.10 Curd yield plant^{-1} as impact of foliar spray of micronutrients on broccoli *cv.* Green Magic under polyhouse condition.

Notations	Treatments	Curd yield (g)
T_0	Control (Water spray)	192.70
T_1	Copper sulphate (Cu) @ 0.20%	245.01
T_2	Copper sulphate (Cu) @ 0.40%	252.76
T_3	Copper sulphate (Cu) @ 0.60%	232.71
T_4	Boric acid (B) @ 0.20%	318.52
T_5	Boric acid (B) @ 0.40%	**326.46**
T_6	Boric acid (B) @ 0.60%	286.31
T_7	Zinc sulphate (Zn) @ 0.20%	262.82
T_8	Zinc sulphate (Zn) @ 0.40%	273.87
T_9	Zinc sulphate (Zn) @ 0.60%	305.16
	SE(m)	3.83
	C.D (p = 0.05)	11.31

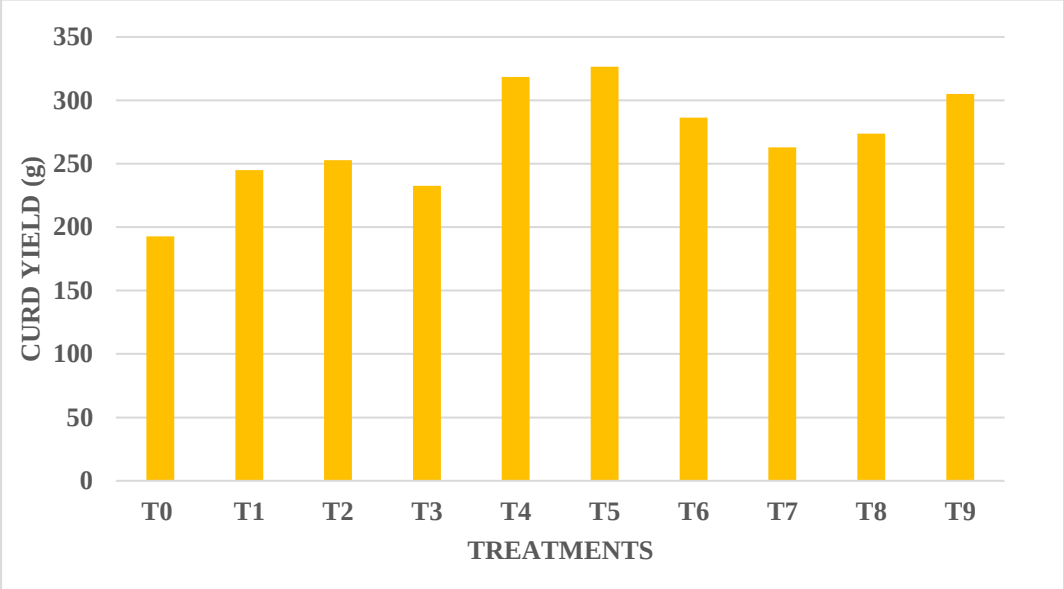

Fig.4.10 Curd yield plant^{-1} (g) as affected by foliar spray of micronutrients on broccoli *cv.* Green Magic under polyhouse condition.

4.3.2. Curd yield plot^{-1} (kg)

It is presented in the Table 4.11 and fig.4.11 the yield (kg plot^{-1}) is ranged from 2.88 kg to 6.29 kg under the different treatments. Significant differences in yield (kg plot^{-1}) was observed with the application of micronutrient.

The maximum yield 6.29kg was reported in the treatment T_5 {Boric acid (H_3BO_3) @ 0.40%} followed by T_4 {Boric acid (H_3BO_3) @ 0.20%} is 6.10kg and T9 {Zinc sulphate ($ZnSO_4$) @ 0.60%} is 6.04kg. The minimum yield 2.88 kg was obtained in the T_0 (control).

Beneficial impacts of micronutrients on vegetative growth increased curd yield which ultimately led to more photosynthesis activities while, application of boron, improved carbohydrates, nitrogen metabolism of the pectic components and enhance the water metabolism and water relation in plants. These findings corroborate with results reported by Adhikary *et al.* (2004) in cauliflower and Sharma (2002) in broccoli.

Table 4.11 Curd yield (kg plot^{-1}) as impact of foliar spray of micronutrients on broccoli *cv.* Green Magic under polyhouse condition.

Notations	Treatments	Curd yield (Kg)
T_0	Control (Water spray)	2.88
T_1	Copper sulphate (Cu) @ 0.20%	3.67
T_2	Copper sulphate (Cu) @ 0.40%	4.45
T_3	Copper sulphate (Cu) @ 0.60%	3.48
T_4	Boric acid (B) @ 0.20%	6.10
T_5	Boric acid (B) @ 0.40%	**6.29**
T_6	Boric acid (B) @ 0.60%	5.21
T_7	Zinc sulphate (Zn) @ 0.20%	4.60
T_8	Zinc sulphate (Zn) @ 0.40%	5.17
T_9	Zinc sulphate (Zn) @ 0.60%	6.04
	SE(m)	0.25
	C.D (p = 0.05)	0.73

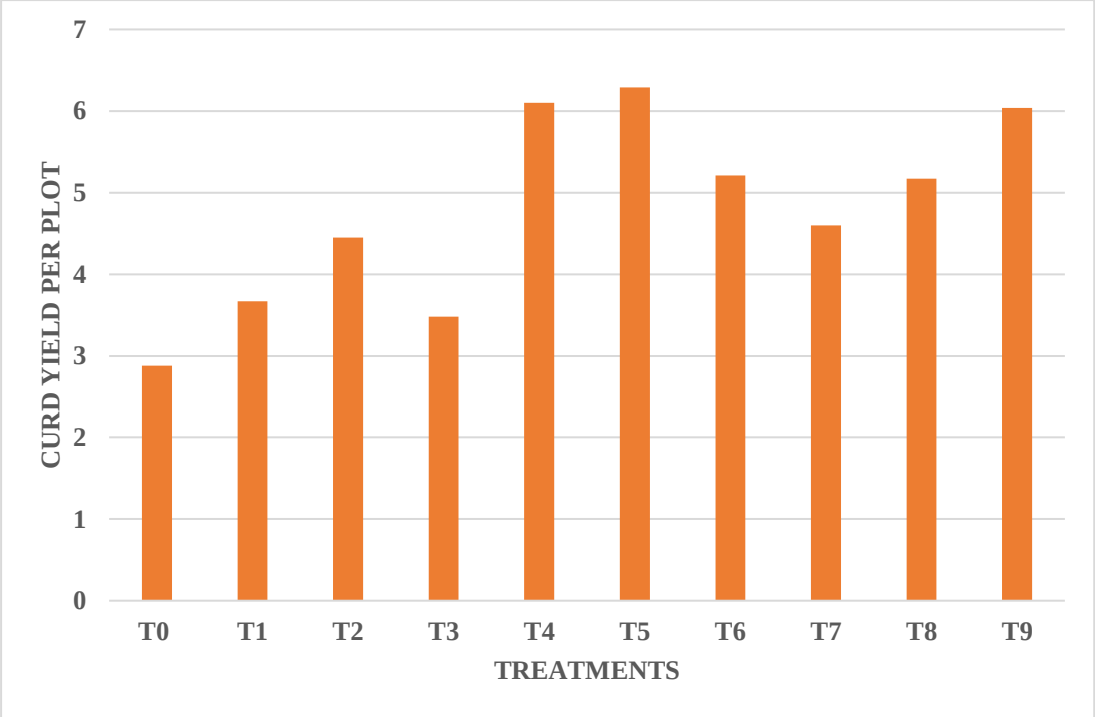

Fig.4.11. Curd yield (kg plot^{-1}) as affected by foliar spray of micronutrients on broccoli *cv.* Green Magic under polyhouse condition.

4.3.3. Curd yield (q ha^{-1})

The yield per plot in various treatments were recorded and change it into yield q ha^{-1}. And the results showed significant variations among other treatments, it is presented from the table 4.12. and Fig.4.12. the yield per hectare was ranged from 72.16 q to 157.24 q under the different treatments.

The greatest yield 157.24 q ha^{-1} was reported with the treatment T_5 {Boric acid (H_3BO_3) @ 0.40%} followed by T4 {Boric acid (H_3BO_3) @ 0.20%} is 153.38 q ha^{-1} and T_9 {Zinc sulphate ($ZnSO_4$) @ 0.60%} is 151.02 q ha^{-1} and T_0 (Control) obtained minimum yield 76q/ha was recorded.

The increase in output might be attributed to the application of several micronutrients in the needed amounts in deficient conditions, which resulted in significant uptake of major nutrients and vigorous plant development, resulting in improved yield and quality. Present result is in agreement with the findings of Singh (2003). The increase in yield could be attributed to stimulating impact of boron, which accelerates the level of absorption of NPK and other nutrients uptake Bhat *et al*. (2010) in cabbage. The decrease in production produced by the application of higher dose of boron could be due to concentration of boron in the root medium beyond tolerance limit of the crops. These results are with the findings of Pizetta *et al***.** (2005), Ain et al., (2016) and Shivran *et al.* (2017) in broccoli.

Table 4.12 Curd yield (q ha^{-1}) as impact of foliar spray of micronutrients on broccoli *cv.* Green Magic under polyhouse condition.

Notations	Treatments	Curd yield (q)
T_0	Control (Water spray)	72.16
T_1	Copper sulphate (Cu) @ 0.20%	91.75
T_2	Copper sulphate (Cu) @ 0.40%	111.24
T_3	Copper sulphate (Cu) @ 0.60%	87.03
T_4	Boric acid (B) @ 0.20%	153.38
T_5	Boric acid (B) @ 0.40%	**157.24**
T_6	Boric acid (B) @ 0.60%	130.23
T_7	Zinc sulphate (Zn) @ 0.20%	115.16
T_8	Zinc sulphate (Zn) @ 0.40%	128.56
T_9	Zinc sulphate (Zn) @ 0.60%	151.02
	SE(m)	3.26
	C.D (p = 0.05)	9.61

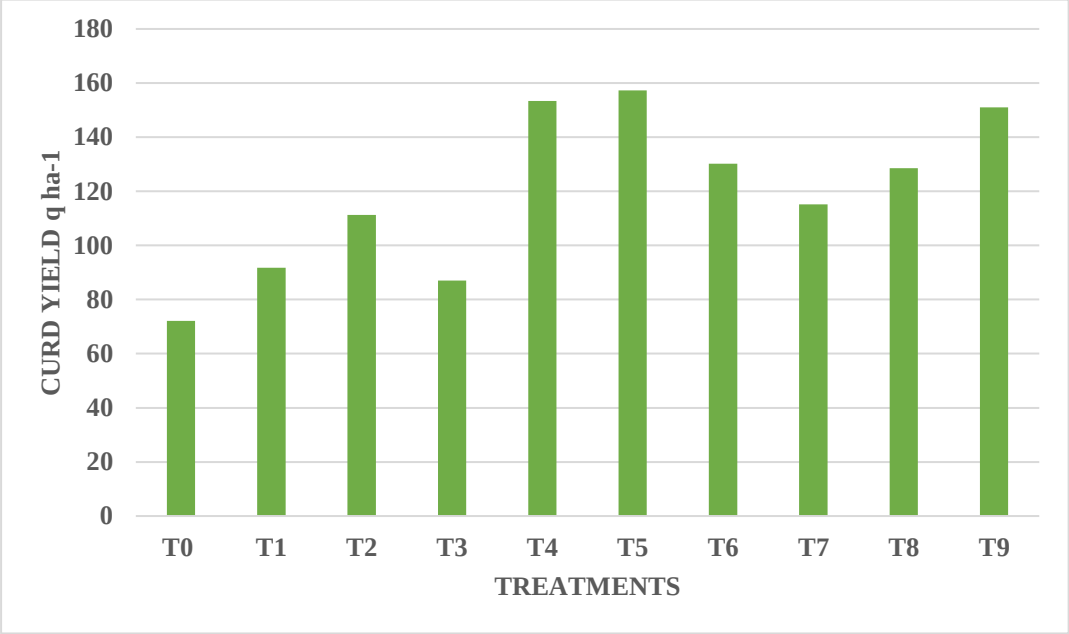

Fig.4.12. Curd yield (q ha^{-1}) as affected by the foliar spraying of micronutrients on broccoli *cv.* Green Magic under polyhouse condition.

4.3.4 Curd diameter (cm)

The data obtained on curd diameter after foliar applications of micro-nutrients during plant growth was recorded at the time of harvesting are presented in Table 4.13 and Fig.4.13.

Among the treatments there was significant differences were observed with respect to curd diameter. The maximum curd diameter observed 17.57 cm under the treatment T_5 {Boric acid (H_3BO_3) @ 0.40%} followed by T_4 {Boric acid (H_3BO_3) @ 0.20%} is 17.37 cm and T_9 {Zinc sulphate ($ZnSO_4$) @ 0.60%} is 16.87 cm and the minimum curd diameter 12.49cm was observed under the treatment T_0 (Control).

Micronutrients increase the curd width and curd weight through boosting the physiological activities also including photosynthesis during which food is developing by the plant, translocation of assimilates from leaves to curd and their storage in curd for which boron was a responsible factor.Improvement in yield characters as a result of foliar application of micronutrients administration could be attributable to an increase in several plant metabolites responsible for cell division and elongation as a result of increased photosynthesis and other metabolic activity. Hatwar *et al.* (2003), Singh *et al.* (2017) and Chowdhury and Sikder (2019) in broccoli.

Table 4.13 Curd diameter in cm as impact of foliar spray of micronutrients on broccoli *cv.* Green Magic under polyhouse condition.

Notations	Treatments	Curd diameter (cm)
T_0	Control (Water spray)	12.49
T_1	Copper sulphate (Cu) @ 0.20%	15.23
T_2	Copper sulphate (Cu) @ 0.40%	15.48
T_3	Copper sulphate (Cu) @ 0.60%	14.82
T_4	Boric acid (B) @ 0.20%	17.37
T_5	Boric acid (B) @ 0.40%	**17.57**
T_6	Boric acid (B) @ 0.60%	16.13
T_7	Zinc sulphate (Zn) @ 0.20%	15.84
T_8	Zinc sulphate (Zn) @ 0.40%	16.08
T_9	Zinc sulphate (Zn) @ 0.60%	16.87
	SE(m)	0.43
	C.D (p = 0.05)	1.28

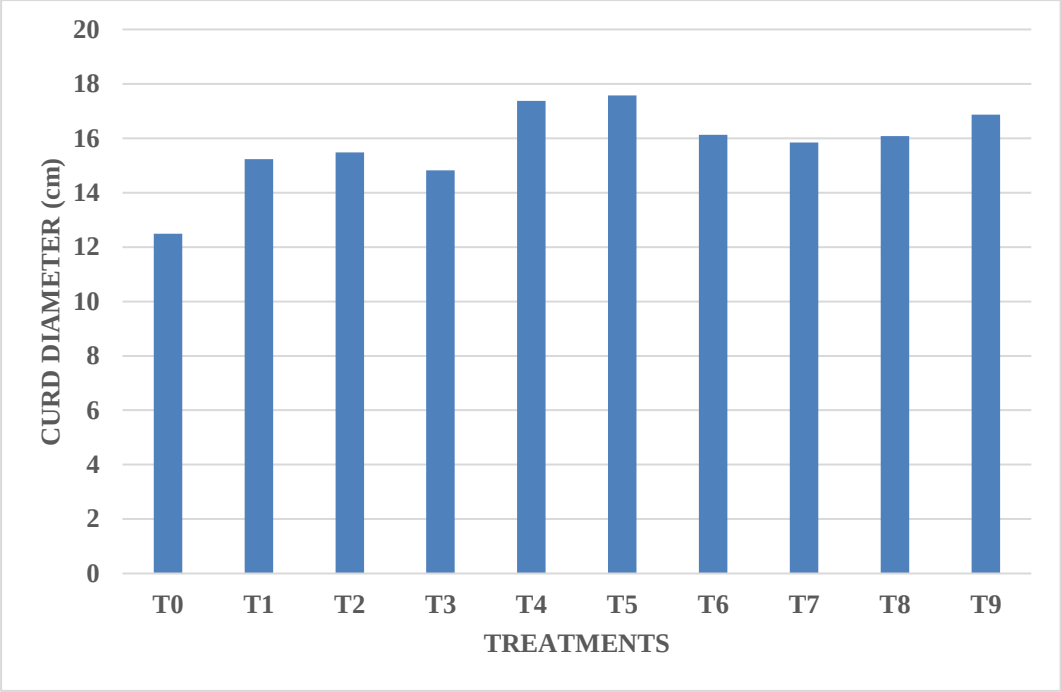

Fig.4.13. Curd diameter (cm) as affected by the foliar spray of micronutrients on broccoli cv. Green Magic under polyhouse condition.

4.3.5. Fresh weight of plant (g)

Table 4.14 and fig.4.14 show that different treatments substantial impact on fresh weight of plant. The range of plant weight was observed between 1194.45g to 1597.45g was significant differences. In treatment T_9 {Zinc sulphate ($ZnSO_4$) @ 0.60%} fresh weight of plant was highest 901.98 gm followed by T_8 {Zinc sulphate ($ZnSO_4$) @ 0.40 %} is 872.03 gm. The lowest was observed in T_0 (Control) is 728.79 gm. These results were recorded closely by Hassan *et al.* (2013) and Abd El-Al (2014) in broccoli.

4.3.6. Dry Weight of Plant (g)

The data presented in table 4.14 and fig.4.15 shows that various treatments significantly influence the dry weight of plant. Range of the plant dry weight was observed between 94.53 g to 104.22 g was significant differences. The data indicated that the treatment T_9 {Zinc sulphate ($ZnSO_4$) @ 0.60%} recorded the maximum dry weight was 104.22 g followed by T_8 {Zinc sulphate ($ZnSO_4$) @ 0.40%} was 103.73 g. The lowest dry weight found in T_0 (control) was 96.53 g. These results were recorded closely by Hassan *et al.*, (2013) and Singh *et al.*, (2018) in broccoli.

Table 4.14 Fresh and dry weight of plant as impact by foliar spraying of micronutrients on broccoli *cv.*Green Magic under polyhouse condition.

Notations	Treatments	Fresh Weight (g)	Dry weight (g)
T_0	Control (Water spray)	728.79	94.53
T_1	Copper sulphate (Cu) @ 0.20%	757.92	96.55
T_2	Copper sulphate (Cu) @ 0.40%	763.06	99.15
T_3	Copper sulphate (Cu) @ 0.60%	761.45	98.66
T_4	Boric acid (B) @ 0.20%	835.16	98.61
T_5	Boric acid (B) @ 0.40%	847.56	101.64
T_6	Boric acid (B) @ 0.60%	820.88	99.63
T_7	Zinc sulphate (Zn) @ 0.20%	828.14	101.38
T_8	Zinc sulphate (Zn) @ 0.40%	872.03	103.73
T_9	Zinc sulphate (Zn) @ 0.60%	**901.98**	**104.22**
	SE (m)	2.86	1.30
	CD(p=0.05)	8.46	3.86

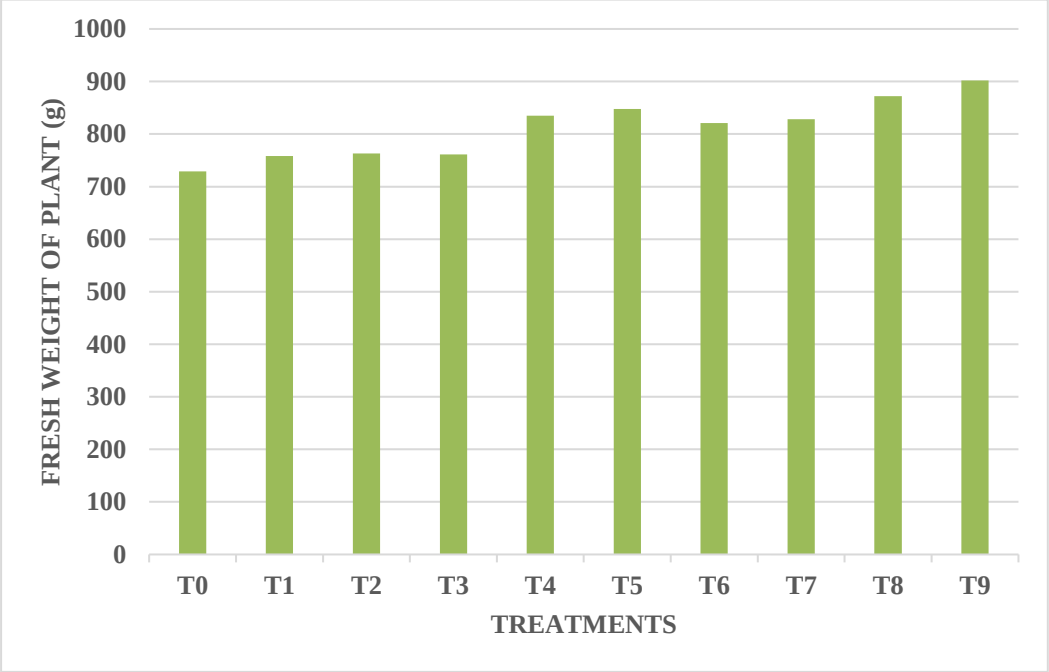

Fig.4.14. Fresh weight of plant (g) as affected by the foliar spray of micro-nutrients on broccoli *cv.* Green Magic under polyhouse condition.

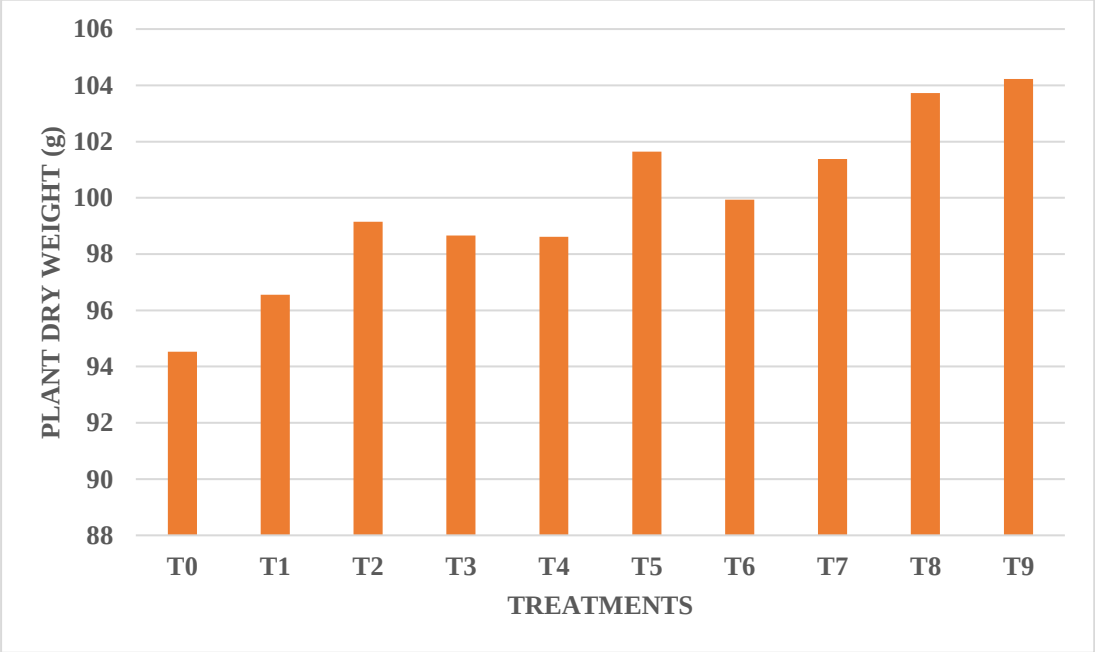

Fig.4.15. Dry weight of plant (g) as affected by foliar spray of micronutrients on broccoli cv Green Magic under polyhouse condition.

4.3.7. Fresh weight of curd (g)

It is presented in the Table 4.15. and fig.4.16 the fresh weight of curd (g) was ranged from 192.70 g to 326.46 g under the different treatments. As per the result is concerned the maximum fresh weight of curd was observed under the treatment T_5 {Boric acid (H_3BO_3) @ 0.40%} was 326.46 g followed by T_4 {Boric acid (H_3BO_3) 0.20%} was 318.52 g, while the minimum result was found under the treatment T_0 (control) is 192.70g.

4.3.8. Dry weight of curd (g)

The data for different treatments with regard to the dry weight of curd (g) are represented in the table 4.15. and fig. 4.17. Dry weight of curd range between 22.04 g to 36.51 g as impact of application of micronutrients showed significant differences for curd yield. The data indicated that the maximum dry weight was observed is 36.51g under the treatment T_5 {Boric acid (H_3BO_3) @ 0.40%} followed by T_4 {Boric acid (H_3BO_3) @ 0.20%} is 34.28 g and the minimum dry weight 22.04g was reported in the treatment T_0 (control).

Table 4.15 Fresh and dry weight of curd as impact of foliar spray of micro-nutrients on broccoli *cv.* Green Magic under polyhouse condition.

Notations	Treatments	Fresh Weight (g)	Dry weight (g)
T_0	Control (Water spray)	192.70	22.04
T_1	Copper sulphate (Cu) @ 0.20%	245.01	23.80
T_2	Copper sulphate (Cu) @ 0.40%	252.76	28.27
T_3	Copper sulphate (Cu) @ 0.60%	232.71	24.81
T_4	Boric acid (B) @ 0.20%	318.52	34.28
T_5	Boric acid (B) @ 0.40%	**326.46**	**36.51**
T_6	Boric acid (B) @ 0.60%	286.31	33.92
T_7	Zinc sulphate (Zn) @ 0.20%	262.82	32.30
T_8	Zinc sulphate (Zn) @ 0.40%	273.87	33.22
T_9	Zinc sulphate (Zn) @ 0.60%	305.16	34.23
	SE (m)	3.83	0.50
	CD(p=0.05)	11.31	1.49

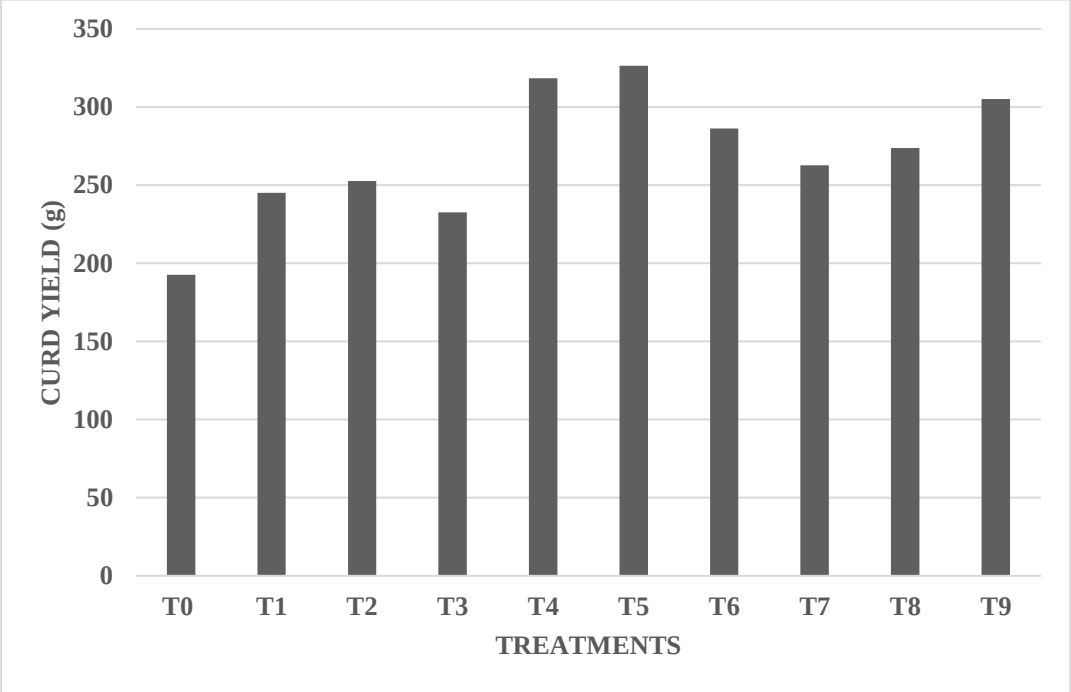

Fig.4.16. Fresh weight of curd (g) as affected by foliar spray of micronutrients on broccoli *cv.* Green Magic under polyhouse condition.

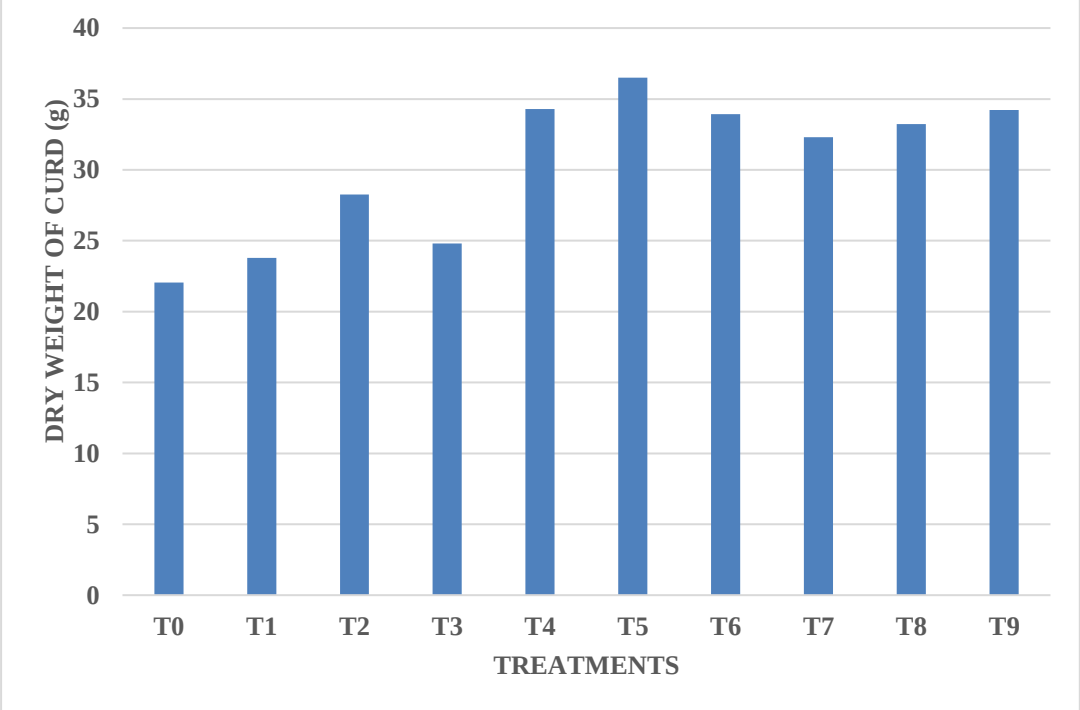

Fig. 4.17. Dry weight of curd (g) as affected by the foliar spray of micronutrients on broccoli *cv.* Green Magic under polyhouse condition.

4.4. Economics

Studies on the economics of the treatment application are critical because they are of key importance to farmer in terms of monetary returns and profitability from crop suggestion and the farmer's adaption of any package of activities is depends on the treatment's economic feasibility. As a result, in order to determine the correct treatment, it is important to calculate the economics of various therapies used in the experiment.

4.4.1. Cost of cultivation

The total cost of each treatment was separated into two parts: general costs and treatment-specific costs. Costs of field preparation, seed, sowing expenses, weeding and insecticide spraying, irrigation, harvesting, and general expenses are all common charges. The cost of cultivation of Rs.178635 was common for all the treatments (table 4.4) but the cost of different treatments of micronutrients varied from treatments to treatments. The highest total cost of cultivation (Rs180735/ha) was incurred under T_3 {copper sulphate @ 0.60%} against the total cost of Rs 178635/ha involved in control (T_0).

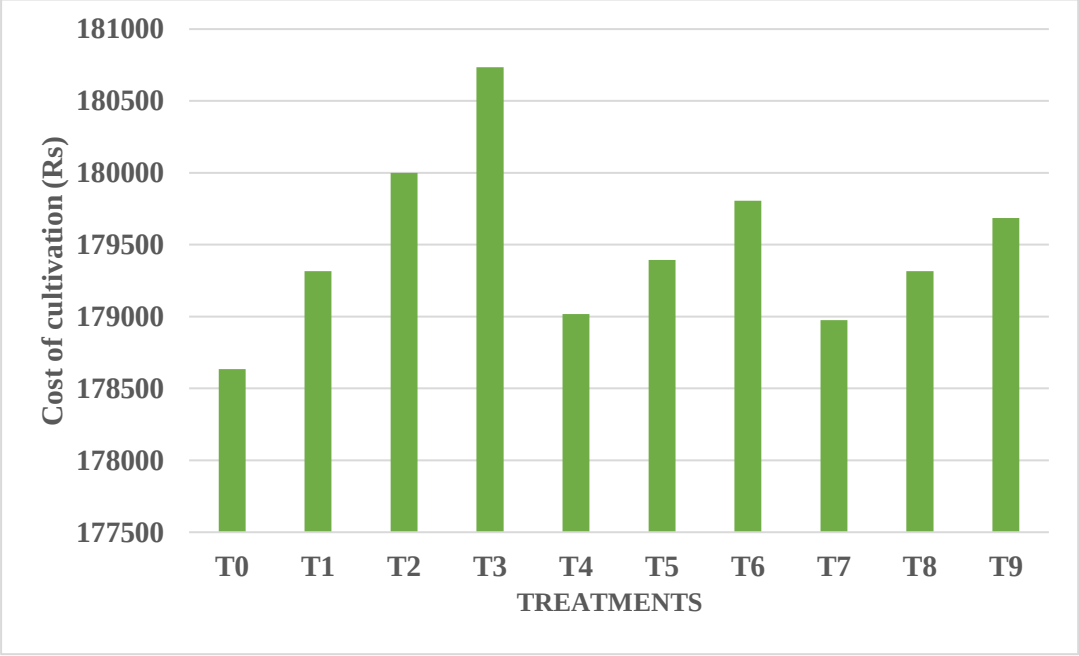

Fig.4.18 Cost of cultivation (Rs) as affected by the foliar spray of micronutrients on broccoli *cv.* Green Magic under polyhouse condition.

4.4.2 Gross income

Data embodied in Table revealed that the maximum gross income of Rs 471720/ha was obtained with the Boric acid @ 0.40% (T_5) followed by in order resulting are T_4 (Rs 460140), T_9 (Rs 453060), T_6 (Rs 390690), T_8 (Rs 385680), T_7 (Rs 345480), T_2 (Rs 333720) and T_1 (Rs 275250) against T_0- control (Rs 216480).

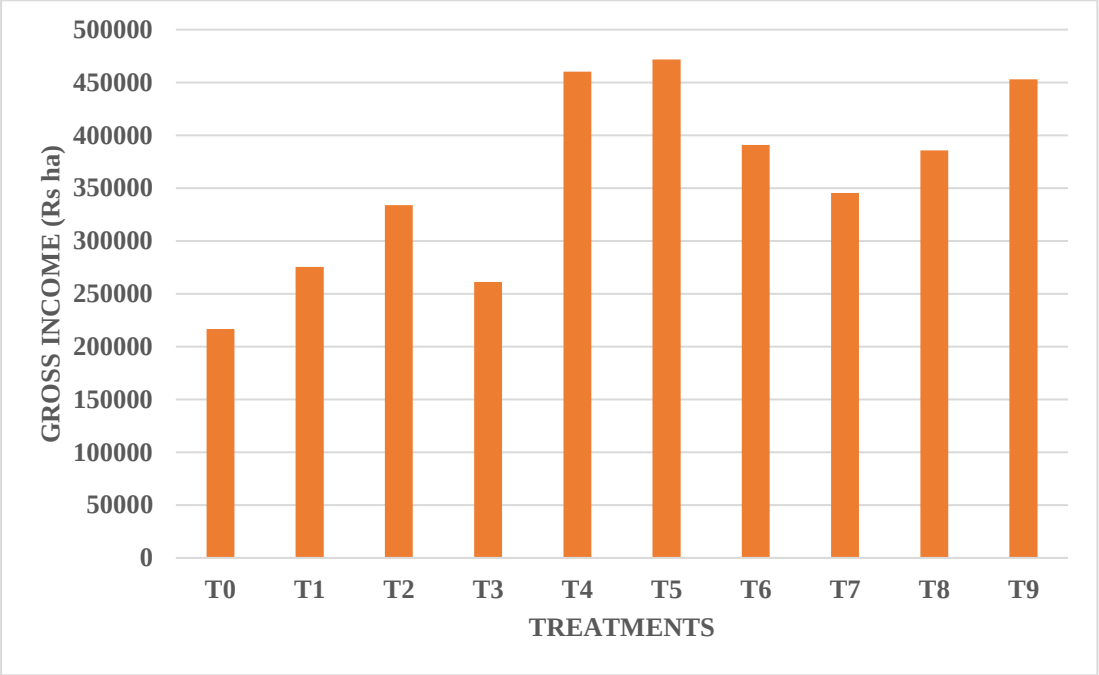

Fig.4.19 Gross income (Rs/ha) as affected by the foliar spray of micronutrients on broccoli *cv.* Green Magic under polyhouse condition.

4.4.3 Net income

The net income obtained by foliar application of ten micro-nutrients treatments to broccoli crop was ranging from Rs 37845 to Rs 292325 per hectare, maximum net return of Rs 292325/ha was obtained with treatment T_5 followed by T_4 (Rs 281123), T_9 (Rs 273375), T_6 (Rs 210885), T_8 (Rs 206363), T_7 (Rs 166505), T_2 (Rs 153720), T_1 (Rs 95934) and T_3 (Rs 80355) respectively against T_0 (Rs 37845).

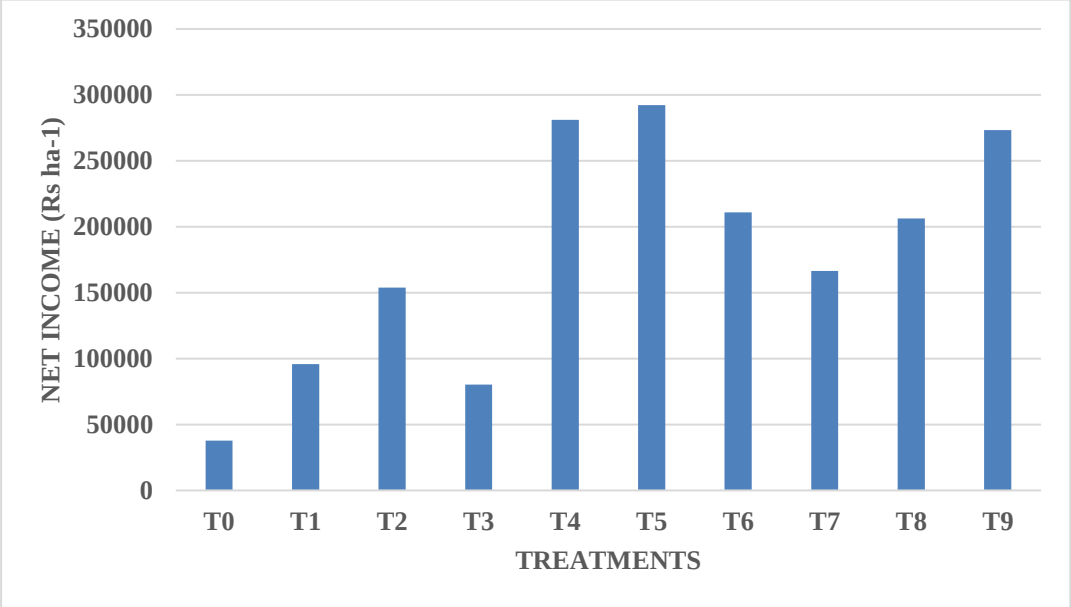

Fig.4.20 Net income (Rs) as affected by the foliar spray of micronutrients on broccoli *cv.* Green Magic under polyhouse condition.

4.4.4 Benefit: Cost ratio

The B:C ratio for foliar application of ten micro-nutrients treatments was ranging from 1.21 to 2.62 while maximum benefit: cost ratio obtained with T_5 (2.62) followed by T_4 (2.57), T_9 (2.52), T_6 (2.17), T_8 (2.15), T_7 (1.93), T_2 (1.85), T_1 (1.53) and T_3 (1.44) respectively against T_0 (1.21).

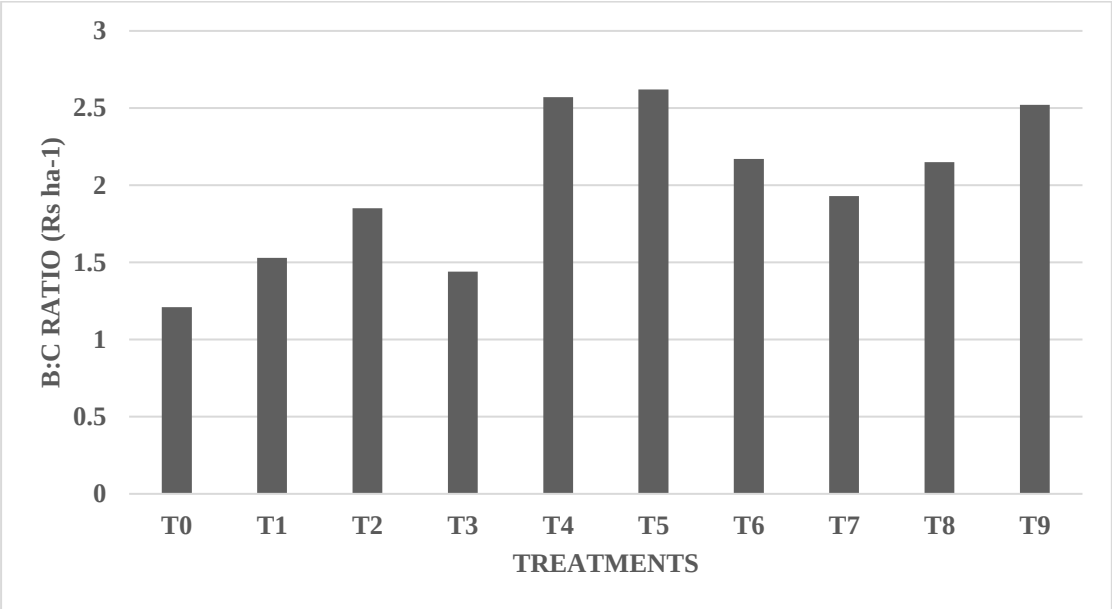

Fig.4.21. B:C ratio (Rs/ha) s affected by the foliar spray of micronutrients on broccoli *cv.* Green Magic under polyhouse condition.

Table 4.16. Economics of different treatment combination

Treatment	Yield Q ha^{-1}	Treatment's cost (Rs/ha)	Common cost (Rs/ha)	Total cost of Cultivation (Rs/ha)	Gross income (Rs/ha)	Net income (Rs/ha)	B:C ratio
T_0	74.66	0	178635	178635	216480	37845	1.21
T_1	136.00	681	178635	179316	275250	95934	1.53
T_2	104.08	1365	178635	180000	333720	153720	1.85
T_3	150.83	2100	178635	180735	261090	80355	1.44
T_4	178.58	380	178635	179017	460140	281123	2.57
T_5	187.83	760	178635	179395	471720	292325	2.62
T_6	142.83	1170	178635	179805	390690	210885	2.17
T_7	127.66	340	178635	178975	345480	166505	1.93
T_8	108.83	682	178635	179317	385680	206363	2.15
T_9	94.50	1050	178635	179685	453060	273375	2.52

CHAPTER V

SUMMARY AND CONCLUSIONS

The field experiments entitled "Impact of foliar spray of micro-nutrients on growth, yield and quality of Broccoli (*Brassica oleraceae L. var italica*) under poly house condition" was carried out during 2020-21 at the Centre of Excellence on Protected Cultivation and Precision Farming, College of Agriculture, IGKV, Raipur (C.G.).

Finally, data was subjected to statistical analysis by applying statistical procedure and undertaken on the basis of observations taken during the experiment for ten treatments. The results obtained on the various topics as per synopsis of programme during the investigation.

The results are summarized below:

1. Highest plant height (cm) was recorded in T_9- zinc sulphate ($ZnSO_4$) @ 0.60% and the lowest was recorded under the treatment T_0- Control (water spray).
2. Maximum no. of leaves was recorded in T_9- Zinc sulphate ($ZnSO_4$) @ 0.60% and the minimum no. of leaves was under T_0- control (water spray).
3. Highest stalk length (cm) was recorded in T_9- zinc sulphate ($ZnSO_4$) @ 0.60% and T_8- zinc sulphate ($ZnSO_4$) @ 0.40% and lowest stalk length was recorded under T_0- control (water spray).
4. Maximum days to first curd initiation was recorded in T_0- control (water spray) and minimum days to curd initiation was recorded in T_5- Boric acid (H_3BO_3) @ 0.40%.
5. Minimum days to 50% curd maturity was recorded in T_5- Boric acid (H_3BO_3) @ 0.40% and maximum days was under T_0- control (water spray).
6. Minimum days to curd maturity was recorded in T_5- Boric acid (H_3BO_3) @ 0.40% and maximum days to maturity was recorded under T_0- control (water spray).

7. Highest root length (cm) was recorded under T_9- zinc sulphate ($ZnSO_4$) @ 0.60% followed by T_8- zinc sulphate ($ZnSO_4$) @ 0.40% and the minimum root length were under T_0- control (water spray).
8. Maximum ascorbic acid (mg) content was recorded in T_9- zinc sulphate ($ZnSO_4$) @ 0.60% followed by T_5- Boric acid (H_3BO_3) @ 0.40% and the minimum ascorbic acid content recorded under T_0- control (water spray).
9. Maximum total soluble solid (%) was recorded under the T_9- zinc sulphate ($ZnSO_4$) @ 0.60% and minimum was observed under T_0- control (water spray).
10. Maximum curd yield plant^{-1} (g) was recorded in T_5-Boric acid (H_3BO_3) @ 0.40% followed by T_4- Boric acid (H_3BO_3) @ 0.20% and minimum curd yield plant^{-1} T_0- control (water spray).
11. Maximum curd yield plot $^{-1}$ (kg) was recorded under T_5- Boric acid @ 0.40% and minimum was recorded T_0- control (water spray).
12. Maximum curd yield (q ha^{-1}) was recorded under T_5- Boric acid @ 0.40% followed by T_4- Boric acid @ 0.20% and the minimum was observed in T_0- control (water spray).
13. Highest curd diameter in cm was recorded under T_5- Boric acid @ 0.40% and the lowest curd diameter was observed under T_0- control (water spray).
14. Highest fresh and dry weight of plant (g) was observed in T_9- zinc sulphate @ 0.60% and the lowest fresh and dry weight was recorded under T_0- control (water spray).
15. Highest fresh and dry weight of curd (g) was recorded in T_5- Boric acid @ 0.40% and lowest was recorded T_0- control (water spray).
16. Maximum and minimum total cost of cultivation was recorded under T_3 (Rs 180735/ha)- copper sulphate @ 0.60% and T_0 (Rs 178635/ha)- control (water spray).
17. Maximum and minimum gross income was observed in T_5 (Rs 471720/ha) and T_0 (Rs 216480- control (water spray), respectively.
18. Maximum and minimum net income was recorded in T_5 (Rs292325/ha) and T_0 (Rs 37845), respectively.

19. Maximum B:C ratio was observed in T_5 (2.62) followed by T_4 (2.57) and minimum was recorded under T_0 (1.21).

CONCLUSIONS-

The present investigation was carried out in the year 2020-21 for a single season, therefore, it is not possible to draw a definitive conclusion based on one season data. However, on the basis of result obtained, that sprays of different micronutrients (Cu, B, Zn) give effective response in growth, yield and quality in broccoli. The finding revealed that T_9- zinc sulphate @ 0.60% were found better for increasing vegetative and quality parameters where as T_5- Boric acid @ 0.40% were found better performance in yield parameters.

SUGGESTIONS FOR FUTURE RESEARCH WORK

- To identify the best micronutrients for different agro-climatic zones of Chhattisgarh, detailed study is needed.
- Application of some other micronutrients like Mo, Fe, Mn at different concentration to assess its effectiveness on growth, yield and quality in broccoli.
- For attaining any definite recommendations, the same experiment can be repeated for one or more season.

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Appendix A- weekly meteorological data recorded during crop growing period 2020-21

Weeks	Duration	Max. Temp. (^{0}C)	Min. Temp. (^{0}C)	Max. RH (%)	Min. RH (%)	Rainfall Weekly	Sunshine (hours)
46	11 Nov to 17 Nov	34.5	15	91	29	0	8.4
47	18 Nov to 24 Nov	35	10.5	89	29	1	6.4
48	25 Nov to 1 Dec	30.6	13.2	93	26	0	7.3
49	2 Dec to 8 Dec	31.2	11.4	91	24	0	7.5
50	9 Dec to 15 Dec	32	12.5	89	28	0	3.4
51	16 Dec to 22 Dec	30	6.5	82	16	0	7.5
52	23 Dec to 29 Dec	30	7	92	17	0	6.8
1	30 Dec to 5 Jan	30	10.6	93	22	0	0
2	6 Jan to12 Jan	31.1	16.3	78.4	30	0	5.4
3	13 Jan to 19 Jan	30	11.7	83.1	24	0	6.3
4	20 Jan to 26 Jan	31	14.1	80	35.5	0	4.4
5	27 Jan to 1 Feb	28.1	10.3	81.1	27.7	1	3.4
6	2 Feb to 8 Feb	30	10.6	77.5	20.4	0	6.4

Appendix B- Cost of cultivation of broccoli crop

S. No.	Material/work	Expenditure
1.	**Seed cost** (37,500 plants/ha.)	10000
2.	**Land preparation**	
	(a) Ploughing, Tractor rent and leveling @ 800/hr for 3hr	2400
	(b) Furrow/bed preparation	20000
	(c) FYM-21 tones/hectare @ 600/t	12600
	(d) Fertilizers	24000
	(e) Cost of mulching material	20000
	(f) Labours cost	30000
	(g) Drip irrigation installation (Depreciation cost)	4000
3.	**Transplanting**	
	(a) Transplanting cost (15 labors at 287/day)	4500
	(b) Drenching of micronutrients (10labours @ 287/day)	2870
4.	**Intercultural operation**	
	(a) Insect/pests and disease control (cost of insecticides, fungicides, labour for spraying)	15000
5.	**Harvesting**	
	(a) Crop harvesting (80 labours @ 287 per days)	22,960
	(b) Selling (15 labours @ 287 per days)	4305
6.	Overhead expenses (polyhouse depreciation cost)	6000
	Total	**1,78,635**

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