EFFECT OF FOLIAR APPLICATION OF SELECTED MICRONUTRIENTS AND GROWTH REGULATORS ON TUBER DEVELOPMENT, YIELD AND FORTIFICATION STATUS OF SWEET POTATO (*Ipomoea batatas* L.).

by

ARYA S. R

(2017-11-146)

THESIS

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF PLANT PHYSIOLOGY
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM - 695 522
KERALA, INDIA
2019

DECLARATION

I, hereby declare that this thesis entitled **"EFFECT OF FOLIAR APPLICATION OF SELECTED MICRO NUTRIENTS AND GROWTH REGULATORS ON TUBER DEVELOPMENT, YIELD AND FORTIFICATION STATUS OF SWEET POTATO (*Ipomoea batatas* L.)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellayani,
Date: 2-09-19

ARYA S.R
(2017-11-146)

CERTIFICATE

Certified that this thesis entitled **"EFFECT OF FOLIAR APPLICATION OF SELECTED MICRO NUTRIENTS AND GROWTH REGULATORS ON TUBER DEVELOPMENT, YIELD AND FORTIFICATION STATUS OF SWEET POTATO (*Ipomoea batatas* L.)"** is a record of research work done independently by Ms. ARYA S. R under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Vellayani,
Date: 2-09-19

Dr. Viji M. M
(Chairperson, Advisory committee)
Professor and Head,
Department of Plant Physiology,
College of Agriculture, Vellayani
Thiruvananthapuram.

CERTIFICATE

We, the undersigned members of the advisory committee of **Ms. ARYA S. R.** a candidate for the degree of **Master of Science in Agriculture** with major in Plant Physiology, agree that the thesis entitled **"EFFECT OF FOLIAR APPLICATION OF SELECTED MICRO NUTRIENTS AND GROWTH REGULATORS ON TUBER DEVELOPMENT, YIELD AND FORTIFICATION STATUS OF SWEET POTATO (*Ipomoea batatas* L.)"** may be submitted by Ms. ARYA. S. R, in partial fulfilment of the requirement for the degree.

Dr. M.M. Viji
Professor and Head
Department of Plant Physiology
College of Agriculture, Vellayani
Thiruvananthapuram-695 522

Dr. Saravanan Raju
Senior scientist
CTCRI
Sreekaryam
Thiruvananthapuram-695 017

Dr. Roy Stephen
Professor
Department of Plant Physiology
College of Agriculture, Vellayani,
Thiruvananthapuram-695 522

2/9/2019

Dr. Biju Joseph
Assistant Professor
Instructional farm
Dept. of Soil Science and
Agricultural Chemistry
College of Agriculture, Vellayani,
Thiruvananthapuram-695 522

ACKNOWLEDGEMENTS

Thanks to Almighty 'GOD' and 'MOTHER EARTH' who are more benevolent and merciful made me capable to complete this task.

It is with great reverence I place on record, my deepest sense of gratitude and indebtedness to my major advisor ***Dr. Viji M. M.****, Professor and Head, Department of Plant Physiology, College of Agriculture, Vellayani, for her meticulous supervision, soft and sincere suggestions, untiring help and constant encouragement throughout the progress of this study.*

My heartfelt thanks to ***Dr. Roy Stephen****, Professor,* ***Dr. Manju, R. V.****, Professor and* ***Dr, Beena R.,*** *Assistant Professor, Department of Plant Physiology, for their meticulous guidance, valuable suggestions, keen interest, wholehearted help and constructive criticism and also for the realization of the project.*

I am greatly indebted to ***Dr. Saravanan Raju,*** *Senior scientist,CTCRI, Sreekaryam for his support guidance as an advisory committee member during the period of research work.*

I am extremely grateful to the member of advisory committee, ***Dr. Biju Joseph*** *Assistant Professor, Instructional farm, Dept. of Soil Science and Agricultural Chemistry for his valuable suggestions and cooperation during the course of present investigation.*

I am greatly indebted to ***Dr. Sajitha Rani,*** *Professor, Instructional farm, Dept. of Agronomy for her support during the period of research work.*

I am thankful to my classmates ***Ammu Alphonsa John*** *,* ***Sayooj S, Lakshmi G Ajay, Ranghunath M.P.*** *and* ***Chennamsetti Lakshmi Naga Manikanta*** *for their friendship and kind help in times of need.*

I acknowledge the boundless affection, unsolicited help, companionship and moral support rendered by my besties ***Liz, Susu, Ponnza, Anjuz, Aisu, Sappa, Aruni, Thassa, Susan, S, Reni and PV*** *whom I admire a lot. I warmly remember their role in making the period of my study here a memorable and cherished one.*

Also, I am thankful to my friends ***Kavya, Navi, PR, Vava, Achu achuz, Adhithya, Veni, Deptham, Keerthana, Bindhuz, Silpa, Amalu, Dhanu, Thadiyan, Ajmal, Mappan, Manu, Gopettan, Qban, Abuji, Anand, Sruthimol, Ammuchechi, Merin chechi, Nibin chettan and all my friends*** *for their love and support during my PG programme.*

My special thanks goes to my entire friends and seniors from my department whom I must name individually; ***Alif, Srikanth bayya, Gayatri chechi, Yogesh bayya, Nithya chechi, Manasa akka, Afna chechi, Stephen chettan, Saranya Chechi, Vipin cheta, Anila chechi, Beena chechi, and Binu chettan.***

I am thanking my juniors ***Bhavana, Amrutha, Sree vardhan, Sree Rag, Sudha rani, and Eldo,*** *their brotherly affection and kind help without which I may never have completed my research work.*

I am most indebted to At this time of thesis submission, I remember with pleasure the sacrifice and support from ***my dearest family members Achan, Amma, Soorya Chechi, Prakasettan, Devooty, Atharva, Kunjuttty and Ahal*** *for their affection, constant encouragement, moral support and blessings that have enabled me to complete this work, without which I would not have completed this research. Thank you for supporting my decisions and for being a precious source of strength throughout the course of my study here.*

Once again I am thanking everyone who helped me during my research programme……

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LIST OF ABBREVIATIONS

A	Absorbance
B	Boron
CCC	Cycocel
CD (0.05)	Critical difference at 5% level
cm	Centimeter
CTCRI	Crntral Tuber Crop Research Institute
DAP	Days after planting
DI	Days interval
DMSO	Dimethyl sulphoxide
et al.	Co-workers/ Co-authors
Fe	Iron
Fig.	Figure
FYM	Farmyard manure
g	Gram
g^{-1}	Per gram
ha	Hactare
ha^{-1}	Per hactare
i.e.	That is
K	Ptassium
KAU	Kerala Agricultural University
kg	Kilogram
kg^{-1}	Per kilogram,
l	Litre
m^2	square metre
m^{-2}	Per square metre
mg	Milligram
mm	Millimetre
mmolesH_2O m-^{2} s^{-1}	Milli moles H_2O $meter^{-2}$ $second^{-1}$

μ moles CO_2 m^{-2} s^{-1}	Micro moles $meter^{-2}$ $second^{-1}$
ml	Millilitre
M ha^{-1}	Million hactare
Mn	Manganese
MN	Micronutrient
(*)	Micronutrient mixture(Fe+Zn+Mn+B)
MSL	Mean sea level
N	Nitrogen
pH	Potenz hydrogen
POP	Package of practices
ppm	Parts per million
ppt	Parts per trillion
RBD	Randomized block design
rpm	Rotations per minute
SE m	Standard error of mean
t	Tonnes
sec	Second
V	Volume
viz.,	Namely
Zn	Zinc
%	Percentage
@	At the rate of
^{o}C	Degree Celcious
μ	Micro

Introduction

1. INTRODUCTION

Sweet potato (*Ipomoea batatas* L.) is one of the important food crops which comes under the family Convolvulaceae and native to South America. It is considered as the second important root and tuber crop next to cassava (Ray and Ravi, 2005). In many of the developing countries of tropics and subtropics it is the major staple food. Globally it is cultivated in 111 countries with an area of 8.106 million hectare and production of 106.569 million tonnes and an average productivity of 13.147 t ha^{-1} (FAOSTAT, 2009). It is an extremely versatile and delicious vegetable with high nutritional value as well as high medicinal properties including anti-inflammatory, anti-diabetic, anti-cancer, anti-bacterial, anti-oxidant, anti-fungal, anti-viral, anti-ulcer, anti-hepato protective, immune modulatory and wound healing activities (Parle and Monika, 2015). Hence sweet potato is considered as a socially and economically important crop ranking sixth in position among the food crops and it comes after rice, wheat, potato, maize and cassava (Hejjegar *et al.,* 2018).

Micronutrients are very much important to agriculture and human health. In addition to the macro elements (N, P, K, Ca, Mg and S) eight other mineral nutrients are also essential for the normal plant growth and development. Even though they are essential they are required in small quantity and are called as micronutrients, namely iron [Fe], zinc [Zn], manganese [Mn], boron [B], molybdenum [Mo], nickel [Ni], copper [Cu] and chlorine(Cl). Iron, boron and zinc are found in higher quantity in soil than that of their requirement to the plants and their pronounced deficiency occurs because they cannot be readily absorbed due to their fixation in soil (Datnoff *et al.,* 2007; Marschner, 2012).

Cu, Mn, Fe and Cl are essential for various processes in photosynthesis and they are also considered as the cofactors of enzymes involved in various metabolic processes. Fe, Mn, Zn, Cu, Ni, Mo, and Cl are major part of functioning and activation of many of the enzymes such as superoxide dismutases, dehydrogenases, catalases, DNA/RNA polymerases, ATPases, oxidases and enzymes involved in

redox reaction (Broadley *et al.,* 2012). Sweet potato quality as well as productivity are mainly affected by low nutrient status especially low micronutrient levels and poor fertility of soil. Also low concentration of manganese (Mn), copper (Cu), zinc (Zn) and iron (Fe) have become yield limiting factors in various crops (Mona and El-Azab, 2016).

Efficient and rapid uptake and utilization of nutrients for attaining maximum growth and yield of plants is possible by foliar application of nutrients (Oosterhuis, 1995). It also helps in correction of nutrient deficiencies very quickly than that of soil application. Foliar uptake of mineral nutrients is reported to be 8 to 20 times more efficient than soil application (Smolen, 2012). Compared to the soil application of nutrients, foliar application requires only smaller quantity of nutrients and it is more efficient in application of nutrients at proper time and quantity. It is mainly used against hidden hunger, quick remediation at the time of unexpected nutrient deficiencies, late supply of nitrogen during advanced growth stage as well as to overcome nutrient fixation problems in soil (Mikkelsen, 2008). Hence, foliar application has important role in the supply of proper quantity of micronutrients as well as the major nutrients (N, P and K) without causing any kind of plant toxicity (Oosterhuis and Weir, 2010).

In addition to micronutrients, plant growth regulators are also applied through foliar spray. Plant growth regulators are natural or synthetic compounds that are applied to seed or plant which regulate plant growth and development in response to the stimuli and hence any change in the level of plant hormones lead to gene activation shifts (Donthineni *et al.*, 2014). Plant growth regulators have positive effect on biochemical and physiological activities of plants. Some of the growth retardants are also plant growth regulating chemicals which are found to improve grain quality, yield as well as altering the growth of plants (Espindula *et al.,* 2009). Among them cycocel is one of the important plant growth retardant capable of manipulating growth and development processes. It is capable of reducing vegetative

growth and promoting reproductive growth (Stoddart, 1964). Ethylene is one of the plant growth regulators which accelerate ripening, reduce elongation process, promote radial expansion and also cause epinasty and leaf abscission (Pratt and Goeschl, 1969).

Application of ethrel prior to harvest increase the yield (Anon, 1968). Foliar application of ethrel (ethephon) release ethylene inside the plant cells and lead to various physiological changes in plants (Robert and Wilde, 1971). In case of tuber crops ethylene leads to the initiation of tuber and there by enhance yield (Garcia and Gomez, 1972). Cycocel is a growth retardant and it reduces vegetative growth and promotes effective utilization of carbohydrates and enhance the partitioning or translocation of more of the photosynthates from leaves and stem to the economically important parts mainly to the underground tubers (Velayutham and Parthiban, 2013).

Biofortification is a process in which some of the desirable nutrients can be provided to plants in a sustainable and cost effective manner. It is a process that can be used to deliver some of the nutrients (Zn, Se, Ca Fe, I, etc.), some vitamins (A, B1, E, , B6, etc.) as well as folate for the food crops. There are two approaches for biofortification ie., agronomic approach (soil and foliar fertilization) and genetic engineering or plant breeding (Singh *et al.,* 2016). Foliar application is a potential agronomic tool in providing all these minerals and vitamins. The plant biofortification is a commonly applied strategy in staple crops like rice (Boldrin *et al.,* 2013; Shivay *et al.,* 2016; Chen *et al.*, 2017; Mishra *et al.,* 2017), barley (Bityutskii *et al.,* 2017), wheat (Shaikh and Saraf, 2017), maize (Halilu *et al.,* 2016; Liu *et al.,* 2017; Sharma *et al.*, 2017) , common bean (Ram *et al.,* 2016), sweet potato (Laurie *et al.,* 2015) and potato (Kromann *et al.,* 2017).

Micronutrients are very much important for human health too. About 3 billion people in the world suffer from micronutrient deficiencies There are reports stating that including sweet potato along with normal diet can have positive effect in

reducing nutrient deficiency levels in humans (Smolen, 2012). Thus improving nutritional status of the tubers including sweet potato is very much needed. Hence the current study was carried out with the following objectives.

1. To enhance qualitative and quantitative attributes in sweet potato (*Ipomoea batatas* L.) by foliar application of selected micronutrients and growth regulators
2. To study the effect of selected micronutrients and growth regulators on growth, development and changes in fortification status of sweet potato tubers and leaves.

Review of Literature

2. REVIEW OF LITERATURE

Sweet potato is one of the important tuber crops and it has been used as a model plant in the physiological and nutritional studies due to its faster growth and ease of propagation. Due to its higher biomass production it has been used as industrial material mainly for medicinal purposes. The whole sweet potato plant (*Ipomoea batatas* L.) including stem, leaves, tubers are used as food and medicine (Berberich *et al.*, 2005). In addition to this it is used for extracting various processed products like alcohol, starch etc. (Yasmin *et al.*, 2007).

2.1 IMPORTANCE OF FOLIAR APPLICATION

Nutrients can be delivered to the plants through several ways which include soil application and foliar spray. Usually water soluble fertilizers are applied through the aerial parts as foliar spray and they penetrate the cuticle and reach inside the plant through stomata and are used by the plant cells for various metabolisms (Oosterhuis and Weir, 2010). The pH of the spray liquid and age of the leaf affect the absorption by the plants. In addition to this the presence of plasmodesmatal connection within the plant guard cells are also important (Kannan, 2010). Foliar application is the effective method due to the quick feeding of liquid fertilizers at adequate concentration through the leaves. Hence it leads to improved nutrient status, higher yield and quality of the crops (Smolen, 2012). Micronutrient application increases the growth parameters such as plant height, number of branches, yield etc. and also it enhances the overall vegetative growth of plants (El-Tohamy *et al.,* 2014). Foliar application also helps in mitigation of negative effects of stress (e.g., drought, heat, frost, etc.). It also helps in the provision of different plant growth regulators and stimulants, amino acids, nanomaterials, pesticides, fertilizers and nutritional compounds quickly to the plants, based on their need (Smolen, 2012; Shalaby and El-Ramady, 2014; Simoes *et al.* 2017).

2.2 FOLIAR APPLICATION AND BIOFORTIFICATION

Biofortification is capable of producing staple foods with high mineral contents (Se, Ca, Zn, Fe, Mn, B, Cu, I, etc.), in the edible parts. Foliar application of nutrients is cost effective and it helps in obtaining biofortified crops which are mainly enriched with micro and trace elements (Smolen, 2012). In addition to micronutrients some of the nutritional compounds such as thiamin or vitamin B1 (Goyer, 2017), folate (Olivares *et al.,* 2015; Strobbe and van der Straeten 2017), vitamin E (Mene-Saffrane and Pellaud, 2017), provitamin A (Halilu *et al,* 2016; Giuliano, 2017) and vitamin B6 (Fudge *et al.,* 2017) are also enhanced through biofortification. In plants biofortification is mainly used for the enrichment of plants with required nutrients, prevention of hidden hunger and to overcome micronutrient malnutrition. (Singh *et al.,* 2016; de Valença *et al.,* 2017; Gomez *et al.,* 2017). Hence foliar application is considered as an important agro-technical tool for biofortification (Ahmadi-Rad *et al.,* 2016; Davarpanah *et al.,* 2016; Li *et al.,* 2016; Saltzman *et al.,* 2016; Ding *et al.,* 2017; Vasconcelos *et al.,* 2017).

2.3 FOILAR APPLICATION OF MICRONUTRIENTS

Fe, Cu, Mn, Mo, Cu, Cl, Ni, Zn and B are the important eight micronutrients required for all higher plants (Welch and Shuman, 1995). Micronutrients like Fe and Mn are fixed in the soil with alkaline pH. As they are fixed, plant roots cannot absorb these nutrients from the dry top soil (Graham *et al.,* 1992 ; Foth and Ellis, 1996). Similarly at the alkaline pH, phosphate ions react with nutrients like Ca, Mn and Mg and forms less soluble compounds resuling in low mobility of these nutrients and so they cannot be easily translocated to the leaves (Foth and Ellis, 1996). Majority of the micronutrients are not as much mobile compared to the macro elements N, P, and K. Due to this, their application in the soil will not meet the crop requirement. Hence the foliar application is the alternate method to supply these deficient micronutrients. Most of the micro nutrients are involved in the physiological process such as

photosynthesis, respiration, N fixation and in many of the other biochemical pathways (Yuncai *et al.,* 2008). Hence the foliar spray helps in the supply of sufficient quantity of micronutrients without causing any kind of phytotoxicity (Smolen, 2012).

2.4 EFFECT OF FOLIAR APPLICATION OF MICRONUTRIENTS ON BIOMETRIC PARAMETERS

2.4 .1 Branch length

El-Tohamy *et al.* (2014) noticed that foliar application of chelated form of Fe(1g L^{-1}) of two sprays at 14 days interval starting from three weeks after cultivation) exhibited higher branch length in sweet potato. Manas *et al.* (2014) reported that among the foliar application of humic acid(0.5%), zinc (0.5%) and boron(0.2%) on pepper, maximum leaf area was observed with the combined treatment of (HA+Zn+B) whereas individual treatments of Zn and B did not show any significant impact on plant height. Janket *et al.* (2018) reported that individual as well as combined application of micronutrients 2% $ZnSO_4$, 0.5% CuSO4 and 2% $ZnSO_4$ at 15 and 30 DAP on three cassava genotypes (Rayong 9 , CMR 38-125-77 and Kasetsart 5) showed significantly higher plant height compared to control (no fertilizer application).

2.4.2 Number of leaves

Manas *et al.* (2014) studied the effect of foliar application of humic acid(0.5%), zinc (0.5%), and boron(0.2%) on biochemical changes related to the productivity of pepper and reported that among the treatments tried, individual treatment with boron had no significant impact on number of leaves but at the same time more number of leaves were observed with the combined treatment (HA+Zn+B). Deepika and Pitagi (2015) studied the effect of zinc and boron on growth, seed yield and quality of radish (*Raphanus sativus* L.) cv. Arka Nishanth and

reported that maximum number of leaves per plant (34.30) was obtained with the treatment of recommended dose of fertilizers (75:40:40 NPK kg ha^{-1}) along with $ZnSO_4$ @ 10 kg ha^{-1} and borax (0.1%) spray at bud initiation stage. Reddy *et al.* (2018) reported that maximum number of leaves was observed in the combined treatment of micronutrient mixture (Zn, Mo, B, Cu, Mn and Fe each at 250ppm except (Mn @ 50ppm) in two tomato varieties Arka vikas and Arka sourabh.

2.4.3 Specific leaf area

Manas *et al.* (2014) studied the effect of foliar application of humic acid (0.5%), zinc (0.5%), and boron (0.2%) individually and in combination on pepper and found that combined treatments of (HA+ Zn+B) had positive impact on leaf area. Lakshmipathi *et al.* (2018) studied the individual as well as combined effect of foliar spray of zinc ($ZnSO_4$ @ 0.1% and 0.2%) and boron (borax @ 0.5%) on leaf area, photosynthetic pigments, stomatal number and yield of cashew and reported that highest leaf area (156.10 cm^2) was observed with the combined treatment of $ZnSO_4$ (0.5%) + borax (0.1%) sprayed at flushing, flowering as well as fruiting stage.

2.4.4 Shoot weight

El -Banna and Abd El -Salam (2005) studied the response of potato plants to different sources of potassium with the foliar spray of boron and molybdenum and found that application of boron at two different concentrations (50 and 75 ppm) at 60 and 75 days after planting had positive influence on fresh weight of vegetative plant parts of potato. Reddy *et al.* (2018) reported that combined treatment of micronutrient mixture [Zn, Mo, B, Cu, Mn and Fe each at 250ppm except Mn(@ 50ppm) of three sprays at 10 days interval starting from 30 DAP] resulted in maximum shoot weight in two tomato varieties Arka vikas and Arka sourabh.

2.4.5 Tuber length, Tuber diameter and Tuber weight

Kumar *et al.* (1996) reported that foliar application of boron (borax 0.1%) after 3 weeks of sowing showed maximum root size in radish. Mohammadi (2000) reported that foliar application of Zn and Mn resulted in an increase in mean tuber yield of potato. Mousavi *et al.* (2007) reported that foliar spray with combination of $MnSO_4$ and $ZnSO_4$ (2 parts per trillion (ppt), 4ppt and 8ppt) showed significant increase in specific weight of potato tuber and highest mean tuber weight (76.16g) was obtained with the combined treatment of Zn(4ppt) +Mn(8ppt). Janket *et al.* (2018) reported that individual as well as combined application of micronutrients (2% $ZnSO_4$., 0.5% $CuSO_4$ and 2% $ZnSO_4$ at 15 and 30 DAP) on three cassava genotypes (Rayong 9, CMR 38-125-77 and Kasetsart 5) showed significantly higher tuber dry weight compared to control (no fertilizer application).

2.4.6 Tuber yield

Bybordi and Malakouti (1998) reported that onion showed higher bulb yielding capacity with the foliar application of Fe, Zn and Mn. Mousavi *et al.* (2007) studied the effect of foliar application of manganese and zinc on yield and quality of potato and reported that among the various concentrations of zinc and manganese sulphate, the combined application (8ppt $ZnSO_4$+ 4 ppt $MnSO_4$ sprayed at 10 days before and 20 days after flowering) gave maximum yield (38950 kg ha^{-1}) at harvest compared to control. El-Baky *et al.* (2010) reported that among the three foliar sprays of $ZnSO_4$ (@10ppm, 20ppm and 30 ppm) higher doses of Zn (30ppm) resulted in higher yield in sweet potato. Similarly, Ahmd *et al.* (2011) reported that foliar application of Zn had positive effect on potato and among the three doses of Zn chelates (100ppm, 200ppm and 300ppm) studied a higher production of roots was observed with the foliar application of Zn at 300ppm. Boron is also repoted to have an important role in improving the yield in sweet potato (Echer *et al.* 2009). El-Tohamy

(2014) reported that foliar application of chelated form of boron (0.3 g L^{-1} -two sprays at 14 days interval) resulted in higher yield in sweet potato.

Janket *et al.* (2018) studied the effect of foliar spray of three micronutrients (manganese, copper and zinc) on three cassava genotypes (Rayong 9 , CMR 38-125-77 and Kasetsart 5) and reported that more tuber yield was obtained with the foliar application of 2% $ZnSO_4$. Ali and Elkader (2014) also reported that among the four concentrations (0, 10, 20 and 30%) of micronutrient mixtures with Fe , Zn , Mn and Cu (Fe-EDTA (6% Fe), Zn-EDTA (15% Zn), Mn-EDTA (12% Mn), and $CuSO_4.5H_2O$ (25.45 % Cu), foliar spray with 20% and 30% gave maximum tuber yield in cassava.

2.5 EFFECT OF FOLIAR APPLICATION OF MICRONUTRIENTS ON PHYSIOLOGICAL PARAMETERS

Khalifa *et al.* (2011) reported that foliar application of B and Zn significantly increased the chlorophyll concentration in irish plant. Meng *et al.* (2004) noticed that foliar spray of micronutrient solution (Mn, Cu, B, Mo and Cu) increased chlorophyll content of the leaves as well as photosynthetic rate. El-Tohamy (2014) reported that foliar application of B in sweet potato resulted in higher total chlorophyll content. Thirupathaiah *et al.* (2017) studied the response of soil and foliar application of iron, zinc, and boron on biophysical parameters as well as chlorophyll content of sapota and reported that maximum stomatal conductance (0.20 mol m^{-2} S^{-1}) and transpiration rate (5.51 mmol H_2O m^{-2} S^{-1}) were observed by the foliar application of $ZnSO_4$ (0.5%). Also an increase in photosynthetic rate (12.52 mol CO_2 m^{-1} S^{-1}) by the foliar application of $ZnSO_4$ (0.5%) + $FeSO_4$ (0.5%) + boron (0.3%) compared to the control was reported. Janket *et al.* (2018) reported that foliar application of micronutrients (manganese , copper and zinc) on three cassava genotypes (Rayong 9 , CMR 38-125-77 and Kasetsart 5) showed significantly higher chlorophyll content compared to control. Manas *et al.* (2014) reported that among the foliar application of humic acid(0.5%), zinc (0.5%), and boron(0.2%) on pepper the combination of

(HA+Zn+B) gave maximum chlorophyll content compared to the individual treatments. Lakshmipathi *et al.* (2018) studied the individual as well as combined effect of foliar spray of zinc ($ZnSO_4$ @ 0.1% and 0.2%) and boron(borax @ 0.5%) on leaf area, photosynthetic pigments, stomatal number and yield of cashew and reported that total chlorophyll, caroteinoid content, stomatal number and stomatal frequency were higher in the combined treatment of $ZnSO_4$ (0.5%) + borax (0.1%) sprayed at flushing, flowering as well as fruiting stage.

2.6 EFFECT OF MICRONUTRIENTS ON QUALITY PARAMETERS

2.6.1 Total phenolic content, Total sugars and Protein content

Mousavi *et al.* (2007) reported that the combined treatment of (8ppt $ZnSO_4$ and 4 ppt $MnSO_4$) resulted in higher protein content (36.5%) of potato tubers ,compared to the control. El-Tohamy *et al.* (2014) reported that foliar application of chelated form of B (0.3g L^{-1}) twice at 14 days interval was found to give higher total soluble sugar content of sweet potato tubers. Manas *et al.* (2014) studied the effect of foliar application of humic acid (0.5%), zinc (0.5%), and boron (0.2%) on *Capsicum annum* and reported that the treatment combinations of HA+Zn, HA+Zn+B, Zn+B gave higher concentration of total sugars and protein. Trivedi and Dhumal (2017) studied the effect of micronutrients, growth regulators and organic manures on biochemical and mineral components and yield of onion (*Allium cepa* L.) grown in vertisols and reported that foliar application of Fe and Zn resulted in maximum phenolic content in onion. Sarkar *et al.* (2018) studied the effect of growth, tuber quality, yield and profitability of potato upon foliar fertilization of boron and reported that among the various treatments tried, the one with recommended dose of NPK + foliar spray of 0.1% boric acid (0, 50 and 60 DAP) showed low phenolic content and also the phenol content decreased with the number of foliar sprays.

2.7 EFFECT OF PLANT GROWTH REGULATORS

Plant growth regulators (PGRs) are natural or synthetic compounds that are applied to seed or plant which regulate plant growth and development in response to the stimuli and hence any changes in the level of plant hormones leads to gene activation shifts (Donthineni *et al.*, 2014). By modifying the activity of hormones within the plant PGRs improve growth and development as well as plant germination process (Harms and Oplinger, 1988; Hopkins, 1999). Plant growth regulators improve the nutrient status in the edible parts and regulate plant growth and crop quality (Smolen and Sady, 2009). Synthetic hormones have similar effect as that of natural plant hormones and they also can control various physiological process, such as the formation and growth of shoots, roots, flowers, buds and fruits (Flasinski and Hac-Wydro, 2014). Application of growth regulators is reported to improve growth , yield and flowering as well as advance the flowering in many of the tuber crops (Rao *al.*, 2017).

2.8 EFFECT OF CYCOCEL ON BIOMETRIC PARAMETERS

2.8.1 Branch length

Vegetative growth is negatively affected by the application of cycocel (Stoddart 1964). Saikia *et al.* (1981) noticed that with the gradual increase in cycocel concentration there was a significant reduction occuring in the length of potato plants. Usha *et al.* (2009) found that foliar application of CCC at 300 ppm had a negative influence on the shoot length of Rhubarb (*Rheum rhabarbarum* L.). Devi *et al.* (2011) reported that among the three growth regulators [salicyclic acid (50 ppm), ethrel (200 ppm) and cycocel (500 ppm)] studied in soyabean, very low plant length was obtained with the application of cycocel 500ppm. Ouzounidou *et al.* (2011) studied the differential responses of onion and garlic against plant growth regulators viz., prohexadione-calcium ,gibberellic acid-GA_3 and ethephon and reported that

significant reduction in shoot length by 25% and 35% for garlic and onion respectively were observed with pre harvest treatment with ethephon. Velayutham and Parthiban (2013) reported that application of cycocel at the rate of 500ppm reduced the plant height in ginger . Kannabiran and Padmanaban (2016) studied the effect of growth regulators (GA3, CCC, MH, ethrel and NAA each at 250ppm and 500ppm) on plant height and number of branches in Glory Lily (*Gloriosa Superba* L.) and reported that the lowest plant height was obtained with MH (250ppm and 500ppm) and CCC (250ppm and 500ppm) treatments.

2.8.2 Number of leaves

Devi *et al.* (2011) reported that among foliar application of three growth regulators [salicyclic acid (50 ppm), ethrel (200 ppm) and cycocel (500 ppm)] carried out, ethrel (200ppm) was found to give more vegetative growth as well as more number of leaves in soyabean. Velayutham and Parthiban (2013) reported that application of cycocel had positive influence on number of leaves and maximum number of leaves was observed in ginger treated with the application of 500ppm cycocel. .

2.8.3 Specific leaf area

Gollagi *et al.* (2009) noticed that foliar application of cycocel after 65 days of planting resulted in lowest total leaf area (cm^2) per plant in chilli. Obasi and Atanu (2005) studied the effect of foliar application of growth regulators (CCC, GA and ethrel) on flowering , growth, and rhizome yield of ginger and reported that higher leaf area was obtained with the application of cycocel and there was a significant reduction in leaf area with the application of GA and ethtrel. Usha *et al.* (2009) found that foliar application of CCC at 300 ppm had a negative impact on leaf area of Rhubarb (*Rheum rhabarbarum* L.). Kumar and Suchit (2018) studied the effect of different concentrations of ethrel, GA_3 and cycocel (each at 100ppm ,200ppm and

300ppm) on mustard and reported that application of cycocel @ 300ppm resulted in reduction in total leaf area .

2.8.4 Shoot weight

Hejjegar *et al.* (2018) studied the influence of plant growth regulators and their time of application on growth and tuber yield of sweet potato (*Ipomoea batatas* L.) cv. Kiran under southern Telangana conditions and found that among the treatments of six plant growth regulators (cycocel, paclobutrazole, ALAR, salicylic acid, gibberellic acid and ethrel at two different concentration) lower shoot weight was found with the application of cycocel.

2.8.5 Tuber length, Tuber diameter and Tuber weight

Vahab and Kumaran (1980) studied the effect of CCC and ethrel on sweet potato and reported that maximum tuber girth as well as tuber weight could be obtained with the application of cycocel CCC (500 and 1000 ppm). Saikia *et al.* (1981) reported that with the gradual increase in cycocel concentration there was a pronounced increase in weight of potato tuber. Yassin and Anbu (1996) found that foliar application of CCC at 1000 ppm resulted in maximum root girth and root weight in radish. Usha *et al.* (2009) found that foliar application of cycocel at 300 ppm had a significant increase in rhizome diameter in Rhubarb. Wang *et al.* (2010) reported that among the foliar application of different concentrations of cycocel on potato, maximum tuber weight was observed with both the application of 1.5 and 2.0 g L^{-1} cycocel. Yogendra and Kumar (2012) reported that among the plant growth regulators studied (IAA 100 ppm, IAA 200 ppm, CCC 2000 ppm and CCC 3000 ppm, GA 50 ppm, GA 100 ppm) maximum fresh weight and dry weight could be obtained with the application of CCC 3000ppm followed by CCC 2000ppm in ashwagandha (*Withania somnifera* Dunal.).

2.8.6 Tuber yield

Choudhri *et al.* (1976) observed comparitively higher yield in potato with foliar spray of cycocel at 1000-2500ppm. Indira *et al.* (1980) studied the effect of cycocel on yield of *Coleus parviflorus* and reported that the treatment with CCC (100-150ppm) at one month interval was observed as the best one in increasing tuber yield. Bhattacharyya (1990) also found a similar effect of CCC on the yield of *Coleus parviflorus*. Prakash *et al.* (2001) also studied the effect of foliar application of cycocel on potato and reported that maximum tuber yield was obtained with the application of CCC (1000 ppm). Sarkar and Sarma (2008) studied the effect of foliar application of CCC and GA_3 at concentrations of 100, 250, 500 and 1000µg/ml each individually as well as in combinations and reported that highest yield was attained with foliar spray of combined treatment of $GA_3$500 µg/ml plus CCC 1000 µg/ml in sweet potato. Senguptha *et al.* (2008) reported that maximum yield in ginger was obtained with the application of cycocel at 100ppm. Sarkar (2008) studied the effect of CCC and GA_3 along with their interaction effect on sweet potato and came up with the conclusion that irrespective of concentrations all the sprays of CCC and GA_3 gave higher yield. Shedge *et al.* (2008) studied the effect of foliar application of maleic hydrazide and cycocel on growth and yield of sweet potato and reported that the highest yield was obtained with the application of cycocel at 500 ppm followed by maleic hydrazide (1000 ppm) and CCC (250 ppm). Wang *et al.* (2010) studied the effect of foliar application of cycocel at the concentration of 1.5, 2.0 and 2.5gl^{-1} at 24 and 28 days after emergence of potato, on leaf mineral nutrition, antioxidant enzyme activity, and tuber yield and reported that among the different concentrations of cycocel 1.5 and 2.0 gl^{-1} gave maximum potato yield . Yogendra and Kumar (2012) studied the effect of stand geometry and plant growth regulators (IAA 100 ppm, IAA 200 ppm, , CCC 2000 ppm and CCC 3000 ppm, GA 50 ppm, GA 100 ppm - 30, 60 and 90 days of transplanting) on root yield and alkaloid content of Ashwagandha (*Withania somnifera* Dunal.) on cultivar JA- 20 and Poshita. and he

reported that higher root yield was obtained in treatment with CCC 3000ppm. Velayutham and Parthiban (2013) reported that application of cycocel reduced the vegetative growth in ginger which resulted in partitioning of photosynthates to rhizomes and hence the rhizome yield improved and the highest rhizome yield was obtained with the application of 500ppm of cycocel.

2.9 EFFECT OF CYCOCEL ON PHYSIOLOGICAL PARAMETERS

Imbamba (1973) reported that foliar application of cycocel resulted in increase in the number of stomata per unit area as well as stomatal conductance of cowpea. In addition to the stomatal conductance, chlorophyll content of the leaves and net photosynthetic rate of cowpea also were reported to increase. Generally, growth retardants including cycocel reduce the leaf area which leads to lower transpiration rate as well as higher water use efficiency (Luoranen *et al.,* 2002). Grewal *et al.* (1990) noticed a positive effect of combined treatment of cycocel (250 and 500 ppm) along with nitrogen (50 and 100 kg N/ha) on chlorophyll content of *Brassica napus* leaves. Devi *et al.* (2011) studied the effect of foliar spray of three growth regulators such as salicyclic acid (50 ppm), ethrel (200 ppm) and cycocel (500 ppm) on soyabean and reported maximum chlorophyll and carotenoid contents in soyabean treated with cycocel 500ppm.

2.10 EFFECT OF CYCOCEL ON QUALITY PARAMETERS

2.10.1 Total phenolic content,Total sugars and Protein content

Afria *et al.* (1998) reported that there was a significant increase in protein content of guar (*Cymopsistetragonoloba L. Taub*) due to the foliar application of cycocel. Devi *et al.* (2011) reported that among the foliar application of three growth regulators [salicyclic acid (50 ppm), ethrel (200 ppm) and cycocel (500 ppm)] cycocel 500ppm was found to enhance the protein content in soyabean compared to other treatments. Sarkar (2008) studied the effect of foliar application of CCC and

GA_3 at concentrations of 100, 250, 500 and 1000µg/ml each individually as well as in combinations on sweet potato and reported that maximum reducing sugar content was obtained with the combination treatment (CCC 1000ppm+GA_3 500 ppm). Sharifi *et al.* (2016) reported that even under severe salinity stress, seed inoculation (*Azotobacter chrocoocum+Pseudomonas putida*) along with two levels of foliar application of cycocel (600ppm and 1000ppm) have shown positive influence on polyphenol oxidase (PPO) enzymes and higher phenol content in wheat.

2.11 EFFECT OF ETHREL ON BIOMETRIC PARAMETERS

2.11.1 Number of leaves

Bhattacharyya (1990) noticed an increase in number of leaves in *Coleus parviflorus* with the application of ethrel. Lone (2001) studied the effect of ethrel on mustard and found that foliar application of ethrel had positive influence on the number of leaves per plant. Senguptha *et al.* (2008) reported that application of ethrel at 100ppm in ginger significantly increased the number of leaves per clump.

2.11.2 Shoot length

Vreugdenhil and Harro (1989) reported that foliar application of ethrel at higher concentration (500,1000 and 1500ppm) resulted in reduced plant height in radish. Kannabiran and Padmanaban (2016) studied the effect of growth regulators (GA_3, CCC, MH, ethrel and NAA, each at 250ppm and 500ppm) on plant height and number of branches in Glory Lily (*Gloriosa Superba* L.) and reported that there was a significant reduction in plant height with the application of ethrel.

2.11.3 Specific leaf area

Levy and Kedar (1970) studied the effect of ethrel on growth and bulb initiation of onion and found that among the four concentrations tried (500, 1000, 5000 and 10000 ppm) two higher concentrations of ethrel (5000ppm and 10000ppm)

resulted in reduced leaf growth and there by a reduction in the specific leaf area of leaves. Lee and Reid (1997) reported that higher doses of ethephon resulted in reduced leaf area in *Helianthus annus*.

2.11.4 Shoot weight

Mehdi *et al.* (2012) studied the effect of different concentration of ethrel on growth, fruiting behavior and yield of cucumber (*Cucumis sativus* L.) under green house conditions and found that among the five ethrel levels studied (0, 200, 300, 400 and 600 ppm), all the five concentrations of ethrel resulted in an increase in the number of branches per plant and shoot weight in cucumber.

2.11.5 Tuber length, Tuber diameter and Tuber weight

Levy and Kedar (1970) studied the effect of ethrel (500, 1000, 5000 and 10000 ppm) on growth and bulb initiation of onion and found that there was a significant increase in the rate of bulbing as well as early bulb initiation with ethrel spray of higher concentrations (5000ppm and 10000ppm). Also there was a decrease in the bulb size and bulb weight noticed at these higher concentration of ethrel.

2.11.6 Tuber yield

Vahab and Kumaran (1980) studied the individual effects of ethephon (150, 300 and 450 ppm) and CCC (250, 500 and 1000 ppm) on sweet potato and reported that maximum tuber yield was obtained with ethephon (300ppm and 450ppm) applied at 30 days after planting. Bhattacharyya (1990) observed a positive effect of ethrel spray on *Coleus parviflorus* and recorded a higher tuber yield. Devi *et al.* (2011) reported that among foliar application of three growth regulators [salicyclic acid (50 ppm), ethrel (200 ppm) and cycocel (500 ppm)]; ethrel 200ppm was found to give higher yield (1.75 t ha^{-1}) in soyabean compared to other treatments.

2.12 EFFECT OF ETHREL ON PHYSIOLOGICAL PARAMETERS

Bhattacharyya (1990) noticed an increase in chlorophyll content in *Coleus parviflorus* with the application of ethrel. Grewal and Kolar (1990) noticed a positive effect of combined treatment of ethrel 500 ppm along with 50 and 100 kg N/ha on chlorophyll content of *Brassica napus* leaves as well as a detrimental effect due to the application of ethrel at higher concentration (1000 and 1500 ppm). Mir *et al.* (2008) found that foliar spray of ethephon along with 80 kg N ha^{-1} resulted in higher stomatal conductance and net photosynthic rate in brassica. Pahwa (2013) reported that foliar application of ethrel resulted in increased stomatal conductance in pigeon pea. Ouzounidou *et al.* (2011) reported that among the three growth regulators (prohexadione-calcium ,gibberellic acid (GA_3)and ethephon) chlorophyll a+b content was negatively influenced by ethephon treatment in both onion and garlic and about 14% and 23% of reduction in chlorophyll a+b content was observed in garlic and onion respectively.

2.13 EFFECT OF ETHREL ON QUALITY PARAMETERS

2.13.1 Total phenolic content, Total sugars and Protein content

Sharma *et al.* (1982) reported that in groundnut (*Arachis hypogea*) protein content increased with application of ethrel at the initial stages of the development of pods and further application in the later stages decreased the protein content. Bulman and Smith (1993) reported that protein content in grain increased about 20% with application of ethephon in barley. Mahajan *et al.* (2008) reported a positive effect of ethrel spray (750 ppm) on sugar content in guava. Kulkarni *et al.* (2011) reported higher sugar content in banana with the application of ethrel 500ppm. Gurjar *et al.* (2017) studied the effect of ethrel spray on the ripening behaviour of mango (*Mangifera indica* L.) variety 'Dashehari. and reported that TSS in mango increased with the increase in concentration of ethrel. Wang *et al.* (2013) reported that

preharvest foliar applications of ethephon resulted in an increased cortex phenolic content in storage roots of sweet potato. Gougoulias and Masheva (2013) reported that combination or combined preparation (CP) of phytohormones and ethrel (0.1%) lead to maximum polyphenol content in mavrud grape berries.

2.14 EFFECT OF MICRONUTRIENTS, CYCOCEL AND ETHREL ON MINERAL CONTENT IN TUBER

Stepien and Wojtkowiak (2016) reported that NPK along with the foliar application of micronutrient mixture (1% $CuSO_4$+ 1%$FeSO_4$+ 0.5% $MnSO_4$) significantly increased Cu and Zn content in winter wheat grain and there was about 17.7% increase observed in Zn content. Similar results were reported by Wang *et al.* (2015) in wheat. NPK along with foliar spray of 0.5% Mn SO4 resulted in 14.3% increase in Mn content of wheat grain. Similarly Zhang *et al.* (2012b) reported that 0.4% $ZnSO_4$ increased Zn content in wheat grain (58%). Sveenjak *et al.* (2013) reported that N fertilization resulted in an increase of (14.0% Fe, 9.2% Zn, 19.7% Mn, 13.2% Cu, 15.1% Ni, and 23.0% Cd, respectively) in wheat grain. Pahlavan and Pessarakli (2009) reported that foliar application of Zn increased Zn content and Fe content in the wheat grain by 99% and 8%, respectively. Narwal *et al.* (2012), reported that the foliar application of Mn, increased the Mn content in wheat grain (7%). Shedge *et al.* (2008) reported that foliar application of cycocel and ethrel enhance the translocation of nutrients from leaves to the tubers and also increase the initial vigour and crop growth which in turn result in higher nutrient uptake and further increase in the nutrient availability of plants. Ali and Elkader (2014) also reported that among the four concentrations (0, 10, 20 and 30%) of micronutrient mixtures with Fe , Zn , Mn and Cu (Fe-EDTA (6% Fe), Zn-EDTA (15% Zn), Mn-EDTA (12% Mn), and $CuSO_4.5H_2O$ (25.45 % Cu), foliar spray with 20% and 30% gave maximum chemical constituents such as N, P, K, Fe, Zn and Mn content in cassava.

Materials and Methods

3. MATERIALS AND METHODS

A field experiment entitled "Effect of foliar application of selected micro nutrients and growth regulators on tuber development, yield and fortification status of sweet potato (*Ipomoea batatas L.*)" was conducted at Instructional Farm, College of Agriculture, Vellayani during the period 2017-2019. The details of the materials used and the methods employed during the course of investigation are presented in this chapter.

3.1 MATERIALS

3.1.1 Location

The field experiment was conducted at the instructional farm attached to the College of Agriculture, Vellayani which is situated at 8.5° N latitude and 76.9° E longitude at an altitude of 29 m above MSL with relatively flat and uniform gentle slope.

3.1.2 Climate and soil

Vellayani has a tropical climate with the mean maximum and minimum temperatures of 31.8^{0}C and 23.6 ^{0}C respectively. The mean annual rainfall is 940.70mm and mean maximum and minimum relative humidity are 96.43 and 70.90 percent respectively. The soil of the experimental field was sandy clay loam in texture and the chemical properties of the soil are given in the Table 1.

3.1.3 Season

The experiment was conducted during *rabi* 2018-2019 (August 2018 to February 2019).Vine cuttings of sweet potato variety Bhu Krishna were collected from CTCRI, Sreekaryam and raised in the nursery for multiplication and then the cuttings taken from the nursery were used to plant in the main field and the crop was raised during the period November 2018 to February 2019.

Table 1. Chemical properties of soil at the experimental site before layout

Constituent	Content	Status
pH	6.1	Slightly acidic
Available N	285.35 kg ha^{-1}	Medium
Available P	37.072 kg ha^{-1}	High
Available K	275 kg ha^{-1}	Medium
Iron (Fe)	9.51 mg kg^{-1}	Sufficient
Zinc (Zn)	0.803 mg kg^{-1}	Deficient
Manganese (Mn)	3.61 mg kg^{-1}	Sufficient
Boron (B)	0.352 mg kg^{-1}	Deficient

3.1.4 Variety

Sweet potato variety Bhu Krishna, released from regional centre, CTCRI, Bhuvanewar was used for the experiment. Bhu Krishna is an anthocyanin rich (90mg 100g^{-1}) pink fleshed variety. It is a short duration variety of 110 days duration and has around 18t ha^{-1} yield potential.

3.1.5 Planting material

Vine cuttings were used for the propagation of sweet potato. Apical and middle portion of vines of 20-40cm length with atleast 3-5 nodes were used as planting material.

3.1.6 Manures and fertilizers

The crop sweet potato was raised with manures and fertilizers applied as per package of practices (POP). FYM was applied at the rate of 10 t ha^{-1} as basal during the time of preparation of ridges and furrows. The basal fertilizers were applied at recommended dose of 75:50:75 (N:P_2O_5:K_2O) kg ha^{-1}. N was applied in two equal

split doses, first as basal at the time of planting and second at 4-5 weeks after planting and full dose of P_2O_5 and K_2O were applied as basal at the time of planting.

3.2 METHODS

3.2.1 Treatment details

The field experiment was conducted with eleven treatments as detailed below.

C1 : NPK (as per POP)

C2 : NPK (as per POP) with water spray at 30 DI

T1 : C1+ FN (MN mixture(*) 0.01% each at 30 days interval(DI).

T2 : C1+ FN (MN mixture(*) 0.05% each at 30 DI

T3 : C1+ FN (MN mixture(*) 0.1% each at 30 DI

T4 : T1+ Ethrel 250 ppm at 30 DI

T5 : T1+ Ethrel 500 ppm at 30 DI

T6 : T1+ CCC 250 ppm at 30 DI

T7 : T1+ CCC 500 ppm at 30 DI

T8 : T2+ Ethrel 250 ppm at 30 DI

T9 : T2+ Ethrel 500 ppm at 30 DI

T10:T2+ CCC 250 ppm at 30 DI

T11: T2+ CCC 500 ppm at 30 DI

T12: T3+ Ethrel 250 ppm at 30 DI

T13: T3+ Ethrel 500 ppm at 30 DI

T14: T3+ CCC 250 ppm at 30 DI

T15: T3+ CCC 500 ppm at 30 DI

(MN mixture (*) - micronutrient mixture (Zn+Fe+B+Mn)

$ZnSO_4$, $FeSO_4$, $Mnso_4$ and Borax were used as sources of Zn, Fe, Mn and B respectively and the stock solution of these micronutrient mixtures were prepared, stored and used for the foliar sprays.

3.2.2 Experimental design and layout

The experiment was conducted in a randomized block design (RBD) with 17 treatments and 3 replications. The layout of the experiment is furnished in Fig. 1.

3.2.3 Plot size

The size of the individual plots were 3 m x 1.6 m (4.8 m^2)

3.2.4 Spacing

The spacing adopted was 60cm between rows and 20cm between plants.

3.2.5 Plant population

Number of plants per individual plot = 40

Number of plants per gross plot =2040

3.3 DETAILS OF CULTIVATION

3.3.1 Nursery and planting

Vine cuttings of sweet potato variety Bhu Krishna were used for planting in the nursery. The nursery was raised on 4th August 2018 with an area of 5.4m x 6m . Ridges and furrows were made with 9 rows and 30 vines per row with the spacing of 60 cm between the rows and 20cm between the plants. The nursery was maintained for about 3 months and the vine cuttings taken were used as planting material for the main field.

3.3.2 Main field preparation

After 3 months of raising nursery the vines were taken and 2040 vine cuttings of about 20-40cm length were taken and they were planted in the ridges. Spacing of 20cm between the plants and 60cm between the rows was given. Fertilizers and

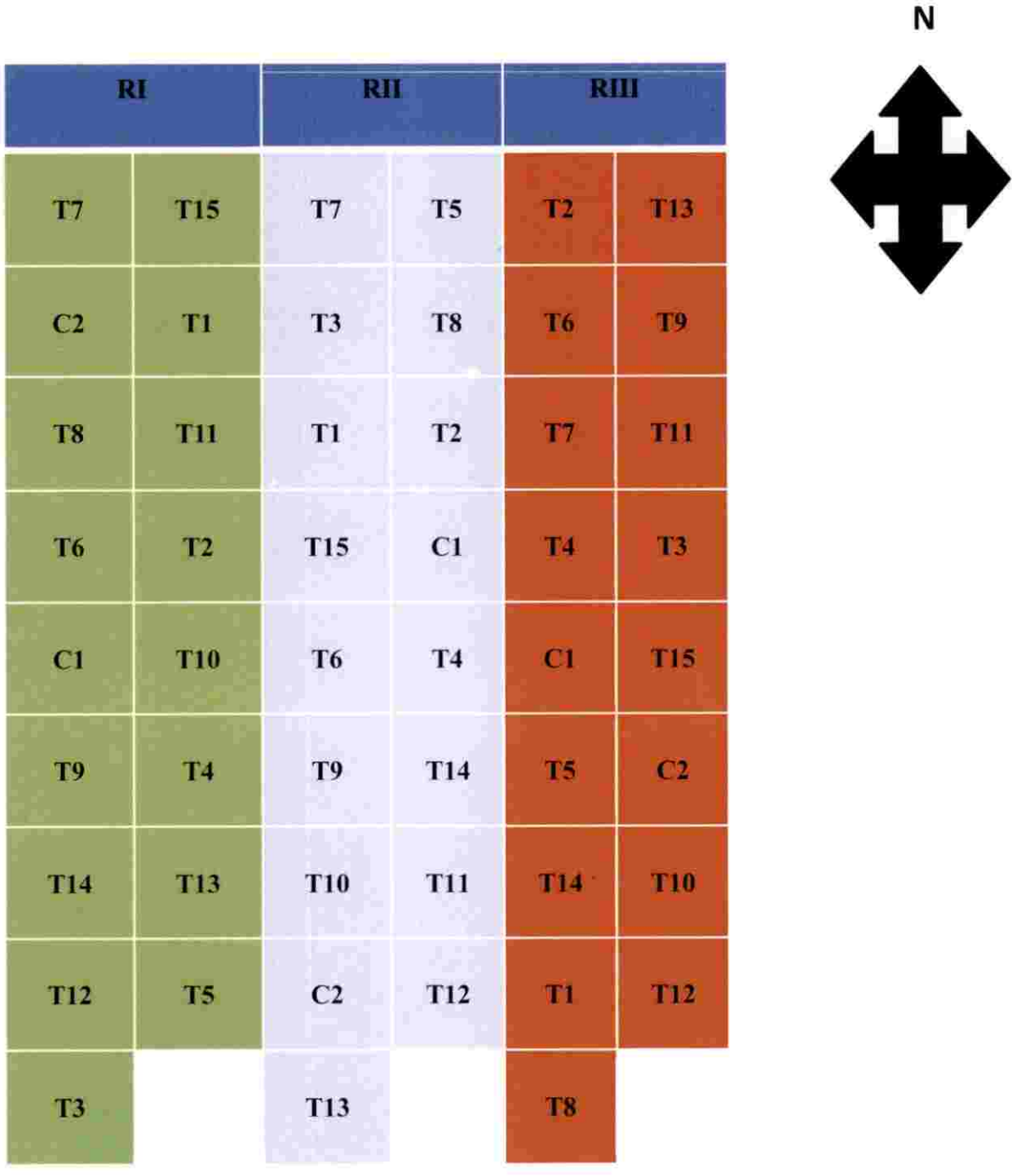


Fig. 1 Layout of the experimental plot

Initial establishment of nursery

Nursery 10 DAP

Nursery 2 month after planting

Plate 1. Nursery

Main field layout

Main field after planting

Plate 2. Main field

manures were given as per POP. The planting was carried out in the main field on November 2nd, 2018.

3.3.3 Irrigation

During the initial days of planting, irrigation was given both in the morning and evening. Later on irrigation was given on alternate days. Prior to one month of harvest irrigation was stopped.

3.3.4 Harvesting

The fading of green colour and appearance of light yellow color and cracks at the base of the plants were taken as the indications of crop maturity. The crop was harvested by digging out the ridges. Border plants were first removed before harvesting the net plot. Later on the vines and tubers were separated.

3.4 BIOMETRIC OBSERVATION

From each net plot, four plants were selected at random from alternate ridges and tagged for taking biometric observations. All the below mentioned biometric observations were recorded on these plants at 25, 50, 75 and 100 days after planting .

3.4.1 Branch length

The branch length is nothing but the length of vine and it was measured from the base to the tip of each vine of the four observation plants and the mean value was taken and expressed in cm.

3.4.2 No. of leaves

From the four observation plants the tubers and vines were separated and the total number of leaves of all the four plants were taken separately and the mean value was taken.

3.4.3 Shoot weight

From the four observation plants the tubers and vines were separated and the whole weight of vines of all the four sample plants were recorded separately and finally the mean value was noted and expressed in grams.

3.4.4 Specific leaf area (SLA)

From the four observation plants specific leaf area was taken.

Specific leaf area was estimated by the formula given below and expressed in cm^2g^{-1}

$$\text{Specific leaf area} = \frac{\text{Leaf area}}{\text{Leaf dry weight}}$$

3.4.5 Tuber length

Length of tubers from the four sample plants were taken at the time of observation. The length was taken from one end to the other end of the tubers and the mean length was recorded and expressed in cm.

3.4.6 Tuber diameter

Average tubers diameter was taken by averaging the tuber diameter of three different portions, one from the middle and two from the quarter distance from both ends of tubers. The tuber diameter was taken from all the four observation plants and the mean value was recorded and expressed in cm.

3.4.7 Tuber weight

The four tagged plants were uprooted carefully without causing any kind of damage to the neighboring plants and later the vines and tubers were separated. Adhered soil particles were removed from the tubers and the tuber weight was recorded and the mean value was calculated and expressed in grams.

3.4.8 Tuber yield

Harvesting in the net plot was carried out and the tubers were dug out from the ridges and the adhered soil particles were removed from the tubers. Tuber yield was recorded from all the plots separately and expressed in $t\ ha^{-1}$.

3.5 PHYSIOLOGICAL PARAMETERS

From each net plot, four plants were selected at random from alternate ridges and tagged for taking biometric observations. All the below mentioned biometric observations were recorded on these plants at 25, 50, 75 and 100 days after planting.

3.5.1 Chlorophyll content

100mg of leaf samples were collected from the sample plants of each plots and chopped into small pieces. 10ml of DMSO (Dimethyl sulphoxide) : Acetone (80%) mixture (1:1) was added and kept overnight. Spectrophotometer readings were taken at 645nm and 663 nm. From the absorbance values, total chlorophyll was calculated using the formulae given below and expressed in mg g^{-1} of fresh leaf (Sadasivam and Manikam, 1976)

Total chlorophyll (a+b) = (8.02 x A_{663} + 20.2 x A_{645}) x V/1000 x 1/Fresh weight

3.5.2 Caroteinoid content

100mg of leaf samples were collected from the sample plants of each plots and chopped into small pieces. 10ml of DMSO (Dimethyl sulphoxide) : Acetone(80%) mixture (1:1) was added and kept overnight. Spectrophotometer readings were taken at 580nm and 610 nm. From the absorbance values, caroteinoid content was estimated using the formula given below and expressed in mg g-1 of fresh leaf (Sadasivam and Manikam, 1976)

Carotenoids = (7.6 x A_{480} – 1.49 x A_{510}) x V/1000 x 1/ Fresh weight

3.5.3 Stomatal conductance

Stomatal conductance was measured at morning time between 8:30 am and 11 by using portable photosynthetic system (CIRA-3 SW, PP System International, MA, USA) and expressed in mmole $H_2O\ m^{-2}\ s^{-1}$

3.5.4 Photosynthetic rate

Photosynthetic rate was measured at morning time between 8:30 am and 11 by using portable photosynthetic system (CIRA-3 SW, PP System International, MA, USA) and expressed in µmole CO_2 m^{-2} s^{-1}.

3.5.5 Traspiration rate

Transpiration rate was measured at morning time between 8:30 am and 11 by using portable photosynthetic system (CIRA-3 SW, PP System International, MA, USA) and expressed in mmole H_2O m^{-2} s^{-1}.

3.5.6 Instantaneous water use efficiency

Instantaneous water use efficiency was measured at morning time between 8:30 am and 11 by using portable photosynthetic system (CIRA-3 SW, PP System International, MA, USA), IRGA (Infra Red Gas Analyzer) and expressed in mmol CO_2 mol^{-1} H_2O.

3.6 QUALITY PARAMETERS

3.6.1 Mineral constituents

Most of the quality parameters were estimated after harvest of the crop and for the estimation both the fresh and dried samples were used, which varied with the parameters. For the estimation of mineral constituents (N, P, K, Fe, Zn, B and Mn) and protein content, the tubers were dried properly and ground to fine powder. The powdered samples were digested with diacid and used for the estimation of mineral elements except nitrogen and it is expressed in (mg g^{-1}) on dry weight basis. Among the quality parameters, total phenolic content and total sugars were estimated with the fresh samples and expressed in (mg g^{-1}). All the methods used for the estimation of nutrients in plants are given in the Table 2.

Table 2. Standard analytical methods followed in plant analysis

Constituent	Method used	Reference
Nitrogen (N)	Micro Kjeldhal digestion and distillation method	(Jackson, 1973)
Phosphorus (P)	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using vanado molybdate yellow colour method	(Jackson,1973)
Potassium (K)	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using flame photometer	(Jackson,1973)
Iron (Fe), Zinc (Zn), Manganese (Mn)	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation atomic absorption spectrometry	(Jackson,1973)
Boron (B)	Spectrophotometry (Azomethone-H method)	Roig *et al.* (1988)

3.6.1.1 Nitrogen content

The nitrogen content in the digested tubers was estimated by Micro Kjeldhal distillation after digestion in sulphuric acid (Jackson, 1973) and expressed in percentage.

3.6.1.2 Phosphorus content

The phosphorus content of the di-acid(nitric-perchloric acid(9:4)) digested tuber samples was determined by using vanado molybdo phosphoric yellow colour method in HNO_3 acid system (Jackson, 1973) and expressed in percentage.

3.6.1.3 Potassium content

The potassium content in di-acid (Nitric-perchloric acid(9:4)) digested tuber samples was determined by flame photometric method as described by Jackson (1973) and expressed in percentage.

3.6.1.4 Micronutrient content (Fe, Zn, Mn and B)

Iron (Fe), zinz (Zn) and manganese (Mn) in di-acid(Nitric-perchloric acid(9:4)) digested tuber samples were determined by atomic absorption spectrophotometer and expressed in mg kg^{-1}. Boron (B) was estimated by using azomethine reagent. For the estimation of boron, first pipetted out 1 ml of digested sample into a test tube and added 2ml of buffer masking solution and 2ml of azomethine- H solution. Mixed them thoroughly and kept for 30 minutes. Readings were taken in spectrophotometer at 420nm. 100% trasmittance was set with blank (1ml 1.2N HCl solution with reagent) for taking readings

$$\text{Micronutrient content in tuber} = \frac{\text{ppm value} \times 100}{0.25}$$

3.6.1.5 Total phenolic content

Phenolic content in the tubers was estimated by using Foli-Ciocalteau method (Sadasivam and Manikam, 1996). 0.5 g of fresh tuber samples from each treatments were taken. First the tissue was homogenized. Samples were taken in a pestle and mortar and added 10 ml of ice-cold methanol (80%) and ground properly. Then filtered the homogenized mixture and centrifuged at 1000rpm for 10min. The supernatant was collected and added 80% methanol to the filtrate for complete extraction. From the sample, 0.1ml of aliquot was taken and made upto 1ml with distilled water. Then added 3 ml of 80% methanol and 5ml of Foli-Ciocalteau reagent. To this 2ml of 20% Na_2CO_3 was added. Further it was kept in boiling water bath for 5 minutes. After cooling, the absorbance was taken at 650nm using

spectrophotometer. Catechol was used for running the standards. Using standard curve with different concentrations of catechol, the phenolic content was quantified and expressed in mg g^{-1}.

3.6.1.6 Total sugar

The total sugar content of tubers was determined by Anthrone method (Hedge and Hofreiter, 1962).100mg of fresh tuber sample was taken into the boiling tube. First 5ml of 2.5 N hydrochloric acid (2.5 N) was added to the boiling tube and kept for three hours for hydrolysing carbohydrates into simple sugars .Then it was cooled to the room temperature and neutralized with solid sodium carbonate until the effervescence ceased and futher the volume was made upto 100ml and centrifuged. From the supernatant ,0.1 ml was taken and made upto 1ml with distilled water. Then prepared the standards by taking 0, 0.2, 0.4, 0.6, 0.8 and 1ml of the working standard (glucose) and made upto 1ml. 4ml of antrone reagent was added to both the samples and standards. Kept in boiling water bath for 8 minutes and then rapidly cooled. Green to dark green color was observed and the absorbance was taken at 630nm. Using standard curve, the carbohydrate was quantified and expressed in mg g^{-1}.

3.6.1.7 Protein content

For the estimation of crude protein, nitrogen content in the digested tuber was estimated by Micro Kjeldhal method (Jackson, 1973) and respective nitrogen values were multiplied by a factor 6.25 (A.O.A.C., 1969) .

3.7 SOIL ANALYSIS

Soil samples were collected randomly from different parts of the experimental site prior to planting, air dried, powdered and sieved through 2mm sieve. Soil pH, total available nitrogen ,available phosphorus, available potassium and micronutrients such as iron, zinc, manganese and boron were estimated from this soil sample. All the procedures used for the soil analysis are given in the Table 3.

Table 3. Standard analytical methods followed in soil analysis

Constituent	Method used	Reference
pH (1:2.5)	Potentiometry (Cyber Scan PC 510, EuTech Instruments, Singapore)	FAI (2017)
Nitrogen (N)	Micro Kjeldhal digestion and distillation method	(Jackson,1973)
Phosphorus (P)	Brays No. 1 extraction and estimation using calorimeter method	Bray and Kurtz (1945)
Potassium (K)	Neutral normal ammonium acetate and estimation using flame photometry	(Jackson,1973)
Iron (Fe), Zinc (Zn), Manganese (Mn)	0.1N HCl extraction and estimation using atomic absorption spectrometry	Sims and Johnson (1991)
Boron (B)	Hot water extraction and spectrophotometry using (Azomethine-H method)	Gupta (1967)

3.8 STATISTICAL ANALYSIS

The data were analyzed by using Analysis of Variance Technique (ANOVA) for Randomized Block Design (Cochran and Cox, 1965) and the significance was tested by F test using the variance (Gomez and Gomez, 1984). Wherever the treatments were found significant, critical differences (C.D.) were calculated and inferences were drawn at 5 per cent level of significance.

Result

4. RESULT

The field experiment entitled 'Effect of foliar application of selected micro nutrients and growth regulators on tuber development, yield and fortification status of sweet potato (*Ipomoea batatas* L.) was conducted at the Instructional Farm, College of Agriculture, Vellayani during 2017-2019. The observations on biometric parameters, physiological parameters and quality parameters were recorded, statistically analyzed and presented in this chapter.

4.1 BIOMETRIC PARAMETERS

4.1.1 Branch length

The data on the effect of micronutrients, cycocel and ethrel on branch length at different stages of growth are presented in Table 4.

The data revealed that all the treatments had significant effect on branch length in all the four stages of observation. Highest branch length was recorded in plants under the treatment T3 in all the four stages (66.51cm, 88.33cm, 112.50cm and 155.50cm at 25^{th} 50^{th} 75^{th} and 100^{th} DAP respectively) and the lowest branch length was observed in plants under the treatment C1 at 25^{th} (30.33 cm) ,50^{th} (56cm) ,75^{th} (73.33cm) and 100^{th} (82.33 cm) DAP and was on par with C2 (30.33cm, 56.67cm, 74.33cm and 83.67cm at 25^{th}, 50^{th}, 75^{th} and 100^{th} DAP respectively). Comparitively highest branch length was observed in plants under the treatments T1, T2 and T3 [*i.e* NPK as per POP along with micronutrient mixture alone (without growth regulators)] whereas plants under the treatments T4, T5, T6, T7, T8, T9, T10, T11, T12, T13, T14 and T15 (NPK as per POP along with micronutrient mixtures and growth regulators) resulted in relatively lower branch length. Among the various treatments, T3 [NPK as per POP along with micronutrient mixture (Fe+Zn+Mn+B @ 0.1% each)] resulted in the maximum branch length.

Table 4. Effect of micronutrients, cycocel and ethrel on branch length per plant of sweet potato

Treatments	Branch length (cm)			
	25 DAP	50 DAP	75 DAP	100 DAP
C1	30.33	56.00	73.33	82.33
C2	30.33	56.67	74.33	83.67
T1	56.90	84.00	107.00	150.23
T2	59.20	84.83	108.10	150.83
T3	66.51	88.33	112.50	155.50
T4	40.17	63.50	83.00	92.83
T5	38.50	64.00	81.97	92.20
T6	39.17	63.50	81.23	92.17
T7	38.50	62.50	81.50	92.50
T8	42.17	64.17	84.00	93.17
T9	40.83	64.17	82.50	92.67
T10	39.50	64.17	83.17	92.47
T11	38.83	64.17	82.47	92.50
T12	43.50	64.67	87.00	95.37
T13	41.83	64.50	86.50	95.00
T14	41.50	64.83	85.17	94.50
T15	39.77	64.50	84.83	94.17
SE m ±	0.576	0.537	1.077	0.714
CD (0.05)	1.666	1.553	3.115	2.066

4.1.2 Number of leaves

The data on the effect of micronutrients, cycocel and ethrel on number of leaves at different stages of growth are presented in Table 5.

There was a significant increase in the number of leaves starting from 25th to 100th DAP. Highest value of number for the number of leaves was recorded at harvest stage for all the treatments. At 25th, 50th, 75th and 100th DAP highest number of leaves were recorded in plants under the treatment T3 (46.00, 67.00, 79.33, 91.33 respectively). At 25th DAP and 100th DAP, number of leaves in plants under the treatment T3 was found to be on par with T15 and T13. It reveals that combined treatment of NPK as per POP along with micronutrient mixtures and growth regulators as well as application of NPK as per POP along with micronutrient mixture alone resulted in highest number of leaves. Lowest number of leaves was observed in plants under the treatment C1 at 25th (33.67), 50th (51.67) 75th (61.33) and 100th (69.33) DAP and was on par with C2 (34.67, 53.33, 62.33 and 71.33 @ 25th, 50th, 75th and 100th DAP respectively). Among all the treatments T3 *i.e* NPK as per POP along with micronutrient mixtures (Fe+Zn+Mn+B @ 0.1% each), T15 *i.e.* (NPK as per POP along with micronutrient mixtures (Fe+Zn+Mn+B @ 0.1% each) + cycocel (500ppm) as well as T13 [*i.e* NPK as per POP along with micronutrient mixtures (Fe+Zn+Mn+B @ 0.1% each) + ethrel (500ppm)] resulted in the maximum number of leaves.

4.1.3 Shoot weight

The data on the effect of micronutrients, cycocel and ethrel on shoot weight at different stages of growth are presented in Table 6.

There was a significant difference in shoot weight observed among the treatments. Highest shoot weight was recorded in plants under the treatment T3 (NPK as per POP along with micronutrient mixture at 0.1% each at 30DI) in all the four stages. Maximum value was recorded for T3 (102.70g) at 25th DAP followed by T2 (94.80g). At 50th day shoot weight recorded was maximum in plants under the

Table 5. Effect of micronutrients, cycocel and ethrel on number of leaves per plant of sweet potato

Treatments	Number of leaves			
	25 DAP	50 DAP	75 DAP	100 DAP
C1	33.67	51.67	61.33	69.33
C2	34.67	53.33	62.33	71.33
T1	44.33	63.00	78.67	87.67
T2	45.00	66.33	79.00	91.00
T3	46.00	67.00	79.33	91.33
T4	44.00	63.67	77.33	89.00
T5	43.67	62.33	77.33	89.67
T6	43.67	65.33	78.67	89.00
T7	44.00	66.33	78.00	89.67
T8	44.00	64.67	79.33	89.00
T9	44.33	66.00	78.33	89.67
T10	44.00	66.33	76.67	89.67
T11	44.67	66.00	76.67	89.00
T12	44.33	65.67	79.00	90.33
T13	45.33	65.33	78.67	91.00
T14	44.33	66.00	79.00	90.00
T15	45.33	64.33	79.00	91.00
SE m ±	0.440	0.909	0.781	0.896
CD (0.05)	1.273	2.629	2.260	2.594

Table 6. Effect of micronutrients, cycocel and ethrel on shoot weight per plant of sweet potato

Treatments	Shoot weight (g)			
	25 DAP	50 DAP	75 DAP	100 DAP
C1	48.30	103.17	201.40	486.00
C2	51.00	103.33	201.83	489.00
T1	89.90	204.70	394.83	601.03
T2	94.80	207.50	404.33	605.17
T3	102.70	212.00	425.17	612.00
T4	60.70	113.20	213.33	513.20
T5	55.70	108.43	202.50	508.43
T6	64.00	107.00	212.33	503.17
T7	57.70	109.63	205.00	509.63
T8	72.00	109.97	264.00	509.97
T9	66.00	108.73	242.67	508.73
T10	72.70	113.23	266.33	513.23
T11	65.30	111.10	255.00	511.10
T12	75.00	118.27	225.83	518.27
T13	79.00	116.57	305.33	516.57
T14	74.00	120.97	335.33	520.97
T15	76.20	116.93	312.70	516.93
SE m ±	1.147	1.149	0.832	1.659
CD (0.05)	3.318	3.325	2.408	4.801

treatment T3 (212.00g) followed by T2 (207.50g) and T1(204.70g). At 75th DAP maximum value was recorded for T3 (425.17g) followed by T2 (404.33g). At 100th DAP highest shoot weight was recorded for T3 (612.00g) followed by T2 (605.17g) and T1 (601.03g). Lowest shoot weight was observed in plants under the treatment C1 at 25th (48.30g), 50th (103.17g) , 75th (201.40g) and 100th (486.00g) DAP and was on par with C2 (51.00g, 103.33g, 201.83g and 489.00g) at 25th, 50th, 75th and 100th DAP respectively). Comparitively highest shoot weight was observed with the treatments of NPK as per POP along with micronutrient mixture alone (without growth regulators) and NPK as per POP along with micronutrient mixtures and growth regulators recorded relatively lower shoot weight. Among the various treatments, T3 [NPK as per POP along with micronutrient mixture (Fe+Zn+Mn+B @ 0.1% each)] resulted in the maximum shoot weight.

4.1.4 Specific leaf area

The data on the effect of micronutrients, cycocel and ethrel on specific leaf area at different stages of growth are presented in Table 7.

Specific leaf area increased with the age of the plant and there was a significant difference among the treatments in all the growth stages of observation. Among the four stages, highest value was recorded at 100 DAP. Highest specific leaf area was recorded in plants under the treatment T3 followed by T2 and T1 at all the four stages of plant growth. The maximum value was recorded in plants under the treatment T3 (157.20 $cm^2\ g^{-1}$, 269.62 $cm^2\ g^{-1}$, 335.67 $cm^2\ g^{-1}$ and 389.44 $cm^2\ g^{-1}$) at 25th, 50th, 75th and 100th DAP respectively. At 25th day maximum specific leaf area was recorded in plants under the treatment T3 and was found to be on par with T2 (149.43 $cm^2\ g^{-1}$) and T1 (142.70 $cm^2\ g^{-1}$). The lowest SLA was observed in plants under the treatment C1 at 25th (101.03 $cm^2\ g^{-1}$), 50th (122.37 $cm^2\ g^{-1}$) 75th (140.83 $cm^2\ g^{-1}$) and 100th (163.15 $cm^2\ g^{-1}$) DAP followed by C2 at all the four stages. Comparitively highest specific leaf area was observed with the treatments of NPK as

Table 7. Effect of micronutrients, cycocel and ethrel on specific leaf area of sweet potato

Treatments	Specific leaf area ($cm^2 g^{-1}$)			
	25 DAP	50 DAP	75 DAP	100 DAP
C1	101.03	122.37	140.83	163.15
C2	101.83	123.07	141.60	172.54
T1	142.70	228.82	317.41	328.39
T2	149.43	255.61	330.02	342.26
T3	157.20	269.62	335.67	389.44
T4	112.83	155.43	170.70	178.17
T5	114.07	162.77	179.18	177.07
T6	111.83	158.70	172.74	183.58
T7	114.67	163.85	183.94	192.09
T8	112.87	164.50	176.30	209.56
T9	116.64	176.92	183.74	213.40
T10	111.97	163.97	174.93	225.73
T11	118.80	177.88	186.73	227.59
T12	119.47	172.65	165.73	234.34
T13	124.87	185.89	192.39	261.61
T14	121.43	173.70	164.83	235.74
T15	127.87	189.27	197.93	273.48
SE m ±	1.095	0.768	0.670	0.738
CD (0.05)	0.378	2.222	1.940	2.136

per POP along with micronutrient mixture alone (without growth regulators) and NPK as per POP along with micronutrient mixtures and growth regulators recorded relatively lower specific leaf area. Among the various treatments, T3 [NPK as per POP along with micronutrient mixture (Fe+Zn+Mn+B @ 0.1% each)] resulted in the maximum specific leaf area.

4.1.5 Tuber length

The data on the effect of micronutrients, cycocel and ethrel on tuber length at different stages of growth are presented in Table 8.

There was a significant increase in tuber length with the growth stages of the crop. Maximum value for the tuber length was recorded at 100 DAP and the highest tuber length was observed in plants under the treatment T15 (T3+ CCC 500 ppm at 30 DI) in all the three stages. Highest value was recorded for T15 (5.91cm and 9.50cm) at 50^{th} and 75^{th} DAP respectively followed by T13 (5.67cm and 9.27cm at 50^{th} and 75^{th} DAP respectively) and at 100^{th} DAP highest value was recorded for T15 (13.13cm) and was on par with T13 (13.07cm) . Lowest tuber length was recorded in plants under the treatment C1 at 50^{th} (4.00cm), 75^{th} (6.87cm) and 100^{th} (9.17cm) and was on par with C2 (4.10cm, 7.27cm and 9.28cm at 50^{th} , 75^{th} and 100^{th} DAP respectively). Comparitively highest tuber length was observed with the combined treatment of NPK as per POP along with micronutrient mixtures and growth regulators whereas the application of NPK as per POP along with micronutrient mixture alone recorded relatively lesser tuber length. Among the various treatments, T15 [NPK as per POP along with micronutrient mixtures (*) (Fe+Zn+Mn+B 0.1% each) + cycocel (500ppm)] resulted in the maximum tuber length. T13 was also on par with T15.

4.1.6 Tuber diameter

The data on the effect of micronutrients, cycocel and ethrel on tuber diameter at different stages of growth are presented in Table 9.

There was a significant increase in tuber diameter with the growth stages of the crop. Maximum value for the tuber diameter was recorded at 100 DAP and the

Table 8. Effect of micronutrients, cycocel and ethrel on tuber length of sweet potato

Treatments	Tuber length(cm)			
	25DAP	50 DAP	75 DAP	100 DAP
C1	--	4.00	6.87	9.17
C2	--	4.10	7.27	9.28
T1	--	4.25	8.00	12.07
T2	--	4.26	8.47	12.40
T3	--	4.30	8.57	12.60
T4	--	4.30	7.73	11.83
T5	--	4.38	8.57	12.17
T6	--	4.35	7.93	11.83
T7	--	4.40	8.53	11.50
T8	--	4.17	8.20	12.10
T9	--	4.40	8.98	12.40
T10	--	4.23	8.47	12.33
T11	--	4.53	9.00	12.43
T12	--	4.57	7.27	13.03
T13	--	5.67	9.27	13.07
T14	--	4.57	7.53	12.00
T15	--	5.91	9.50	13.13
SE m ±	--	0.023	0.071	0.129
CD(0.05)	--	0.068	0.204	0.372

Table 9. Effect of micronutrients, cycocel and ethrel on tuber diameter of sweet potato

Treatments	Tuber diameter (cm)			
	25DAP	50 DAP	75 DAP	100 DAP
C1	--	0.53	1.43	2.86
C2	--	0.55	1.44	2.87
T1	--	0.59	2.50	3.95
T2	--	0.60	2.52	4.08
T3	--	0.61	2.53	4.24
T4	--	0.60	2.47	4.12
T5	--	0.61	2.49	4.50
T6	--	0.63	2.48	4.39
T7	--	0.64	2.54	4.34
T8	--	0.66	2.56	4.50
T9	--	0.69	2.62	4.55
T10	--	0.72	2.56	4.52
T11	--	0.73	2.63	4.55
T12	--	0.74	2.60	4.23
T13	--	0.77	2.90	4.68
T14	--	0.75	2.61	4.28
T15	--	0.78	2.91	4.71
SE m ±	--	0.007	0.002	0.006
CD (0.05)	--	0.021	0.006	0.016

highest tuber diameter was observed in plants under the treatment T15 (T3+ CCC 500 ppm at 30 DI) in all the three stages . At 50th and 100th DAP maximum value was observed for T15 (0.78cm and 4.71cm respectively) which was on par with T13 (0.77cm and 4.68cm respectively). At 75th DAP highest tuber diameter was observed for T15 (2.91 cm) followed by T13 (2.90cm). Lowest tuber diameter was recorded in plants under the treatment C1 at 50th (0.53cm), 75th (1.43cm) and 100th (2.86cm) DAP and was on par with C2 (0.55cm, 1.44cm and 2.87cm at 50th, 75th and 100th DAP respectively). Comparitively highest tuber diameter was observed in the combined treatment of NPK as per POP along with micronutrient mixtures and growth regulators whereas the application of NPK as per POP along with micronutrient mixture alone did not show best results in terms of tuber diameter. Among the treatments, T15 [NPK as per POP along with micronutrient mixtures (*) (Fe+Zn+Mn+B 0.1% each) and growth regulators cycocel (500ppm)] resulted in the maximum tuber diameter. T13 was also on par with T15.

4.1.7 Tuber weight

The data on the effect of micronutrients, cycocel and ethrel on tuber weight at different stages of growth are presented in Table 10.

There was a significant increase in tuber weight with the growth stages of the crop. Maximum value for the tuber weight was recorded at 100 DAP and the highest tuber weight was observed in plants under the treatment T15 (T3+ CCC 500 ppm at 30 DI) in all the three stages. Maximum value was recorded for T15 (36.23g) at 50th DAP followed by T13 (31.13g). At 75th DAP maximum value was recorded for T15 (103.27g) and was on par with T13 (102.50g). At 100th DAP, T15 (196.17g) was found to be on par with T13(194.30g). Lowest tuber weight was recorded in plants under the treatment C1 at 50th (15.40g), 75th (64.67g) and 100th (143.27g) DAP and was on par with C2 (15.47g, 65.73g and 143.67g at 50th, 75th and 100th DAP respectively. Comparitively higher tuber weight was observed with the combined treatment of NPK as per POP along with micronutrient mixtures and growth

Table 10. Effect of micronutrients, cycocel and ethrel on tuber weight of sweet potato

Treatments	Tuber weight (g)			
	25DAP	50 DAP	75 DAP	100 DAP
C1	--	15.40	64.67	143.27
C2	--	15.47	65.73	143.67
T1	--	17.00	66.00	164.10
T2	--	17.33	69.27	171.40
T3	--	18.33	71.47	173.83
T4	--	17.50	71.33	187.33
T5	--	18.50	74.33	187.00
T6	--	19.23	72.47	188.57
T7	--	19.37	74.47	186.50
T8	--	20.67	79.17	191.23
T9	--	21.33	81.77	191.83
T10	--	22.47	80.20	190.37
T11	--	24.17	85.83	191.33
T12	--	23.53	81.00	182.90
T13	--	31.13	102.50	194.30
T14	--	24.97	85.27	186.23
T15	--	36.23	103.27	196.17
SE m ±	--	0.467	0.645	1.278
CD (0.05)	--	1.352	1.868	3.700

regulators whereas the application of NPK as per POP along with micronutrient mixtures alone(without growth regulators) did not show best results in terms of tuber weight. Among the treatments, T15 [NPK as per POP along with micronutrient mixtures(*) (Fe+Zn+Mn+B 0.1% each) + cycocel (500ppm)] recorded the maximum tuber weight. T13 was also on par with T15.

4.1.8 Tuber yield

The data on the effect of micronutrients, cycocel and ethrel on tuber yield at different stages of growth are presented in Table 11.

There was a significant increase in tuber yield with the growth stages of the crop. Maximum value for the tuber yield was recorded at 100DAP and the highest tuber yield was observed in plants under the treatment T15 (T3+ CCC 500 ppm at 30 DI) in all the three stages. Maximum value was recorded for T15 (3.02 t ha^{-1}) at 25^{th} DAP followed by T13 (2.59 t ha^{-1}). At 75^{th} and 100^{th} DAP maximum value was recorded for T15 (8.61 t ha^{-1} and 16.35 t ha^{-1} respectively) and was on par with T13 (8.54 t ha^{-1} and 16.19 t ha^{-1} respectively). Lowest tuber yield was recorded in plants under the treatment C1(1.28 t ha^{-1},5.39 t ha^{-1} and 11.94 t ha^{-1} at 50^{th} 75^{th} and 100^{th} DAP respectively) and was on par with C2 (1.29 t ha^{-1},5.48 t ha^{-1} and 11.97 t ha^{-1} at 50^{th} 75^{th} and 100^{th} DAP respectively). Comparitively higher tuber yield was observed with the combined treatment of NPK as per POP along with micronutrient mixtures and growth regulators whereas the application of NPK as per POP along with micronutrient mixtures alone (without growth regulators) did not show better tuber yield. Among the treatments, T15 NPK as per POP along with micronutrient mixtures (*) (Fe+Zn+Mn+B 0.1% each) + cycocel (500ppm) resulted in the maximum tuber yield. T13 was also on par with T15.

Table 11. Effect of micronutrients, cycocel and ethrel on tuber yield of sweet potato

Treatments	Tuber yield(t ha^{-1})			
	25DAP	50 DAP	75 DAP	100 DAP
C1	--	1.28	5.39	11.94
C2	--	1.29	5.48	11.97
T1	--	1.42	5.50	13.68
T2	--	1.44	5.77	14.28
T3	--	1.53	5.96	14.49
T4	--	1.46	5.94	15.61
T5	--	1.54	6.19	15.58
T6	--	1.60	6.04	15.71
T7	--	1.61	6.21	15.54
T8	--	1.72	6.60	15.94
T9	--	1.78	6.81	15.99
T10	--	1.87	6.68	15.86
T11	--	2.01	7.15	15.94
T12	--	1.96	6.75	15.24
T13	--	2.59	8.54	16.19
T14	--	2.08	7.11	15.52
T15	--	3.02	8.61	16.35
SE m ±	--	0.039	0.054	0.107
CD (0.05)	--	0.112	0.157	0.309

4.2 PHYSIOLOGICAL PARAMETERS

4.2.1 Chlorophyll content

The data on the effect of micronutrients, cycocel and ethrel on chorophyll content at different stages of growth are presented in Table 12.

There was a significant increase in chorophyll content at 25th day to 75th DAP and then it decreased at 100th DAP. Highest chlorophyll content of the leaves was recorded in plants under the treatment T15 (T3+ CCC 500 ppm at 30DI) and was on par with T13(T3+ Ethrel 500 ppm at 30DI) at all the four stages. The maximum value was recorded in plants under the treatment T15 (1.83 mg g^{-1}, 2.70 mg g^{-1}, 4.22 mg g^{-1} and 2.25 mg g^{-1} at 25th 50th and 75th and 100th DAP respectively) and was on par with T13(1.82 mg g^{-1},2.68 mg g^{-1} , 4.14 mg g^{-1} and 2.21 mg g^{-1} at 25th 50th 75th 100th DAP respectively). The lowest chorophyll content was observed in plants under the treatment C1 at 25th(1.09 mg g^{-1}), 50th(1.46 mg g^{-1}), 75th (1.96 mg g^{-1}) and 100th (1.32 mg g^{-1}) DAP and was on par with C2 (1.10 mg g^{-1} , 1.48 mg g^{-1} , 1.97 mg g^{-1} and 1.32 mg g^{-1} at 25th, 50th 75th and 100th DAP respectively). Comparitively higher chorophyll content was observed with the combined treatment of NPK as per POP along with micronutrient mixtures and growth regulators whereas the application of NPK as per POP along with micronutrient mixtures alone (without growth regulators) did not show best results in terms of chorophyll content of the leaves. Among the treatments, T15 NPK as per POP along with micronutrient mixtures(*) (Fe+Zn+Mn+B 0.1% each+ cycocel (500ppm)] resulted in the maximum chlorophyll content of the leaves. T13 was also on par with T15.

4.2.2 Caroteinoid content

The data on the effect of micronutrients, cycocel and ethrel on caroteinoid content at different stages of growth are presented in Table 13.

Table 12. Effect of micronutrients, cycocel and ethrel on total chlorophyll of the sweet potato leaves

Treatments	Total chlorophyll) (mg g^{-1})			
	25 DAP	50 DAP	75 DAP	100 DAP
C1	1.09	1.46	1.96	1.32
C2	1.10	1.48	1.97	1.32
T1	1.44	2.25	2.48	1.84
T2	1.51	2.39	2.70	1.91
T3	1.68	2.62	3.02	2.05
T4	1.10	2.10	2.15	1.39
T5	1.21	2.17	2.36	1.52
T6	1.11	2.00	2.22	1.41
T7	1.22	2.13	2.38	1.55
T8	1.46	2.20	2.43	1.78
T9	1.58	2.26	2.60	1.88
T10	1.49	2.30	2.45	1.83
T11	1.56	2.16	2.64	1.88
T12	1.75	2.57	3.42	1.99
T13	1.82	2.68	4.14	2.21
T14	1.74	2.58	3.45	2.07
T15	1.83	2.70	4.22	2.25
SE m ±	0.013	0.019	0.055	0.019
CD(0.05)	0.038	0.056	0.158	0.056

Table 13. Effect of micronutrients, cycocel and ethrel on caroteinoid content of the sweet potato leaves

Treatments	Caroteinoids (mg g^{-1})			
	25 DAP	50 DAP	75 DAP	100 DAP
C1	0.28	0.29	0.33	0.24
C2	0.32	0.30	0.36	0.28
T1	0.52	0.73	0.60	0.41
T2	0.51	0.57	0.55	0.43
T3	0.60	0.68	0.89	0.67
T4	0.31	0.38	0.44	0.33
T5	0.40	0.47	0.51	0.33
T6	0.30	0.37	0.47	0.33
T7	0.37	0.46	0.53	0.36
T8	0.53	0.57	0.61	0.44
T9	0.59	0.64	0.71	0.45
T10	0.49	0.58	0.66	0.46
T11	0.53	0.68	0.78	0.55
T12	0.55	0.69	0.89	0.73
T13	0.65	0.90	1.05	0.84
T14	0.58	0.75	0.96	0.74
T15	0.66	0.91	1.06	0.87
SE m ±	0.018	0.014	0.011	0.011
CD(0.05)	0.051	0.042	0.032	0.031

Caroteinoid content significantly increased from 25th DAP to 75th DAP and then decreased at 100th DAP. Highest caroteinoid content of the leaves was recorded in plants under the treatment T15(T3+ CCC 500 ppm at 30DI) and was on par with T13(T3+ Ethrel 500 ppm at 30DI) at all the four stages. The maximum value was recorded in plants under the treatment T15 (0.66 mg g^{-1} , 0.91 mg g^{-1}, 1.06 mg g^{-1} and 0.87 mg g^{-1} at 25th 50th and 75th and 100th DAP respectively) and was on par with T13 (0.65 mg g^{-1}, 0.90 mg g^{-1}, 1.05 mg g^{-1} and 0.84 mg g^{-1} at 25th 50th 75th 100th DAP respectively). The lowest caroteinoid content was observed in plants under the treatment C1 (0.28 mg g^{-1}, 0.29 mg g^{-1}, 0.33 mg g^{-1} and 0.24 mg g^{-1} at 25th 50th and 75th day and 100th DAP respectively) and was on par with C2 (0.32 mg g^{-1}, 0.30 mg g^{-1}, 0.36 mg g^{-1} and 0.28 mg g^{-1}) at 25th 50th and 75th day and 100th DAP respectively). Comparitively higher caroteinoid content was observed with the combined treatment of NPK as per POP along with micronutrient mixtures and growth regulators whereas the application of NPK as per POP along with micronutrient mixtures alone (without growth regulators) did not show best results in terms of caroteinoid content of the leaves. Among the treatments, T15 [NPK as per POP along with micronutrient mixtures (Fe+Zn+Mn+B @0.1% each) + cycocel (500ppm)] resulted in the maximum caroteinoid content of the leaves. T13 was also on par with T15.

4.2.3 Stomatal conductance

The data on the effect of micronutrients, cycocel and ethrel on stomatal conductance at different stages of growth are presented in Table 14.

Stomatal conductance significantly increased from 25th day to 75th day and then decreased at 100th day. Highest stomatal conductance of the leaves was recorded in plants under the treatment T15(T3+ CCC 500 ppm at 30DI) at all the four stages. Maximum value for the stomatal conductance was recorded in plants under the treatment T15 (204.33 mmole $H_2O\ m^{-2}\ s^{-1}$, 292.33 mmole $H_2O\ m^{-2}\ s^{-1}$) at 25th and 75th

Table 14. Effect of micronutrients, cycocel and ethrel on stomatal conductance of the sweet potato leaves

Treatments	Stomatal conductance (mmole H_2O m^{-2} s^{-1})			
	25 DAP	50 DAP	75 DAP	100 DAP
C1	140.33	191.33	241.33	87.00
C2	140.33	191.67	242.67	91.00
T1	167.00	225.33	261.33	120.67
T2	179.33	231.33	268.00	125.00
T3	198.33	242.00	280.33	128.67
T4	152.33	230.00	261.33	118.33
T5	162.67	231.00	267.33	121.00
T6	154.67	229.33	267.67	118.33
T7	164.33	230.00	270.67	120.01
T8	142.67	235.67	260.00	120.33
T9	150.33	238.00	274.00	121.33
T10	148.00	240.00	268.67	122.00
T11	150.33	242.00	275.00	123.33
T12	194.67	243.00	284.67	129.00
T13	198.33	251.67	285.67	130.67
T14	198.33	248.33	284.67	129.67
T15	204.33	255.33	292.33	131.33
SE m $\pm$	1.141	1.462	2.138	2.596
CD (0.05)	3.301	4.232	6.187	7.511

DAP respectively. At 50th DAP maximum value was recorded in plants under the treatment T15 (255.33 mmole H_2O m^{-2} s^{-1}) and was on par with T13(251.67 mmole H_2O m^{-2} s^{-1}). At 100th DAP maximum value was recorded in plants under the treatment T15 (131.33 mmole H_2O m^{-2} s^{-1}) and was on par with T13 (130.67 mmole H_2O m^{-2} s^{-1}), T14 (129.67 mmole H_2O m^{-2} s^{-1}), T12 (129.00 mmole H_2O m^{-2} s^{-1}), T3 (128.67 mmole H_2O m^{-2} s^{-1}) and T2 (125.00 mmole H_2O m^{-2} s^{-1}). The lowest stomatal conductance was observed in plants under the treatment C1 (140.33 mmole H_2O m^{-2} s^{-1}, 191.33 mmole H_2O m^{-2} s^{-1}, 241.33 mmole H_2O m^{-2} s^{-1} and 87.00 mmole H_2O m^{-2} s^{-1} at 25th, 50th, 75th and 100th DAP respectively) and was on par with C2 (140.33 mmole H_2O m^{-2} s^{-1}, 191.67 mmole H_2O m^{-2} s^{-1}, 242.67 mmole H_2O m^{-2} s^{-1} and 91.00 mmole H_2O m^{-2} s^{-1} at 25th, 50th, 75th and 100th DAP respectively). Comparitively higher stomatal conductance was observed with the combined treatment of NPK as per POP along with micronutrient mixtures and growth regulators whereas the application of NPK as per POP along with micronutrient mixtures alone did not show best results in terms of stomatal conductance of the leaves. Among the treatments, T15 [NPK as per POP along with micronutrient mixtures (Fe+Zn+Mn+B @ 0.1% each) + cycocel (500ppm)] resulted in the maximum stomatal conductance of the leaves. T13 was also on par with T15.

4.2.4 Photosynthetic rate

The data on the effect of micronutrients, cycocel and ethrel on photosynthetic rate at different stages of growth are presented in Table 15.

Photosynthetic rate significantly increased from 25th DAP to 75th DAP and then decreased at 100th DAP. Highest photosynthetic rate of leaves was recorded in plants under the treatment T15 (T3+ CCC 500 ppm at 30DI) at all the four stages and at 25th DAP maximum value was recorded for T15 (8.44 µmole CO_2 m^{-2} s^{-1}) and was on par with T13 (8.38 µmole CO_2 m^{-2} s^{-1}) and T14(8.20 µmole CO_2 m^{-2} s^{-1}). Maximum value was recorded in plants under the treatment T15 (12.30 µmole CO_2

Table 15. Effect of micronutrients, cycocel and ethrel on photosynthetic rate of the sweet potato leaves

Treatments	Photosynthetic rate (µmole CO_2 m^{-2} s^{-1})			
	25 DAP	50 DAP	75 DAP	100 DAP
C1	6.43	7.55	10.23	1.23
C2	6.60	7.56	10.30	1.28
T1	7.42	7.87	13.20	3.75
T2	7.57	8.19	13.37	3.92
T3	7.63	9.92	13.81	4.11
T4	6.60	9.67	13.00	2.03
T5	7.17	9.53	12.73	2.09
T6	6.63	9.87	12.90	2.38
T7	7.09	10.03	13.03	2.58
T8	7.07	10.37	13.17	3.00
T9	7.50	10.70	13.37	3.15
T10	7.50	10.97	13.57	3.20
T11	7.70	10.79	13.57	3.58
T12	8.18	11.80	14.17	4.15
T13	8.38	12.00	14.37	4.28
T14	8.20	11.90	14.30	4.21
T15	8.44	12.30	14.43	4.49
SE m ±	0.092	0.274	0.189	0.074
CD (0.05)	0.267	0.792	0.548	0.215

m^{-2} s^{-1}, 14.43 µmole CO_2 m^{-2} s^{-1} at 50th and 75th DAP respectively) and was on par with T13, T14,and T12. At 100th day maximum value was recorded in plants under the treatment T15(4.49 µmole CO_2 m^{-2} s^{-1}) and was on par with T13(4.28 µmole CO_2 m^{-2} s^{-1}).The lowest photosynthetic rate was recorded in plants under the treatment C1 (6.43 µmole CO_2 m^{-2} s^{-1}, 7.55 µmole CO_2 m^{-2} s^{-1}, 10.23 µmole CO_2 m^{-2} s^{-1} and 1.23 µmole CO_2 m^{-2} s^{-1} at 25th,50th,75th and 100th DAP respectively) and was on par with C2 (6.60 µmole CO_2 m^{-2} s^{-1} , 7.56 µmole CO_2 m^{-2} s^{-1} , 10.30 µmole CO_2 m^{-2} s^{-1} and 1.28 µmole CO_2 m^{-2} s^{-1} at 25th 50th and 75th day and 100th DAP respectively). Comparitively higher photosynthetic rate was observed with the combined treatment of NPK as per POP along with micronutrient mixtures and growth regulators whereas the application of NPK as per POP along with micronutrient mixtures alone did not show best results in terms of photosynthetic rate. Among the treatments, T15 [NPK as per POP along with micronutrient mixtures (Fe+Zn+Mn+B @0.1% each) and growth regulators cycocel(500ppm) as well as ethrel (500ppm)] resulted in the maximum photosynthetic rate of the leaves.. T13 was also on par with T15.

4.2.5 Transpiration rate

The data on the effect of micronutrients, cycocel and ethrel on tuber yield at different stages of growth are presented in Table 16.

Transpiration rate significantly increased from 25th DAP to 75th DAP and then decreased at 100th DAP and the maximum transpiration rate was observed in plants under the treatment C1 (NPK as per POP) at all the stages. Highest transpiration rate was recorded in plants under the treatment C1 (1.48 mmole H_2O m^{-2} s^{-1}) and was on par with C2 (1.47 mmole H_2O m^{-2} s^{-1}) at 25th DAP . At 50th DAP maximum value was recorded for C1 (1.55 mmole H_2O m^{-2} s^{-1}) and was on par with C2 (1.55 mmole H_2O m^{-2} s^{-1}), T1 (1.55 mmole H_2O m^{-2} s^{-1}), T2 (1.54 mmole H_2O m^{-2} s^{-1}) and T3 (1.52 mmole H_2O m^{-2} s^{-1}). At 75th DAP maximum value was recorded in plants under the treatment C1 (1.97 mmole H_2O m^{-2} s^{-1}) and was on par with C2 (1.97 mmole H_2O m^{-2}

Table 16. Effect of micronutrients, cycocel and ethrel on transpiration rate of the sweet potato leaves

Treatments	Transpiration rate (mmole H_2O m^{-2} s^{-1})			
	25 DAP	50 DAP	75 DAP	100 DAP
C1	1.48	1.55	1.97	0.84
C2	1.47	1.55	1.97	0.84
T1	1.44	1.55	1.92	0.84
T2	1.42	1.54	1.89	0.83
T3	1.39	1.52	1.67	0.82
T4	1.34	1.42	1.67	0.82
T5	1.34	1.45	1.67	0.82
T6	1.35	1.44	1.67	0.82
T7	1.36	1.43	1.69	0.84
T8	1.32	1.43	1.68	0.83
T9	1.36	1.45	1.70	0.83
T10	1.35	1.43	1.66	0.83
T11	1.33	1.44	1.67	0.83
T12	1.34	1.41	1.66	0.82
T13	1.26	1.36	1.55	0.69
T14	1.31	1.37	1.63	0.80
T15	1.25	1.35	1.50	0.68
SE m $\pm$	0.012	0.016	0.018	0.007
CD(0.05)	0.035	0.045	0.051	0.02

s^{-1}) and T1(1.92 mmole H_2O m^{-2} s^{-1}). At 100th DAP maximum value was recorded in plants under the treatment C1 (0.84 mmole H_2O m^{-2} s^{-1}) and was on par with C2 (0.84 mmole H_2O m^{-2} s^{-1}), T1 (0.84 mmole H_2O m^{-2} s^{-1}), T2 (0.83 mmole H_2O m^{-2} s^{-1}). The lowest transpiration rate was observed in plants under the treatment T15(1.25 mmole H_2O m^{-2} s^{-1}, 1.35 mmole H_2O m^{-2} s^{-1}, 1.50 mmole H_2O m^{-2} s^{-1} and 0.68 mmole H_2O m^{-2} s^{-1} at 25th, 50th, 75th and 100th DAP respectively) and was on par with T13(1.26 mmole H_2O m^{-2} s^{-1}, 1.36 mmole H_2O m^{-2} s^{-1}, 1.55 mmole H_2O m^{-2} s^{-1} and 0.69 mmole H_2O m^{-2} s^{-1} at 25th, 50th,75th and 100th DAP respectively). Comparatively highest transpiration rate was observed with the combined treatment of NPK as per POP along with micronutrient mixtures and growth regulators whereas the application of NPK as per POP along with micronutrient mixtures alone did not show best results in terms of transpiration rate. Among the treatments T15 [NPK as per POP along with micronutrient mixtures (Fe+Zn+Mn+B @0.1% each) + cycocel (500ppm)] resulted in the minimum transpiration rate of the leaves. T13 was also on par with T15.

4.2.6 Water use efficiency

The data on the effect of micronutrients, cycocel and ethrel on tuber yield at different stages of growth are presented in Table 17.

Water use efficiency significantly increased from 25th DAP to 75th DAP and then decreased at 100th DAP. Highest water use efficiency was recorded in plants under the treatment T15 (T3+ CCC 500 ppm at 30DI) at all the four stages. Maximum value was recorded for T15 (5.82 mmol CO_2 mol^{-1} H_2O) at 25th DAP and was on par with T13 (5.79 mmol CO_2 mol^{-1} H_2O) and T14 (5.76 mmol CO_2 mol^{-1} H_2O). At 50th DAP maximum value was recorded in plants under the treatment T15 (7.89 mmol CO_2 mol^{-1} H_2O) which was on par with T13 (7.65 mmol CO_2 mol^{-1} H_2O) and T14 (5.76 mmol CO_2 mol^{-1} H_2O). At 75th DAP maximum value recorded for WUE was in plants under the treatment T15 (8.27 mmol CO_2 mol^{-1} H_2O) and was on par with T13 (8.16 mmol CO_2 mol^{-1} H_2O) , T14 (8.11 mmol CO_2 mol^{-1} H_2O) and T12

Table 17. Effect of micronutrients, cycocel and ethrel on water use efficiency of the sweet potato leaves

Treatments	Water use efficiency (mmol CO_2 mol^{-1} H_2O)			
	25 DAP	50 DAP	75 DAP	100 DAP
C1	5.15	5.56	6.65	1.81
C2	5.24	5.59	6.82	1.85
T1	4.94	5.77	7.31	2.47
T2	4.93	5.83	7.34	2.54
T3	5.23	6.57	7.44	2.94
T4	5.35	6.79	7.50	3.14
T5	5.49	6.91	7.71	3.75
T6	5.36	6.86	7.62	3.64
T7	5.53	6.95	7.72	3.84
T8	5.57	6.95	7.79	4.25
T9	5.66	7.11	7.88	4.80
T10	5.58	7.00	7.84	4.71
T11	5.66	7.40	8.05	4.97
T12	5.69	7.50	8.10	5.10
T13	5.79	7.65	8.16	5.16
T14	5.76	7.63	8.11	5.12
T15	5.82	7.89	8.27	5.35
SE m ±	0.077	0.216	0.143	0.1
CD(0.05)	0.222	0.624	0.414	0.29

(8.10 mmol CO_2 mol^{-1} H_2O). At 100th DAP maximum value in plants under the treatment T15 (5.35 mmol CO_2 mol^{-1} H_2O) and was on par with T13(5.16 mmol CO_2 mol^{-1} H_2O), T14 (5.12 mmol CO_2 mol^{-1} H_2O) and T12 (5.10 mmol CO_2 mol^{-1} H_2O). The lowest WUE was recorded in plants under the treatment C1 was (5.15 mmol CO_2 mol^{-1} H_2O, 5.56 mmol CO_2 mol^{-1} H_2O, 6.65 mmol CO_2 mol^{-1} H_2O and 1.81 mmol CO_2 mol^{-1} H_2O at 25th 50th 75th 100th day respectively) and was on par with C2 (5.24 mmol CO_2 mol^{-1} H_2O, 5.59 mmol CO_2 mol^{-1} H_2O, 6.82 mmol CO_2 mol^{-1} H_2O and 1.85 mmol CO_2 mol^{-1} H_2O at 25th 50th 75th 100th DAP respectively). Comparitively higher water use efficiency was observed with the combined treatment of NPK as per POP along with micronutrient mixtures and growth regulators whereas the application of NPK as per POP along with micronutrient mixtures alone (without growth regulators) did not show best results in terms of water use efficiency. Among the treatments, T15 [NPK as per POP along with micronutrient mixtures (Fe+Zn+Mn+B @ 0.1% each) + cycocel (500ppm) resulted in the maximum water use efficiency. T13 was also on par with T15.

4.3 QUALITY PARAMETERS

4.3.1 Mineral constituents

The data on the effect of micronutrients, cycocel and ethrel on mineral constituents of tubers at harvest stage of the crop is presented in Table 18.

There was a significant difference in mineral constituents in tubers among the treatments. The highest mineral constituents in tubers (N, P, K, Fe, Zn, Mn and B) at harvest stage was recorded in plants under the treatment T15(T3+ CCC 500 ppm at 30DI) and lowest was recorded in plants under the treatment C1 (NPK as per POP). Maximum value for N content in tuber was recorded in plants under the treatment T15 (0.614%). Similarly highest P content (0.056%), highest K content (0.489%), Fe content (16.30ppm), Zn content (15.07ppm), Mn content (7.37ppm) and B content (1.27ppm) were also recorded in plants under the treatment T15. Lowest N (0.192%),

Table 18. Effect of micronutrients, cycocel and ethrel on mineral constituents of the sweet potato tuber

Treatments	Mineral constituents at harvest stage						
	N(%)	P(%)	K(%)	Fe ($mg\ kg^{-1}$)	Zn ($mg\ kg^{-1}$)	Mn ($mg\ kg^{-1}$)	B ($mg\ kg^{-1}$)
C1	0.192	0.021	0.185	8.33	6.73	2.93	0.40
C2	0.196	0.024	0.186	8.53	7.17	2.97	0.47
T1	0.211	0.042	0.273	10.40	8.10	4.20	0.63
T2	0.213	0.042	0.286	11.77	9.97	5.20	0.82
T3	0.225	0.043	0.311	13.37	12.33	6.17	1.10
T4	0.333	0.045	0.370	10.97	9.00	4.70	0.67
T5	0.348	0.049	0.391	12.00	9.33	4.93	0.70
T6	0.328	0.045	0.396	11.33	9.13	4.90	0.68
T7	0.330	0.048	0.410	12.87	10.00	5.07	0.73
T8	0.449	0.044	0.347	11.67	10.50	5.43	0.85
T9	0.485	0.050	0.377	13.03	11.97	5.60	0.88
T10	0.473	0.045	0.390	12.23	10.97	5.50	0.87
T11	0.490	0.049	0.422	13.83	12.57	5.93	0.93
T12	0.597	0.051	0.423	14.33	13.00	6.80	0.95
T13	0.604	0.054	0.456	15.60	14.50	6.87	1.19
T14	0.599	0.052	0.427	14.77	13.43	6.37	0.97
T15	0.614	0.056	0.489	16.30	15.07	7.37	1.27
SE m ±	0.001	0.001	0.009	0.169	0.124	0.127	0.011
CD (0.05)	0.004	0.002	0.026	0.489	0.358	0.366	0.032

P (0.021%), K (0.185%), Fe (8.33ppm), Zn (6.73ppm), Mn (2.93ppm) and B (0.40ppm) in tubers were observed in the treatment C1. Comparitively higher mineral content in tubers was observed with the combined treatment of NPK as per POP along with micronutrient mixtures and growth regulators (cycocel followed by ethrel) whereas the application of NPK as per POP along with micronutrient mixtures alone did not show best results in terms of mineral constituents in tubers.

4.3.2 Total phenol

The data on the effect of micronutrients, cycocel and ethrel on total phenol content of tubers at harvest stage of the crop is presented in Table 19.

There was a significant difference in total phenol content observed among the treatments. Highest total phenol content in tubers was recorded in the plants under the treatment T15(T3+ CCC 500 ppm at 30DI) and lowest total phenol content in tubers was observed in plants under the treatment C1(NPK as per POP) at harvest. Maximum value was recorded in plants under the treatment T 15 (13.33 mg g^{-1}) and the minimum value was recorded in plants under the treatment C1 (6.43 mg g^{-1}) and was on par with C2 (6.47 mg g^{-1}). Comparitively highest total phenol content in tubers was observed with the combined treatment of NPK as per POP along with micronutrient mixtures and growth regulators and the application of NPK as per POP along with micronutrient mixtures alone did not show best results in terms of total phenol content in tubers. Among the various treatments, T15 [NPK as per POP along with micronutrient mixtures (*) (Fe+Zn+Mn+B 0.1% each) + cycocel (500ppm)] resulted in the maximum total phenol content of tubers.

4.3.3 Total sugar

The data on the effect of micronutrients, cycocel and ethrel on total sugar content of tubers at harvest stage of the crop is presented in Table 19.

Table 19. Effect of micronutrients, cycocel and ethrel on Total phenolic content, Total sugars and Protein content of the sweet potato tuber at harvest

Treatments	Total phenolic content (mg g^{-1})	Total sugars (mg g^{-1})	Protein content (mg g^{-1})
C1	6.43	19.92	12.00
C2	6.47	19.93	12.20
T1	8.13	22.15	13.20
T2	9.30	23.43	13.30
T3	10.60	23.93	14.00
T4	8.43	24.44	20.80
T5	8.93	25.66	21.80
T6	8.60	24.04	20.50
T7	9.20	24.14	20.60
T8	9.57	29.94	28.10
T9	10.97	31.09	30.30
T10	10.60	28.02	29.50
T11	11.20	28.97	30.60
T12	11.50	32.46	37.30
T13	12.50	33.53	37.80
T14	12.00	33.52	37.40
T15	13.33	34.48	38.40
SE m	0.156	0.133	0.083
CD (0.05)	0.452	0.386	0.241

There was a significant difference in total sugar content in tubers observed among the treatments. Highest total sugar content in tubers was recorded in plants under the treatment T15 (T3+ CCC 500 ppm at 30DI) and lowest total sugar in tubers was observed in plants under the treatment C1(NPK as per POP) at harvest. Maximum value was recorded in plants under the treatment T15 (34.48 mg g^{-1}) and the minimum value was recorded in plants under the treatment C1 (19.92 mg g^{-1}) and was on par with C2 (19.93 mg g^{-1}). Comparitively highest total sugar content in tubers was observed with the combined treatment of NPK as per POP along with micronutrient mixtures and growth regulators whereas the application of NPK as per POP along with micronutrient mixtures alone did not show best results in terms of total sugar content in tubers. Among the various treatments, T15 [NPK as per POP along with micronutrient mixtures (Fe+Zn+Mn+B @0.1% each) + cycocel(500ppm)] resulted in the maximum total sugar content of tubers.

4.3.4 Protein content

The data on the effect of micronutrients, cycocel and ethrel on protein content of tubers at harvest stage of the crop is presented in Table 19.

There was a significant difference in protein content in tubers observed among the treatments. Highest protein content in tubers was recorded in plants under the treatment T15 (T3+ CCC 500 ppm at 30DI) and lowest protein content in tubers was in plants under the treatment C1(NPK as per POP) at harvest. Maximum value was recorded in plants under the treatment T 15 (38.40 mg g^{-1}) and the minimum value was recorded in plants under the treatment C1 (12.00 mg g^{-1}) and was on par with C2 (12.20 mg g^{1}). Comparitively highest protein content in tubers was observed with the combined treatment of NPK as per POP along with micronutrient mixtures and growth regulators whereas the application of NPK as per POP along with micronutrient mixtures alone did not show best results in terms of protein content in tubers. Among the various treatments, T15 (NPK as per POP along with

micronutrient mixtures (Fe+Zn+Mn+B @0.1% each) + cycocel (500ppm) resulted in the maximum protein content of tubers.

Discussion

5. DISCUSSION

Sweet potato is one of the important dicotyledonous tuber crops grown in tropical and subtropical regions of the world. Globally, India ranks twelfth position in area, eighth position in production and fifth position in productivity of sweet potato (Edison *et al.*, 2009).

Micronutrients are important to world agriculture and human health. Sweet potato productivity and quality are very much affected due to the poor fertility and low nutrient availability, especially due to the low micronutrient levels in soils. Zinc (Zn), iron (Fe), manganese (Mn) and copper (Cu) have become yield limiting factors and are also reported to be partly responsible for low food nutrition. Foliar feeding using foliar fertilizer is an effective method for correcting soil deficiencies and overcoming the soil inability to transfer nutrients to sweet potato (Mona, 2016).

Foliar application of nutrients along with growth regulators can effectively manage crop growth and quality (Smolen and Sady 2009). Biofortification is a process by which we can enrich the nutrient content in the edible parts of the plants. Foliar spray is one of the approches of biofortification and in the present study the effect of micronutrient mixture (Fe+Zn+Mn+B @ 0.1%, 0.05%, 0.01% each) and growth regulators(cycocle and ethrel @ 250ppm, 500ppm each) on growth, development and changes in fortification status of sweet potato tubers and leaves was evaluated.

The data collected on different biometric parameters, physiological parameters and quality parameters on the experiment entitled 'Effect of foliar application of selected micro nutrients and growth regulators on tuber development, yield and fortification status of sweet potato (*Ipomoea batatas* L.) is discussed in this chapter.

5.1 BIOMETRIC PARAMETERS

5.1.1 Branch length

In the present study, branch length significantly increased with the application of micronutrients. Highest branch length was recorded in plants under the treatment T3 (C1+ FN (MN mixture Fe+Zn+Mn+B (*) 0.1% each at 30DI). T3 resulted in significant increase in the branch length from 25th to 100th DAP, followed by T2 (C1+ FN (MN mixture(*) 0.05% each at 30DI) and T1 (C1+ FN (MN mixture(*) 0.01% each at 30DI) whereas lowest branch length was observed in plants under the treatment C1 (NPK as per POP) and was on par with C2 (NPK as per POP with water spray at 30DI) .

Most of the micronutrients are activators of many of the enzymes, responsible for various metabolic reactions in plants. Foliar application of Fe, Zn ,Mn and B were reported to be highly effective in enhancing photosynthesis and many of the metabolic activities responsible for cell division and elongation which in turn result in increased cell growth in plants. An increased branch length was observed with the micronutrient spray in vegetables (Rawat and Mathpal, 1984 ; Hatwar *et al.*, 2003). Among the micro nutrients, Zn has important role in synthesis of tryptophan (precursor of IAA). Hence it promotes auxin biosynthesis which results in apical dominance and consequently increase the growth and development of plants (Teiz and Zeiger, 2006). Combined treatment of 0.1% B and 0.1% Zn was reported to increase the plant height in ginger (Alloway, 2008 ; Hatwar *et al.*, 2003) Similarly Manas *et al.* (2014) reported that combined treatment of humic acid 0.05%+ 0.02% B +0.05% Zn increased the plant height in pungent pepper.

Cycocel is considered as a growth retardant and it is an anti-gibberillin compound which suppress the vegetative growth of plants (Nambiar *et al.*, 1976; Ravisankar, 1983). It inhibit gibberellin biosynthesis by blocking the conversion of geranyl pyrophosphate to coponyl pyrophosphate in the first step of GA biosynthesis

(Moore, 1980) and which result in inhibition of cell division (Maruthi *et al.,* 2003) and reduce the internodal length (Maruthi *et al.,* 2003). Velayutham and Parthiban (2013) reported that foliar spray of cycocel 500ppm resulted in lowest plant height in ginger.

Ethrel has dwarfing effect on plants and it reduces the branch length due to the inhibition of internodal elongation. Kumar *et al.* (2010) reported that there was a significant decrease in plant height observed in african marigold with the application of ethrel at 400ppm concentration. It was also found that with an increase in ethrel concentration from 100ppm to 400ppm there was a reduction in plant height in african marigold. Sengupta (2008) reported that the plant height was reduced in ginger when the plants were treated with ethrel 150ppm. Vreugdenhil and Harro (1989) reported that foliar application of ethrel at higher concentrations (500, 1000 and 1500ppm) resulted in reduced plant height in radish.

The present study also revealed that application of cycocel and ethrel at 250ppm and 500ppm along with the micronutrient mixture resulted in lowest branch length whereas NPK as per POP along with foliar application of micronutrient mixture (Fe+Zn+Mn+B @ 0.1% each) resulted in highest branch length in sweet potato followed by micronutrient mixtures (*) @ 0.05 % each and 0.01% each).

5.1.2 Number of leaves

In the present study number of leaves significantly increased with the application of micronutrients, cycocel and ethrel. In all the treatments there was significant increase in number of leaves per plant from 25th to 100th DAP. Number of leaves were found to be higher in T3 (C1+ FN (MN mixture(*) 0.1% each at 30DI) and was on par with T2 (C1+ FN (MN mixture(*) 0.05% each at 30DI), T15(T3+ CCC 500 ppm) and T13(T3+ ethrel 500 ppm) in the initial and final stage of the observation and the lowest number of leaves per plant was recorded in plants under the treatment C1 and was on par with C2.

Micronutrients promote cell division and cell elongation in the apical buds and it also regulates expansion of cell and formation of new cell wall which result in increased branch length and consequently production of more number of leaves. Among the micronutrients ,especially Zn has important role in inducing the apical growth of plant and it further accelerate the formation of highest number of leaves per plant. Number of branches has positive influence on the number of leaves per plant. The combined treatment of 0.1% B and 0.1% Zn, increased the number of branches and it further resulted in increased number of leaves per plant in chilli (Hatwar *et al.*, 2003). Similarly the combined treatment of humic acid 0.05%+ 0.02% B +0.05% Zn increased the number of branches and also increased the number of leaves in pungent pepper (Manas *et al.*, 2014).

Foliar spray of CCC and ethrel increase the number of branches per plant by the inhibitory action of vine elongation and it further result in increased number of branches as well as more number of leaves per plant. CCC has important role in suppression of apical dominance and it divert the polar transport of auxin towards the basal buds of plant which lead to increased tiller production in ginger (Ravisankar, 1983) and similar results were also reported by Vijayakumar and Abdhul Khader (1986) in cassava. CCC 3000ppm increased the number of branches which resulted in increased number of leaves per branch in potato (Kumar *et al.*, 2012). Similarly foliar spray of cycocel 500ppm resulted in highest number of leaves in ginger. Also Hejjegar *et al.* (2018) reported that foliar spray of cycocel 500ppm produced maximum number of branches per vine as well as number of leaves in sweet potato.

Ethrel spray also result in more number of leaves per plant through the higher production of branches per plant. Ethrel application result in more number of branches due to the higher metabolic and meristematic activity in shoot apical meristem. Shoot apical meristem activity is influenced by specific balance of gibberellins, auxins and cytokinins (Taiz and Zeiger, 2006). Ethrel increase the number of branches by the inhibition of apical dominance and it further result in

breaking of lateral bud dormancy (Campos *et al.,* 2010). Removal of apical bud lead to higher ethylene level which resulted in higher cytokinin content for the lateral bud development and in turn more number of branches as well as leaves were formed in soyabean (Tancredi, 2004). Senguptha *et al.* (2008) reported that application of ethrel at 100ppm in ginger significantly increased the number of leaves per clump.

The present study also revealed that application of cycocel and ethrel at 500ppm along with the micronutrient mixture (Fe+ Zn+Mn+B at 0.1% each at 30DI) as well as the foliar application of NPK as per POP along with micronutrient mixture (Fe+Zn+Mn+B at 0.1% and 0.05% each) resulted in highest number of leaves in sweet potato .

5.1.3 Shoot weight

Highest shoot weight was recorded in plants under the treatment T3 (C1+ FN (MN mixture (*) 0.1% each at 30DI). T3 resulted in significant increase in the shoot weight from 25th to 100th DAP followed by T2 (C1+ FN (MN mixture(*) 0.05% each at 30DI) and T1 (C1+ FN (MN mixture(*) 0.01% each at 30DI). Lowest shoot weight per plant was recorded in plants under the treatment C1 and was on par with C2. Due to the higher branch length and higher number of leaves produced in the treatment T3, shoot weight per plant was also found to be maximum in T3.

El-Banna and Salam (2005) reported that B at two different concentrations (50 and 75 ppm) resulted in maximum fresh weight of shoot in potato. Similarly combined treatment of six micronutrients (Zn, Mo, B, Cu, Mn and Fe each at 250ppm except (Mn @ 50ppm) resulted in increased shoot length, number of branches , number of leaves and shoot weight per plant in tomato (Reddy *et al.* 2018).

The present study also revealed that application of cycocel and ethrel at 250 and 500ppm along with the micronutrient mixture (Fe+Zn+Mn+B at 0.1%, 0.05% and 0.01% each) resulted in comparatively lower shoot weight whereas the

application of NPK as per POP along with micronutrient mixture (Fe+Zn+Mn+B at 0.1% each) resulted in highest shoot weight in sweet potato.

5.1.4 Specific leaf area

Highest specific leaf area was recorded in plants under the treatment T3 (C1+ FN (MN mixture (*) 0.1% each at 30DI) followed by T2 (C1+ FN (MN mixture(*) 0.05% each at 30DI). T1 (C1+ FN (MN mixture(*) 0.01% each at 30DI) resulted in highest specific leaf area and the lowest specific leaf area was observed in plants under the treatment C1 and was on par C2. Foliar application of $ZnSO_4$ (0.5%) + borax (0.1%) recorded maximum leaf area in cashew due to the influence of micronutrient on cell division and cell elongation (Lakshmipathi *et al.*, 2018)

Cycocel and ethrel are growth retardants. They reduce the leaf area for the reduction of transpiration loss of water (Luoranen *et al.,* 2002). Reduction in leaf area by cycocel and ethrel has been reported by Kasele *et al.* (1995); Lee and Reid (1997). Usha *et al.* (2009) reported that foliar application of CCC at 300 ppm had a negative impact on leaf area of Rhubarb (*Rheum rhabarbarum* L.). Kumar and Suchit (2018) reported that with the application of cycocel @ 300ppm there was reduction in total leaf area in mustard. Levy and Kedar (1970) reported that among the various concentrations of ethrel studied (500, 1 000, 5000 and 10,000 ppm) higher concentrations of ethrel resulted in reduced leaf area. Similarly Lee and Reid (1997) reported that higher doses of ethephon reduced the leaf area of *Helianthus annus.*

The present study also revealed that application of cycocel and ethrel at 250 and 500ppm along with the micronutrient mixture(Fe+Zn+Mn+B at 0.1%, 0.05% and 0.01% each) recorded comparatively lower specific leaf area whereas the application of NPK as per POP along with micronutrient mixture (Fe+Zn+Mn+B at 0.1% each) resulted in highest shoot weight in sweet potato

5.1.5 Tuber length, Tuber diameter and Tuber weight

Among various treatments, higher tuber length, tuber diameter and tuber weight were obtained in plants under the treatment T15 (T3+ CCC 500 ppm CCC 500ppm) and was on par with T13 (T3+ Ethrel 500 ppm CCC 500ppm). Lowest tuber length, tuber weight and tuber diameter were recorded in plants under the treatment C1 and was on par with C2. Micronutrients along with growth regulators resulted in higher tuber length, girth and weight. Micronutrients have important role in photosynthesis and other metabolic activities such as cell division and elongation which result in better tuberization (Teiz and Zeiger, 2006). Goyal *et al.* (2017) reported that (Zn 0.5%) followed by T8 (Zn 0.5% + Mn 1.0% + B 0.25% + Cu 1.0%) significantly increased bulb diameter and fresh weight in onion.

Velayudham and Parthibham (2013) reported that CCC 500 ppm recorded the highest length and girth of primary and secondary rhizomes as well as highest rhizome fresh weight value of 226.36 g per plant in Ginger . Hejjegar *et al.* (2018) reported that CCC 500 ppm recorded highest tuber diameter, tuber length as well as number of tubers per vine in sweet potato.The reduced vegetative growth due to the application of cycocel increased the production of sizable rhizomes. Similar findings were reported by Nambiar *et al.* (1976) and Vahab and Kumaran (1980) in sweet potato and Phogat and Singh (1987) in ginger. Enhanced photosynthetic activity as well as improved translocation of photosynthates to the developing rhizomes result in higher rhizome length, weight and diameter. Similar findings were also reported by Sarkar and Sarma (2008) and Shedge *et al.* (2008) in sweet potato. Cycocel inhibit GA biosynthesis and enhance allocation of photo assimilates to tuber portions.

Ethrel inhibit the vegetative and apical growth and result in allocation of more photosynthates from vegetative organs to tuber or under ground economic parts (Raafat and Kuehn, 1975). Levy and Kedar (1970) reported higher bulb girth and

weight in onion with the foliar spray of ethrel at 500 and 1000ppm. Similarly ethrel (250 ppm) treatment increased the tuber weight in potato(Ravindra *et al.*, 2016).

The present study also revealed that application of cycocel and ethrel at 500ppm along with the micronutrient mixture (Fe+Zn+Mn+B at 0.1% each) resulted in highest tuber length, tuber diameter and tuber weight in sweet potato.

5.1.6 Tuber yield

Among various treatments highest tuber yield was obtained in plants under the treatment T15 (T3+ CCC 500 ppm at 30 DI) and was on par with T13 (T3+ Ethrel 500 ppm at 30 DI). The lowest tuber yield was recorded in plants under the treatment C1 and was on par with C2. Micronutrients favours higher enzymatic activity as well as photosynthesis which in turn result in translocation of more photosynthates to seed (Teiz and zeiger, 2006). Zeidan *et al.* (2006) reported highest yield in lentil due to the foliar application of micronutrients .Similarly Janket *et al.* (2018) reported highest yield in cassava due to foliar application 2% $ZnSO_4$. Similar results were also reported by El-Baky *et al.* (2010) in sweet potato due to the foliar spray of zinc. Echer *et al.* (2009) reported maximum sweet potato yield with the combined application of boron and potassium.

Velayudham and Parthibham (2013) reported that foliar application of CCC 500 ppm recorded highest rhizome yield of 26.08 tonnes per hectare in ginger. Application of CCC 500ppm resulted in highest number of rhizomes, highest length and girth of rhizomes as well as higher yield in ginger. Similar findings were also reported by Banerjee and Das (1984) and Sarkar and Singh (1984) in potato, Vijayakumar and Abdhul Khader (1986) in cassava, Mishra *et al.* (1987) in sweet potato. Sarkar and Sarma (2008) and Shedge *et al.* (2008) reported highest tuber yield in sweet potato by the application of CCC 500 ppm

Sanmugam and Sanmugavelu (1974) reported that 250 and 500 ppm ethrel increased the yield about 17.87 % and 20.3% resectively in tapioca. Higher tuber

T15

T13

C1

Plate 3. Treatments with higher yield (T15 and T13) and lower yield(C1)

yield with ethrel is mainly due to redistribution of assimilates to sink or due to enhancement of sink capacity of roots (Ramos *et al.*, 1989). Burg (1968) reported that the production of ethylene near the meristematic tissues lead to increased cell division rather than enlargement of tubers. Enhanced cell division result in increased yield of tubers. Similarly Vahab and Kumaran (1980) reported maximum tuber yield in sweet potato with the application of ethephone at 450 ppm and 300ppm. Nagwa *et al.* (2013) reported higher bulb yield in onion with the foliar application of ethrel (100ppm).

The present study also revealed that application of cycocel (500ppm) as well as ethrel (500ppm) along with the micronutrient mixture (Fe+Zn+Mn+B at 0.1% each) resulted in highest tuber yield in sweet potato. Fig. 2 reveals the effect of micronutrient, cycocel and ethrel on tuber yield and among the various treatments T15 (16.35 t ha^{-1}) was found to be the best in terms of tuber yield and was on par with T13 (16.13 t ha^{-1}). Fig. 3 reveals that the percentage increase in tuber yield as compared with the control (C1). There was about 36.93% and 35.59% increase in tuber yield recorded in T15 and T13 respectively compared to control.

5.2 PHYSIOLOGICAL PARAMETERS

5.2.1 Photosynthetic pigments

In all the treatments there was significant increase in total chlorophyll and caroteinoid content observed from 25th ,50th and 75th DAP and there was a reduction in these pigments at 100th DAP. Total chlorophyll and caroteinoid of the leaves were found to be higher in plants under the treatment T15 (T3+ CCC 500 ppm at 30 DI) and was on par with T13(T3+ ethrel 500 ppm at 30 DI) at all the stages of observation and lowest total chlorophyll content was recorded in plants under the treatment C1 and was on par with C2.

Application of micro nutrients results in enhancement of chlorophyll biosynthesis. Among the micronutrients, iron has important role in the synthesis of

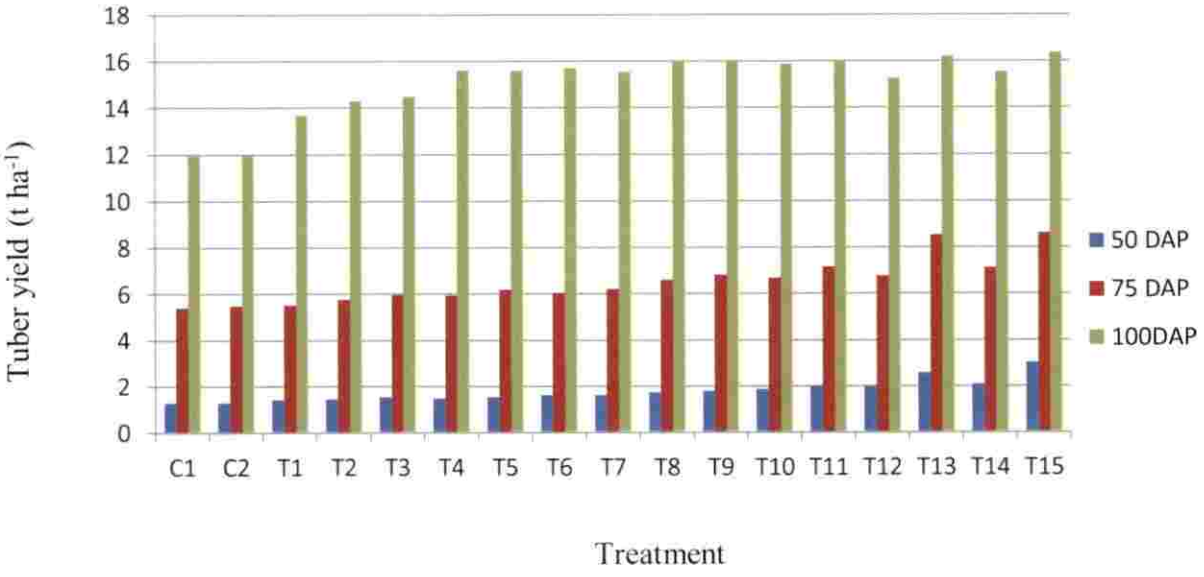


Fig. 2 Effect of micronutrients, cycocel and ethrel on tuber yield(t ha^{-1})

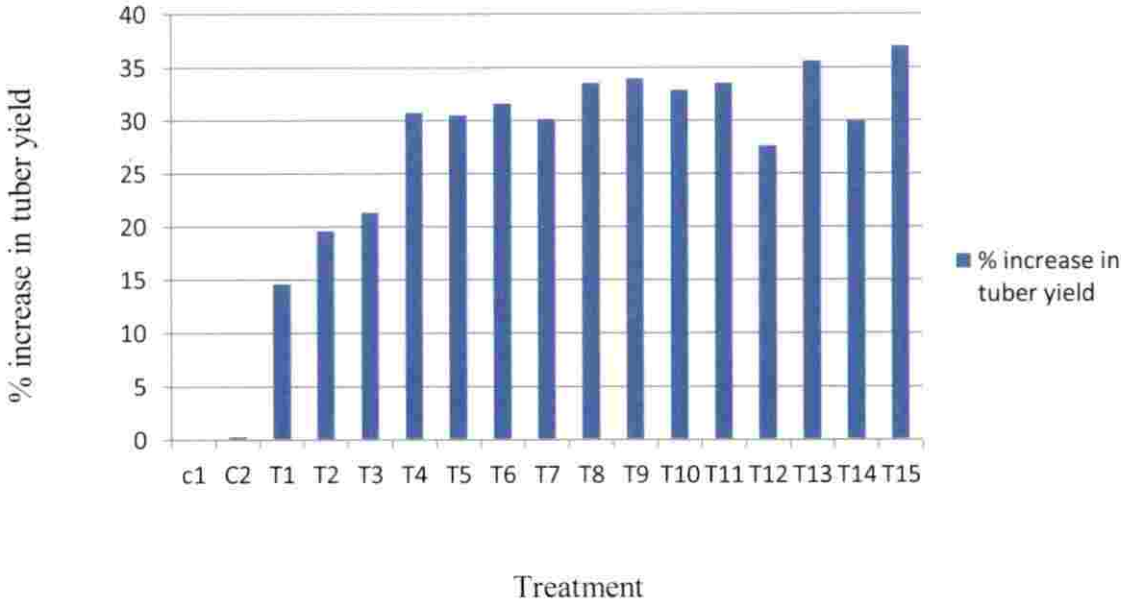


Fig. 3 Effect of micronutrients, cycocel and ethrel on yield on %increase in yield

chloroplastic protein. In addition to this manganese also has important role in chlorophyll synthesis. Meng *et al.* (2004) noticed that foliar spray of micronutrient solution (Mn, Cu, B, Mo and Cu) increased chlorophyll content of the leaves of potato. Lakshmipathi *et al.* (2018) reported that combined treatment of ZnSO4 (0.5%) + borax (0.1%) at flushing, flowering as well as fruiting stage of cashew produced higher total chlorophyll and caroteinoid in the leaves. Similarly Manas *et al.* (2014) reported that the combined treatment of HA(0.5%), +Zn(0.5%), +B(0.2%), gave maximum chlorophyll content in cassava.

Srivastava and Goswami (1988) reported that CCC delay senescence, arrest chlorophyll degradation and there by enhance chlorophyll content. Cycocel and ethrel enhance chlorophyll biosynthesis through acceleration of chloroplasts differentiation. Anti-transpirants are highly effective in chlorophyll biosynthesis by the enhanced activity of high Rubisco (Teiz and Zeiger, 2006). Devi *et al.* (2011) reported that maximum chlorophyll and carotenoid contents were observed in soyabean treated with cycocel 500ppm. Imbamba (1973) reported that foliar application of cycocel resulted in increased chlorophyll content in soyabean. Grewal and Kolar (1990) reported that cycocel 250 and 500 ppm increased the chlorophyll content of *Brassica napus* leaves. Similarly increased chlorophyll content with the application of cycocel was reported by Parkash and Ramachandran (2000) in brinjal.

Ethrel at 500ppm significantly increased the chlorophyll content in leaves of mustard Grewal and Kolar (1993). Bhattacharyya (1990) also noticed an increase in chlorophyll content in *Coleus parviflorus* with the application of ethrel. At harvest stage, chlorophyll content reduce due to the chloroplast breakdown by the application of ethrel and cycocel because both ethrel and cycocel inhibit cytochrome P450 dependent hydroxylation reactions in the chlorophyll biosynthesis which result in chloroplast breakdown as well as leaf senescence. Ouzounidou *et al.* (2011) reported that chlorophyll a+b content reduced by ethephon treatment in both onion(14%) and garlic(23%) at final stage of growth.

The present study also revealed that application of cycocel and ethrel at 500ppm along with the micronutrient mixture(Fe+Zn+Mn+B at 0.1% each) recorded highest total chlorophyll and caroteinoid content in sweet potato.

5.2.2 Stomatal conductance

In all the treatments there was significant increase in stomatal conductance observed from 25th 50th and 75th DAP and there was a reduction in stomatal conductance at 100th DAP. Stomatal conductance of the leaves was found to be higher in plants under the treatment T15(T3+ CCC 500 ppm at 30 DI) and was on par with T13(T3+ ethrel 500 ppm at 30 DI) at 25th 50th and 75th DAP. T15(T3+ CCC 500 ppm at 30 DI) was on par with T13(T3+ ethrel 500 ppm at 30 DI), T14(T3+ CCC 500 ppm at 30 DI), T12(T3+ ethrel 250 ppm at 30 DI), T3 (C1+ FN (MN mixture(*) 0.1% each at 30DI) and T2 (C1+ FN (MN mixture(*) 0.05% each at 30DI) at 100DAP and the lowest stomatal conductance was recorded in plants under the treatment C1 and C2 .It was observed that highest photosynthetic rate in all of the above mentioned treatments resulted in maximum stomatal conductance of the leaves.

Lakshmipathi *et al.* (2018) reported that foliar application of ZnSO4 (0.5%) + borax (0.1%) recorded higher stomatal conductance in cashew due to their positive influence on leaf area. Similarly Thirupathaiah *et al.* (2017) reported maximum stomatal conductance (0.20 mol m^{-2} S^{-1}) in sapota due to the foliar application of $ZnSO_4$ (0.5%). Ethrel and cycocel increased the number of stomata as well as stomatal conductance by the production of more number of leaves. Imbamba (1973) reported that foliar application of cycocel increased the number of stomata per unit area as well as the stomatal conductance in cowpea.

The present study also revealed that application of cycocel and ethrel at 500ppm along with the micronutrient mixture (Fe+Zn+Mn+B at 0.1% each) recorded highest stomatal conductance in sweet potato .

5.2.3 Photosynthetic rate

In all the treatments there was significant increase in photosynthetic rate observed from 25th 50th and 75th DAP and there was a reduction in photosynthetic rate at 100th DAP. Photosynthetic rate of the leaves was found to be higher in plants under the treatment T15 (T3+ CCC 500 ppm at 30 DI) and was on par with T13 (T3+ ethrel 500 ppm at 30 DI) in all the stages of observation and the lowest photosynthetic rate was recorded in plants under the treatment C1 and was on par with C2.

Micronutrients (Fe, Mn, Zn and B) are cofactors of many of the enzymes involved in photosynthesis and among the micronutrients viz. Fe, Mn, Zn and B plays major role in photosynthetic electone transport chain in the dark reaction. Fe has important role in activation of several enzymes which are involved in the oxidation or reduction processes involved in photosynthesis as well as respiration (Ram and Bose, 2000). Zn has important role in the structure of Rubisco, and it also activates several biochemical reactions involved in the photosynthetic metabolism (Brown *et al.,* 1993; Alloway, 2008); Tsonko and Lidon, 2012). Manganese (Mn) participate in photolysis of water in the photosystem II and it result in the release of an electron needed for electrone transport system and hence it has important role in photosynthesis (Millaleo *et al.,* 2010a). Overall all the micronutrients enhance the photosynthetic rate in plants. Lakshmipathi *et al.* (2018) reported that foliar application of $ZnSO_4$ (0.5%) + borax (0.1%) gave maximum leaf area which resulted in higher photosynthetic rate in cashew. Similar findings were reported by Nunez *et al.* (1998); Zoffoli *et al.,* 2009 and Zahoor *et al.,* 2011) also. Similarly Thirupathaiah *et al.* (2017) reported that foliar application of $ZnSO_4$ (0.5%) + $FeSO_4$ (0.5%) + boron (0.3%) recorded maximum photosynthetic rate (12.52 mol CO_2 m^{-1} S^{-1}) in sapota.

Ethrel and cycocel increase the photosynthetic rate by means enhancement of chlorophyll biosynthesis through the acceleration of chloroplasts differentiation and stimulation of photosynthetic enzymes which lead to higher photosynthetic rate. Also the growth retardants are reported to increase the number of branches as well as number of leaves in plants which in turn increase the photosynthetic rate. Imbamba (1973) reported that foliar application of cycocel could increase the photosynthetic rate in cowpea. Pahwa (2013) reported that foliar application of ethrel increased the stomatal conductance and photosynthetic rate in pigeon pea.

The present study also revealed that the application of cycocel and ethrel at 500ppm along with the micronutrient mixture (Fe+Zn+Mn+B at 0.1% each at 30 DI) recorded highest photosynthetic rate in sweet potato.

5.2.4 Transpiration rate and Water use efficiency

In all the treatments there was significant increase in traspiration rate observed from 25th 50th and 75th DAP and there was a higher reduction in traspiration rate at 100th DAP. Traspiration rate was found to be higher in plants under the treatment C1(T3+ CCC 500 ppm at 30DI) and it was at par with C2, T1 and T2 and 73 in all the stages. Whereas lower transpiration rate was observed in plants under the treatment T15(T3+ CCC 500 ppm at 30 DI) and was on par with T13 (T3+ ethrel 500 ppm 30 DI). Water use efficiency was found to be higher in plants under the treatment T15 (T3+ CCC 500 ppm at 30 DI) and it was at par with T13 (T3+ ethrel 500 ppm at 30 DI),T14(T3+ CCC 250 ppm at 30 DI) and T12 (T3+ ethrel 250 ppm at 30 DI). Lowest water use efficiency was recorded in plants under the treatment C1 and was on par with C2.

Cycocel and ethrel are growth retardants which reduce the transpiration rate by closure of stomata and also their application result in reduced leaf area (Luoranen *et al.,* 2002). Though foliar application of cycocel and ethrel along with micronutrients could enhance the number of leaves it influence reduction of leaf area.

With higher concentration of cycocel and ethrel internodal length as well as overall length of vine get reduced due to the less exposure of leaf area to the sunlight for transpiration and this in turn increase the water use efficiency (Luoranen *et al.,* 2002)

The present study also revealed that the application of cycocel and ethrel at 500ppm along with the micronutrient mixture (Fe+Zn+Mn+B at 0.1% each at 30 DI) was recorded lowest transpiration rate and highest water use efficiency in sweet potato.

5.3 QUALITY PARAMETERS

5.3.1 Mineral constituents

Among the various treatments, higher mineral constituents (N, P, K, Fe, Zn, Mn and B) in tubers was obtained in plants under the treatment T15 (T3+ CCC 500 ppm at 30DI) followed by T13 and the lowest mineral content was observed in plants under the treatment C1.

Foliar application of micronutrients influence higher nutrient uptake. Similarly foliar application of cycocel and ethrel also helps in higher nutrient uptake, nutrient availability, better transport and allocation of nutrients to the reproductive organs. Combined foliar application of Cu, Zn and Mn increased Cu, Zn and Zn content in winter wheat grain (Bameri *et al.,* 2012). Wang *et al.* (2015) reported that foliar application of Zn increased the Fe concentration in winter wheat. Pahlavan and Pessarakli (2009) reported that foliar application of Zn increased Zn content and Fe content in the wheat grain by 99% and 8%, respectively. Narwal *et al.* (2012), reported that the foliar application of Mn increased the Mn content in wheat grain by 7% . Zhang *et al.* (2012b) reported that foliar application of 0.4% $ZnSO_4$ increased the Zn content(58%) in the wheat grain.

Foliar application of cycocel enhance the traslocation of nutrients from leaf. The increase in nutrient status of plants is mainly due to the changes in endogenous growth substances (cytokinins, auxins and abscisic acid) or increased antioxidant

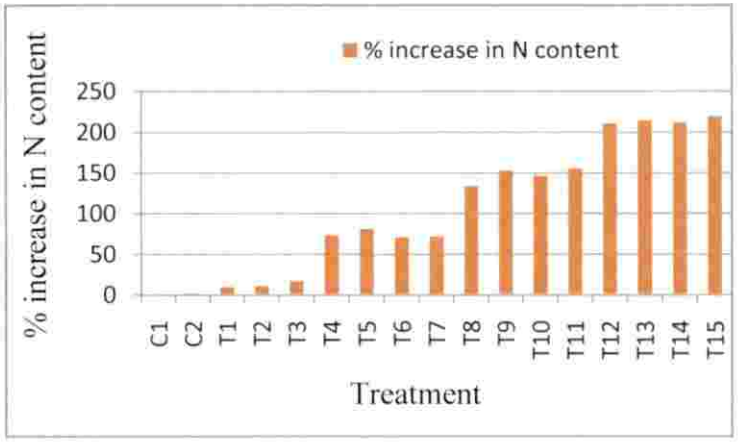
activity due to exogenous application of growth regulators. Cycocel influence high initial vigour and crop growth which ultimately lead to higher nutrient uptake and increased nutrient availability to the plants (Shedge *et al.*, 2008).

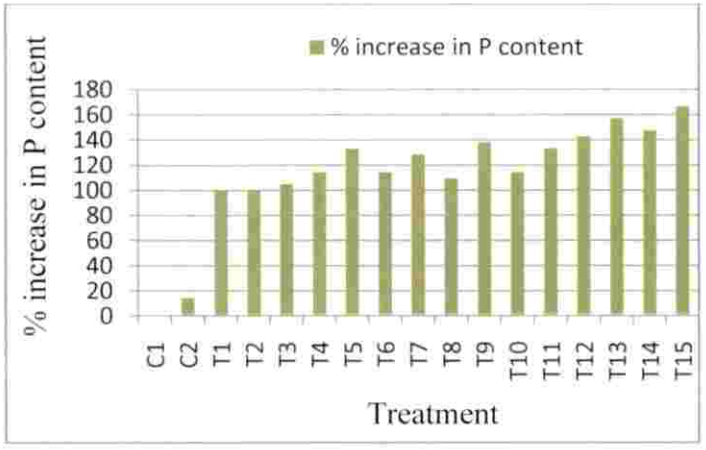
The present study also revealed that application of cycocel at 500ppm along with the micronutrient mixture (Fe+Zn+Mn+B at 0.1% each at 30 DI) resulted in the highest mineral constituents in sweet potato. Fig. 4 & 5 shows the percentage increase of mineral constituents in tubers compared to control and among the various treatments, T15 was found to be the best in terms of mineral constituents in tubers and there was about two fold increase in mineral constituents recorded in the treatment (T15) compared with control (C1)

5.3.2 Total phenol, total sugar and protein content

Among the various treatments, highest total phenol, total sugar and protein content in tubers were recorded in plants under the treatment T15 (T3+ CCC 500 ppm at 30DI) followed by T13 and the minimum value was recorded in plants under the treatment C1 and was on par with C2.

Micronutrients along with growth regulators improve the total phenol ,total sugar and protein content in tubers. Miconutrients have important role in the biosynthesis of protein and sugar. Also higher phenol content in tuber is observed due to the application of micronutrients.. Among the micronutrients, boron has an important role in translocation of sugars from source to sink (Gauch and Dugger, 1953). Boron also complexes phenol and results in increased phenol content (Lee and Arnoff, 1967). In addition to this, boron also favours protein synthesis. Fe has important role in protein metabolism and Zn activates many of the enzymes that are involved in carbohydrate metabolism and protein synthesis (Marschner, 2012). Mn also is reported to have important role in biosynthesis of amino acid (tyrosine) and protein (Lidon *et al.,* 2004). Manas *et al.* (2014) reported that combined application





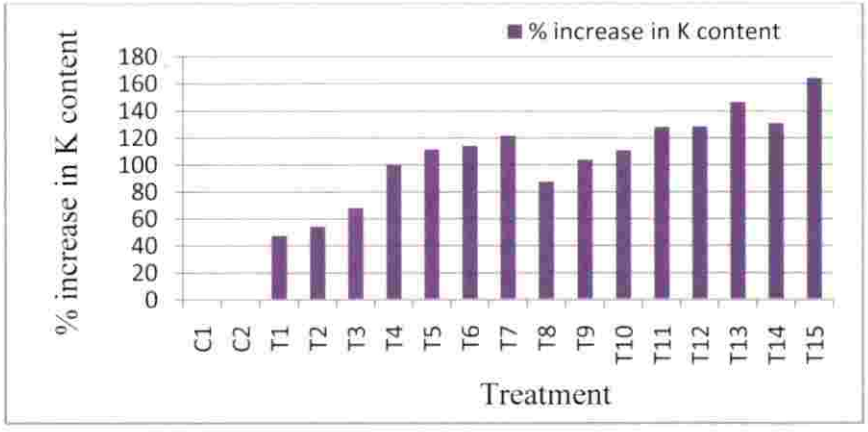
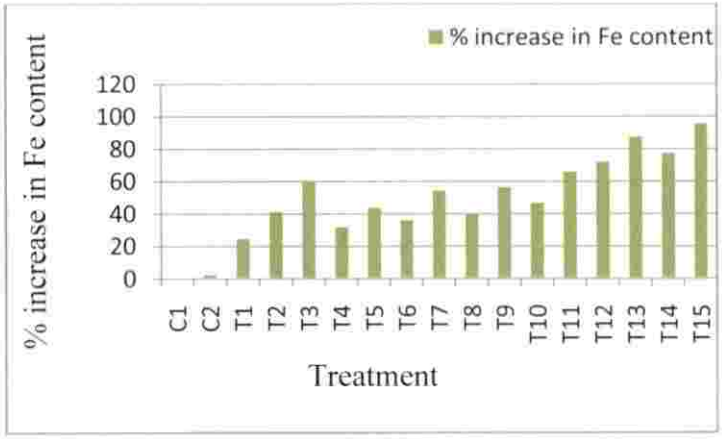
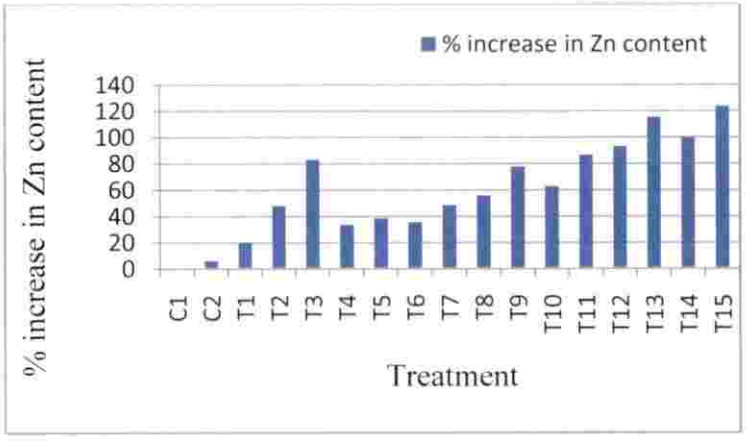
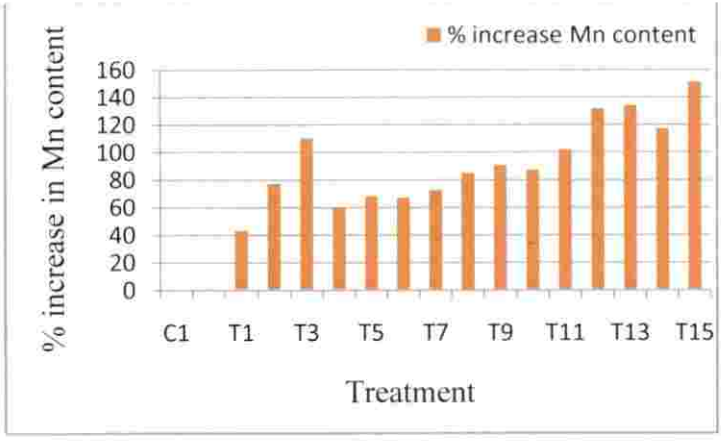


Fig 4. Effect of micronutrients, cycocel and ethrel on % increase in N , P and K content in tuber







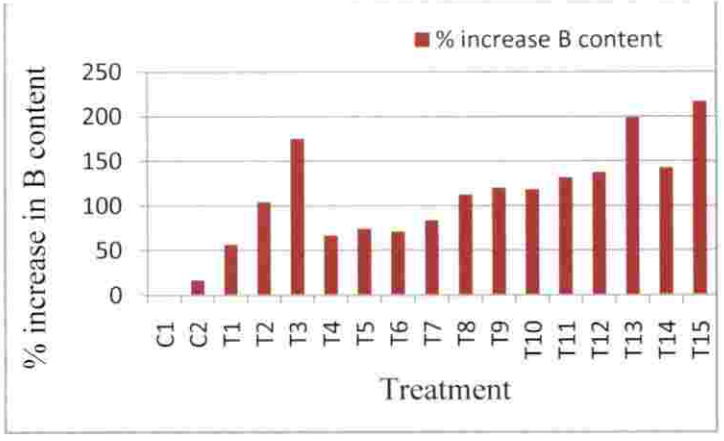


Fig 5. Effect of micronutrients, cycocel and ethrel on % increase in Fe, Zn Mn, and B content in tuber

of HA (0.5%)+ Zn (0.5%), HA (0.5%)+ Zn(0.5%)+B (0.2%) and Zn(0.5%) +B (0.2%) increased the total sugars and protein content in pepper.

Similarly cycocel and ethrel has important role in translocation of these compounds from leaves to the tubers. Hence their application results in higher total sugar ,protein and phenol in the reproductive organs or economic part due to the increased translocation of photosynthates from the leaves. In addition to these, their effect on increased chlorophyll content in leaf also help in higher photosynthetic activity as well as sink capacity of crops. Lesser vegetative growth due to growth retardants help in better utilization of nitrogen for the biosynthesis of carbohydrates and protein and their effective translocation from the source to sink (Mishra *et al,* 1987). CCC also promotes the synthesis of soluble protein and enzymes (Srivastava and Goswami, 1988). Plant growth retardants significantly increase the protein content in crop plants (Yang *et al.,* 1994; Kulkarni *et al.,* 1993). They also control the allocation of protein and its accumulation in developing cereal grains (Oritant and Yoshida, 1971). Ibrahim *et al.* (2001) reported higher protein content in cycocel treated maize seedlings. Devi *et al.* (2011) reported that cycocel 500ppm recorded higher protein content in soyabean. CCC also enhance the sucrose synthesis, via stimulation of sucrose synthetase enzyme. Sarkar (2008) reported that foliar application of GA3 @ 500 ppm and CCC @ 1000 ppm increased the reducing sugars and starch content in sweet potato tubers. Sharifi *et al.* (2016) reported that foliar application of cycocel has shown positive influence on polyphenol oxidase (PPO) enzymes and hence higher phenol content in wheat. Mahajan *et al.* (2008) reported a positive effect of 750ppm ethrel spray on the sugar content in guava. Similarly Marriot (1980) reported higher sugar content in banana with the application of ethrel 500ppm. Wang *et al.* (2013) reported that preharvest foliar applicatios of ethephon increased the skin and cortex phenolic content in storage roots of sweet potato.

The present study also revealed that application of cycocel at 500ppm along with the micronutrient mixture (Fe+Zn+Mn+B at 0.1% each at 30 DI) resulted in the

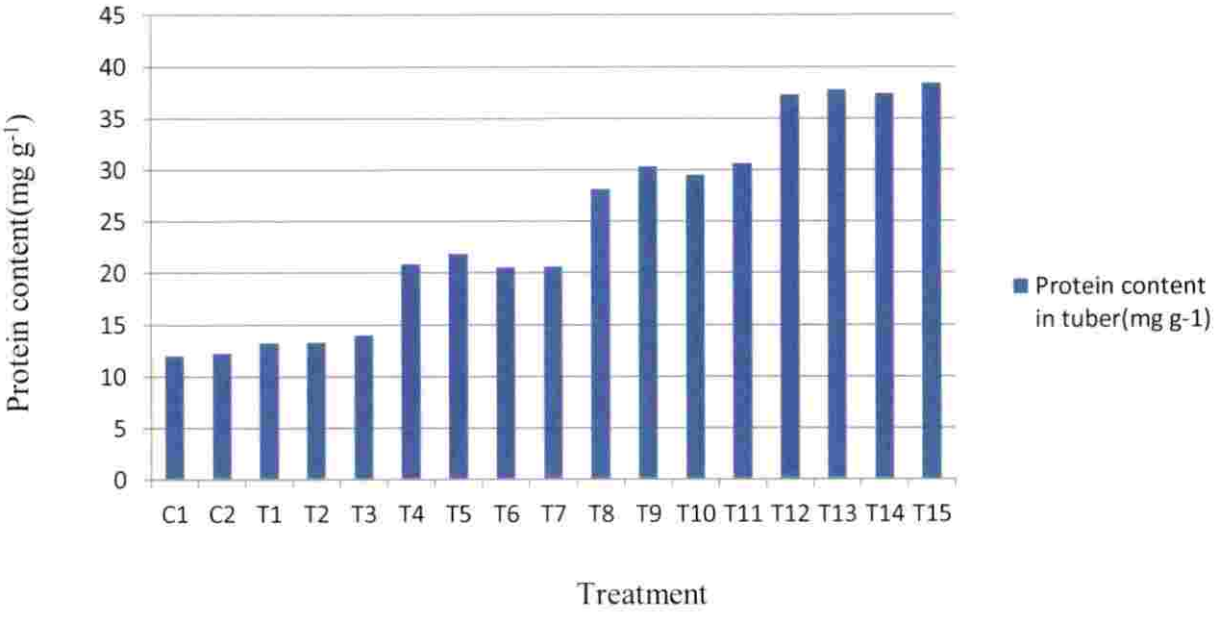


Fig. 6 Effect of micronutrients, cycocel and ethrel on protein content in tuber (mg g^{-1})

highest total phenol, total sugar and protein content in sweet potato tubers. Fig. 6 reveals the effect of micronutrient, cycocel and ethrel on protein content in tubers and among the various treatments T15 was found to be the best treatment in terms of protein content (38.4 mg g^{-1}) of tubers.

It shows that combined treatments of micronutrient mixture (Fe, Zn, Mn and B) and growth regulators (cycocel and ethrel) were more effective in enhancing the qualitative parameters (total phenol, total sugar and protein content) rather than application of micronutrient mixture alone. Among the growth regulators, application of cycocel was found to be the best in terms of improving quality attributes of the sweet potato tubers due to the high allocation capacity of photosynthates and nutrients to the tubers.

Summary

6. SUMMARY

A field experiment entitled "Effect of foliar application of selected micro nutrients and growth regulators on tuber development, yield and fortification status of sweet potato (*Ipomoea batatas* L.)" was conducted at Instructional Farm, College of Agriculture, Vellayani during the period 2017-2019. The sweet potato variety used for the experiment was Bhu Krishna. The technical programme consisted of 17 treatments and 3 replications with the design simple RBD. The treatments were **C1** : NPK (as per POP) , **C2** : NPK (as per POP) with water spray, **T1 :** C1+ FN (MN mixture(*) 0.01% each , **T2 :** C1+ FN (MN mixture(*) 0.05% each , **T3 :** C1+ FN (MN mixture(*) 0.1% each , **T4 :** T1+ Ethrel 250 ppm , **T5 :** T1+ Ethrel 500 ppm , **T6 :** T1+ CCC 250 ppm , **T7 :** T1+ CCC 500 ppm , **T8 :** T2+ Ethrel 250 ppm , **T9 :** T2+ Ethrel 500 ppm , **T10:** T2+ CCC 250 ppm , **T11:** T2+ CCC 500 ppm, **T12:** T3+ Ethrel 250 ppm , **T13:** T3+ Ethrel 500 ppm , **T14:** T3+ CCC 250 ppm and **T15:** T3+ CCC 500 ppm [MN mixture (*) : (Zn+Fe+B+Mn)]. Except C1, for all other treatments foliar sprays were given three times at 30 days interval (30 DI). All the biometric and physiological parameters were taken at 25th, 50th, 75th and 100th days after planting (DAP) and the quality parameters were taken at harvest. Observations on biometric parameters, physiological parameters and quality parameters with the different treatments are tabulated, statistically analysed and presented in this chapter.

The results revealed that the micronutrients and growth regulators had significant influence on most of the biometric parameters, physiological parameters as well as quality parameters. Application NPK as per POP along with micronutrient mixture (Zn+Fe+B+Mn @ 0.1% each) followed by 0.05 % each and 0.01% each resulted in higher shoot length, number of leaves, shoot weight and specific leaf area (SLA). Highest branch length (155.50cm), shoot weight (612 g) and specific leaf area (389.44 cm^2 g^{-1}) were recorded in plants under the treatment T3 (C1+ FN (MN mixture(*) 0.1% each at 30DI). The number of leaves also were found to be higher in T3 (91.33) and it was at par with T2, T13 and T15. Cycocel and ethrel are growth

retardants and they were found to have dwarfing effect on plants and hence shoot length and shoot weight did not increase in the treatments T15(T3+ CCC 500at 30DI) and T13(T3+ Ethrel 500 ppm at 30DI) and on the other hand the number of leaves increased in both these treatments T15 and T13.

The present study also revealed that application of NPK as per POP along with micronutrient mixture (Zn+Fe+B+Mn @ 0.1% each) and cycocel (500ppm) as well as ethrel (500ppm) resulted in better tuber characters and yield in sweet potato. Tuber characters such as tuber length (13.13cm), tuber diameter (4.71cm), tuber weight (196.17g) and tuber yield (16.35 t ha^{-1}) were found to be the best in plants under the treatment T15 (T3+ CCC 500 ppm at 30DI) and it was on par with T13 (T3+Ethrel 500ppm). Due to the higher allocation capacity of photosynthates, cycocel and ethrel are found to have better role in improving tuber characters.

Except transpiration rate all other physiological parameters studied *viz*., total chlorophyll content (2.25 mg g^{-1}), caroteinoid content (0.87mg g^{-1}), stomatal conductance (131.33 mmole H_2O m^{-2} s^{-1}), photosynthetic rate (4.49 µmole CO_2 m^{-2} s^{-1}) and water use efficiency (5.35 mmol CO_2 mol^{-1} H_2O) were found to be best in plants under the treatment T15 (T3+ CCC 500 ppm) and T13 was on par with T15. Combination treatments of NPK as per POP along with micronutrient mixture [(Fe+Zn+Mn+B @ 0.1%, 0.05% and 0.01% each] as well as growth regulators [cycocel (250ppm and 500ppm) and ethrel (250ppm and 500ppm)] were found effective in improving all major physiological parameters compared to the treatments without combining growth regulators. Among the treatments NPK as per POP along with micronutrient mixture (Fe+Zn+Mn+B 0.1% each) and growth regulators [cycocel (500ppm) as well as ethrel (500ppm)] showed best results for the physiological parameters.

The present study also revealed that application of NPK as per POP along with micronutrient mixture (0.1% each at 30 DI) and cycocel (500ppm) resulted in

significantly higher mineral constituents, total phenol, total sugar and protein content in sweet potato tubers. Mineral contents of tubers viz., N (0.614 %), P (0.056%), K (0.489%),Fe (16.30mg kg^{-1}), Zn (15.07mg kg^{-1}), Mn (7.37 mg kg^{-1}) and B (1.27 mg kg^{-1}) as well as other quality parameters like total phenol (13.33mg g^{-1}), total sugar (34.48 mg g^{-1}) and protein content (38.40mg g^{-1}) were found maximum in tubers under the treatmentT15 (T3+ CCC 500 ppm) followed by treatment T13 .

Compared to treatments with NPK as per POP along with micronutrient mixture (Fe+Zn+Mn+B @ 0.1%, 0.05% and 0.01% each) alone without any growth regulators, the combined treatments of NPK as per POP along with micronutrient mixture (Fe+Zn+Mn+B @ 0.1%, 0.05% and 0.01% each) and growth regulators (cycocel and ethrel each at 500ppm) were found more effective in enhancing the qualitative parameters (mineral constituents, total phenol, total sugar and protein content). Among the micronutrient mixtures (Fe+Zn+Mn+B 0.1% each) and among the growth regulators, cycocel (500ppm) were found as best in terms of improving quality attributes of the sweet potato tubers due to the high allocation capacity of photosynthates and nutrients to the tubers.

Overall plants under the treatment T15 (ie.NPK as per POP along with foliar nutrition of micronutreint mixture (Fe+Zn+Mn+B @ 0.1% each) + cycocel (500ppm) at 30 days interval) was found to be the best in terms of improving both the quantitative and qualitative attributes in sweet potato. Hence it is concluded that the treatment T15 (ie., NPK as per POP along with foliar nutrition of micronutrient mixture (Fe+Zn+Mn+B @ 0.1% each) + cycocel (500ppm) at 30 days interval) improved the growth and development of plants, physiological parameters of leaves, tuber yield as well as fortification status of sweet potato tubers. Thus this study helped in identifying the best treatment combination of micronutrients and growth regulators for improving growth, development, yield and fortification status in sweet potato.

FUTURE LINE OF WORK

Assessment of the influence of NPK foliar sprays on sweet potato yield and quality are to be studied.Climate resilience studies can be done in sweet potato and through this the influence of temperature on tuberization can be studied.

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Appendices

APPENDIX I

B:C ratio

Treatments	Gross returns (Rs ha^{-1})	Cost of cultivation(Rs ha^{-1})	B:C ratio
C1	477600.00	420751.6	1.14
C2	478800.00	420751.6	1.14
T1	547200.00	433006.5	1.26
T2	571200.00	441176.5	1.29
T3	579600.00	449346.4	1.29
T4	624400.00	486111.1	1.28
T5	623200.00	488153.6	1.28
T6	628400.00	482026.1	1.30
T7	621600.00	494281.0	1.26
T8	637600.00	496323.5	1.28
T9	639600.00	490196.1	1.30
T10	634400.00	492238.6	1.29
T11	637600.00	502451	1.27
T12	609600.00	504493.5	1.21
T13	647600.00	498366	1.30
T14	620800.00	500408.5	1.24
T15	654000.00	500408.5	1.31

APPENDIX II

Harvest Index

Treatments	Economic Yield (kg ha^{-1})	Biological yield(kg ha^{-1})	Harvest index
C1	11940	52440	0.228
C2	11970	52720	0.227
T1	13680	63765.83	0.215
T2	14280	64710.83	0.221
T3	14490	65490	0.221
T4	15610	58376.67	0.267
T5	15580	57949.17	0.269
T6	15710	57640.83	0.273
T7	15540	58009.17	0.268
T8	15940	58437.5	0.273
T9	15990	58384.17	0.274
T10	15860	58629.17	0.271
T11	15940	58531.67	0.272
T12	15240	58429.17	0.261
T13	16190	59237.5	0.273
T14	15520	58934.17	0.263
T15	16350	59427.5	0.275

APPENDIX III

Anthrone reagent

Anthrone reagent made by dissolving 200 mg of anthrone in 100 ml ice cold 95 percent concentrated sulphuric acid.

EFFECT OF FOLIAR APPLICATION OF SELECTED MICRONUTRIENTS AND GROWTH REGULATORS ON TUBER DEVELOPMENT, YIELD AND FORTIFICATION STATUS OF SWEET POTATO (*Ipomoea batatas* L.).

by

ARYA S. R

(2017-11-146)

ABSTRACT

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF PLANT PHYSIOLOGY
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM - 695 522
KERALA, INDIA

2019

ABSTRACT

A field experiment entitled " Effect of foliar application of selected micro nutrients and growth regulators on tuber development, yield and fortification status of sweet potato (*Ipomoea batatas* L.)" was conducted at the Instructional farm, College of Agriculture, Vellayani during the period 2017-2019 with an objective to enhance the qualitative and quantitative attributes in sweet potato (*Ipomoea batatas* L.). Foliar application of selected micronutrients and growth regulators were carried out to study their effect on growth, development and changes in fortification status of sweet potato tubers and leaves. The sweet potato variety used for the experiment was Bhu Krishna. The technical programme consisted of 17 treatments and 3 replications with the design simple RBD. The treatments were **C1** : NPK (as per POP) , **C2** : NPK (as per POP) with water spray, **T1 :** C1+ FN (MN mixture(*) 0.01% each , **T2 :** C1+ FN (MN mixture(*) 0.05% each , **T3 :** C1+ FN (MN mixture(*) 0.1% each , **T4 :** T1+ Ethrel 250 ppm , **T5 :** T1+ Ethrel 500 ppm , **T6 :** T1+ CCC 250 ppm , **T7 :** T1+ CCC 500 ppm , **T8 :** T2+ Ethrel 250 ppm , **T9 :** T2+ Ethrel 500 ppm , **T10:** T2+ CCC 250 ppm , **T11:** T2+ CCC 500 ppm, **T12:** T3+ Ethrel 250 ppm , **T13:** T3+ Ethrel 500 ppm , **T14:** T3+ CCC 250 ppm and **T15:** T3+ CCC 500 ppm [*MN mixture (Zn+Fe+B+Mn)]. Except C1, for all other treatments foliar sprays were given 3 times ie. at 30 days interval(30 DI). All the biometric and physiological parameters were taken at 25^{th},50^{th},75^{th} and 100^{th} days after planting and the quality parameters were taken at harvest.

The results revealed that the micronutrients and growth regulators had significant influence on most of the biometric parameters, physiological parameters as well as quality parameters. Tuber characters such as tuber length, tuber diameter, tuber weight and tuber yield were found to be best in plants under the treatment T15 (T3+ CCC 500 ppm at 30DI) and it was on par with T13(T3+Ethrel 500ppm). Branch length (155.50cm), shoot weight (612 g) and specific leaf area (389.44 cm^2 g^{-1}) were found to be best in plants under the treatment T3(C1+ FN (MN mixture(*) 0.1% each at 30DI). Number of leaves also were found to be higher in T3 (91.33) and it was on par with T2, T13 and T15. Cycocel and ethrel are growth retardants and they were found to have dwarfing effect on plants and hence shoot length and shoot weight did not increase in the treatments, T15(T3+ CCC 500at 30DI) and T13(T3+ Ethrel 500 ppm at 30DI)

and on the other hand the number of leaves got positively influenced in both these treatments T15 and T13.

Except transpiration rate all physiological parameters *viz*., total chlorophyll content (2.25 mg g^{-1}), caroteinoid content (0.87mg g^{-1}), stomatal conductance (131.33 mmole H_2O m^{-2} s^{-1}), photosynthetic rate (4.49 µmole CO_2 m^{-2} s^{-1}) and water use efficiency (5.35 mmol CO_2 mol^{-1} H_2O) were found to be best in plants under the treatment T15 (T3+ CCC 500 ppm) and T13 was on par with T15 in all these physiological parameters studied.

Mineral constituents; N (0.614 %), P (0.056%), K (0.489%),Fe (16.30 mg kg^{-1}), Zn (15.07 mg kg^{-1}), Mn (7.37 mg kg^{-1}) and B (1.27 mg kg^{-1}) as well as other quality parameters like total phenol (13.33mg g^{-1}), total sugar (34.48 mg g^{-1}) and protein content (38.40mg g^{-1}) were found to be higher in tubers under the treatment T15 (T3+ CCC 500 ppm) followed by treatment T13 which is considered as the second best treatment with respect to mineral content in tubers. Overall, the combined treatments of micronutrients along with growth regulators were found most effective in influencing quality parameters.

Treatment T15 (ie.,NPK as per POP along with foliar nutrition of micronutreint mixture (Fe+Zn+Mn+B @ 0.1% each) + cycocel (500ppm) at 30 days interval) was found to be the best in terms of improving both the quantitative and qualitative attributes in sweet potato. Hence it is concluded that the treatment T15 improved the growth and development of plants, physiological parameters of leaves, tuber yield as well as fortification status of sweet potato tubers. Thus this study helped in identifying the best treatment combination of micronutrients and growth regulators for improving growth, development, yield and fortification status in sweet potato.