NUTRIENT MANAGEMENT IN KHASI MANDARIN (*Citrus reticulata* Blanco) UNDER SUBTROPICAL AGRO- CLIMATIC CONDITION IN MIZORAM

JENNY ZOREMTLUANGI

DEPARTMENT

OF

HORTICULTURE, AROMATIC AND MEDICINAL PLANTS

MIZORAM UNIVERSITY

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BY

Jenny Zoremtluangi

Horticulture, Aromatic and Medicinal Plants Department

Submitted

in partial fulfillment of the requirement of the Degree of Doctor of Philosophy

in Horticulture, Aromatic And Medicinal Plants

of Mizoram University, Aizawl

Dedicated to My Late Father and my Loving Family

DECLARATION BY THE CANDIDATE

Mizoram University

June, 2019

I, **Jenny Zoremtluangi**, hereby declare that the subject matter of this thesis entitled "Nutrient Management in Khasi Mandarin (*Citrus reticulata* Blanco) under Subtropical Agro- Climatic Condition in Mizoram" is the record of work done by me, that the contents of this thesis did not form basis of the award of any previous degree to me or to the best of my knowledge, to anybody else, and that the thesis has not been submitted by me for any research degree in any other University/ Institutes.

This is being submitted to the Mizoram University for the Degree of Doctor of Philosophy in Horticulture, Aromatic and Medicinal Plants.

Jenny Zoremtluangi

(Candidate)

(Head)

Dr. Debashis Mandal

(Supervisor)

Mizoram University, Aizawl

(A Central University under the Act of Parliament)

Department of Horticulture, Aromatic & Medicinal Plants

उद्यानिकी, सगन्धएवंऔषधीयपादपविभाग

Dr. Chhungpuii Khawlhring

Head of the Department

No. 9/16/Ph.D. Prog./MZU-HAMP/25 Dated 19.06.201**9**

TO WHOM IT MAY CONCERN

This is to certify that Mrs Jenny Zoremtluangi, a Ph. D. scholar, registration no. MZU/Ph.D./738 of 19/05/2015 has worked on this thesis entitled **"Nutrient management in Khasi Mandarin (*Citrus reticulata* Blanco) under Subtropical Agro-climatic Condition in Mizoram"**. She has fulfilled all criteria prescribed by the UGC (Minimum Standard and Procedure governing Ph.D. Regulation). She has fulfilled the mandatory publication (publication enclosed). It is also certified that the scholar has been admitted in the department through an entrance test followed by an interview as per Clause 9 (i) & (ii) of the UGC regulation 2009.

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PARTICULARS OF THE CANDIDATE

NAME OF THE CANDIDATE	:	JENNY ZOREMTLUANGI
DEGREE	:	Ph. D
DEPARTMENT	:	Horticulture, Aromatic And Medicinal Plants
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EXTENSION (IF ANY)	:	NA

Head

Department of ____________________

Mizoram University, Aizawl

(A Central University under the Act of Parliament)

Department of Horticulture, Aromatic & Medicinal Plants

उद्यानिकी, सगन्धएवंऔषधीयपादपविभाग

Dr. DebashisMandal

Assistant Professor

No. 9/16/Ph.D. Prog./MZU-HAMP/26 Dated 19.06.2019

CERTIFICATE

This is to certify that **Jenny Zoremtluangi** has prepared a Thesis under my Supervision on the topic "Nutrient management in Khasi Mandarin (*Citrus reticulata* Blanco) under Subtropical Agro- Climatic Condition in Mizoram" in partial fulfillment for the award of the Degree of Doctor of Philosophy (Ph. D.) in the department of Horticulture, Aromatic and Medicinal Plants, Mizoram University, Aizawl. This thesis has been the outcome of her original work and it does not form a part of other thesis submitted for the award of any other degrees.

She is duly permitted to submit the Thesis.

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Supervisor

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Jenny Zoremtluangi
Dept. of Horticulture, Aromatic and Medicinal Plants, Mizoram University, Aizawl, Mizoram, India

Elizabeth Saipari
Directorate of Horticulture, Government of Mizoram, Aizawl, Mizoram, India

Debashis Mandal
Dept. of Horticulture, Aromatic and Medicinal Plants, Mizoram University, Aizawl, Mizoram, India

Correspondence
Debashis Mandal
Dept. of Horticulture, Aromatic and Medicinal Plants, Mizoram University, Aizawl, Mizoram, India

Foliar application of zinc, manganese, copper and boron influenced the fruit growth, development and quality of Khasi Mandarin (*Citrus reticulata* Blanco)

Jenny Zoremtluangi, Elizabeth Saipari and Debashis Mandal

Abstract
An experiment was conducted during 2016 and 2017 at Mizoram University, Aizawl, Mizoram to study role of micronutrients on fruit growth and development of Khasi Mandarin (*Citrus reticulata* Blanco). Randomized block design was adopted with sixteen treatments such as, Foliar application of T_1: Zinc (Zn),T_2:Manganese (Mn),T_3: Copper (Cu), T_4: Boron (B), T_5: Zn + Mn,T_6: Zn + Cu,T_7: Zn + B,T_8: Mn + Cu,T_9: Mn + B,T_{10}: Cu +B,T_{11}: Zn + Mn + Cu,T_{12}: Zn + Mn + B,T_{13}: Zn + Cu + B,T_{14}: Mn + Cu + B,T_{15}: Zn + Mn + Cu + B,T_{16}: Control (no micro nutrients). From the pooled analysis of two consecutive years during the experiment, foliar application of Zn+Cu+ B (T_{13}) showed maximum fruit set percentage, maximum fruit yield, maximum number of fruits per tree, highest fruit retention percentage, highest ascorbic acid content, total sugar and minimum total fruit drop percentage, seed number per fruit and acidity percentage. Whereas, highest TSS and minimum seed weight and minimum peel weight were observed with treatment which received micronutrient combination of Zn + Mn + Cu+ B (T_{15}) against control. However, maximum fruit weight was observed with application of Zn + Mn + B (T_{12}) and maximum fruit juice content with foliar application of Zn + Mn + Cu (T_{11}).

Keywords: Khasi Mandarin, foliar micro nutrients, fruit quality, ascorbic acid

Introduction

Citrus belongs to the family Rutaceae, are rich in refreshing fragrance, thirst-quenching ability, and vitamin C (Ladaniya, 2008) [12]. Citrus production in India is 12.55 million tons from 1.003 million hectares under this crop (Anon., 2018b) [4]. The production of citrus fruit is 12.89 per cent of total fruit production in the country. Oranges constitute about 60 per cent of the total citrus output, Mandarins are the second most important fruit crop in Citrus group after Sweet Orange and has 40.66 % share of total citrus production (Anon., 2018b) [4]. 'Khasi' mandarin is commercially grown in North-East India, historically it is believed that it is the centre for the spreading citrus to other part of the World (Srivastava and Singh, 2006) [21].
Mizoram has the second highest area share under Khasi mandarin in NEH. Khasi mandarin production in Mizoram is 44.02 thousand MT from an area of 16.37thousand Ha (Anon., 2018a) [3]. As per data of National Horticulture Board (2001-2002), Khasi mandarin production was 32.1 thousand MT from an area of 6.90 thousand Ha which clearly showed that Khasi Mandarin production is declining at Mizoram even the area under cultivation has increased to 137%. Improper management of soil fertility and plant nutrition is the major shortcoming in NEH citrus industry apart from the disease or pests problems (Srivastava, 2012) [22]. Citrus is a highly nutrient responsive crop, the productivity of plants depends largely on fruit nutrition. However, due to depletion of soil carbon stock and emerged multiple nutrient deficiencies, the high yield expectancy on a long term basis has failed to sustain by soil application of inorganic fertilizer (Khehra, 2014) [11]. The depletion of the major and minor nutrients limits the productivity of major crops. Most of the applied fertilizer is lost from soil-plant system by leaching, run-off, denitrification and volatilization and pollutes the soil, water bodies and the atmosphere. Imbalance nutrient, soil fertility fast depletion and continuous deterioration in soil physical properties are some added disadvantages of chemical agriculture. Therefore proper management of plant nutrition involving foliar application of micronutrients has strong basis for remunerative Khasi mandarin production. Citrus requires 17 essential elements for the normal growth and production. Though micronutrients are required in small, yet they are very effective and important in fruit growth and development. Foliar application of micronutrients often gives a quicker response than soil application (Obreza *et al*., 2010; Anees *et al*., 2011) [16, 2] since the plants readily absorbed the nutrients through the leaf surface.

Despite of some shortcomings, it is regarded as the best under certain conditions (Marschner and Marschner, 2012) [14]. Micronutrients help in uptake of macronutrients, helps in cell wall development, formation of chlorophyll, respiration, photosynthesis, activity of enzyme, synthesis of hormone, fixation of nitrogen and reduction (Das, 2003) [7]. Deficiencies of micronutrients are very prominent in citrus reducing crop productivity, stability and sustainability in many Indian soils. In view of this, there is a need for systematic work to evaluate the role of foliar application of micro nutrients in Khasi Mandarin in Mizoram condition to improve the fruit growth and development.

Materials and Method

The experiment was laid out during 2016 and 2017 at farmer's field situated at Thiak, Aizawl district, Mizoram, situated at 23.47^0N latitude & 92.71^0E longitude having an altitude of 1070 m above mean sea level (MSL). The experiment was laid out in randomized block design (RBD) with sixteen treatments namely, Foliar application of T_1: Zinc (Zn),T_2: Manganese (Mn),T_3: Copper (Cu), T_4: Boron (B), T_5: Zn + Mn,T_6: Zn + Cu,T_7: Zn + B,T_8: Mn + Cu,T_9: Mn + B,T_{10}: Cu +B,T_{11}: Zn + Mn + Cu,T_{12}: Zn + Mn + B,T_{13}: Zn + Cu + B,T_{14}: Mn + Cu + B,T_{15}: Zn + Mn + Cu + B,T_{16}: Control (no micro nutrients). Recommended dose of fertilizers N:P:K (Nitrogen: Phosphorus: Potassium) 600:300:600 g per plant per year were applied in all the plants. Full dose of phosphorus and potassium and half split dose of nitrogen in the form of urea, Single Super Phosphate (SSP) and Murate of Potash (MOP) were applied in the month of March during flowering and the remaining half split dose of nitrogen were applied in the month of September, while foliar micronutrients were applied during April and October. Zn was given @0.5%, Mn @0.4%, Cu @ 0.4%, B @ 0.1%. Total number of fruits per plant was counted and expressed in number. Yield per tree (kg $tree^{-1}$) was calculated by multiplying the average weight (50 fruits) of the fruits with total number of fruits per plant produced at harvest whereas, the percentage of fruit set was calculated as Fruit set (%) = (Number of fruitlets per branch/ Total number of flower per branch) X 100. Data on fruit drop was recorded from date of fruit set to till harvest at specific interval and was expressed in percentage. The percentage of fruit drop was calculated as Fruit drop (%) = {(Fruit Set-Fruit Retention) / Fruit Set} X100, data on the fruit retention was recorded under every treatment at different intervals and at the time of fruit harvesting. The fruit retention percentage was worked out by using the following formula:Fruit retention (%) = {(Total number of fruit set – total no. of fruit drop) / Total no. of fruit set} X 100.The fruit weight was measured by taking 50 representative fruits at random from each replication; these were weighed and expressed in g (average fruit weight). Total number of seeds per fruit were counted and expressed in number. The fruit was cut out and seeds were separated and washed with water, weighed and expressed in gm. Weight of the peel was measured using a digital balance and expressed in gm. After peeling and extracting the seeds, fruit was squeezed to obtain juice and was measured using a measuring cylinder and given in ml. Total Soluble Solids (TSS) content of freshly harvested matured fruit was measured by Handheld Refractrometer which was calibrated at 20ºC and expressed in terms of °Brix. Total titratable acidity was determined by titrating the extracted juice against N/10 NaOH using phenolphthalein as indicator and expressed in percentage (AOAC, 1990) [1]. The total sugar content of fruits were estimated by standard procedure of AOAC (1990) [1] using Fehling's A and Fehlings B reagents with methylene blue as an indicator through copper reduction method and to estimate the ascorbic acid content of the fruit, 2, 6 – dichlorophenol indophenol dye titration method was used (AOAC, 1990; Ranganna 1997) [1, 19] and expressed as mg / 100mg of aril.

Results and Discussions

Influence on fruit set, fruit drop percentage, total fruit retention and yield

Significant increase was observed with different treatments in perusal of the pooled data presented in Table 1. Foliar application of Zn + Cu + B (T_{13}) recorded highest fruit set percent (61.89%), highest yield per tree (19.99 kg per tree) along with highest percentage of fruits retention per plant (65.40%) and lowest total fruit drop percent (34.17%) compared with control. Quaggio (2011) [18] reported that Zinc (Zn), manganese (Mn) and boron (B) are important micronutrient for citrus production. Garcia *et al*., 1984 [8] reported that as leaf Zn and Mn content increased, fruit let drop decreased. Karim *et al*., (2017) [9] reported that consequences for tree health and crop production depends on boron (B) in citrus. Foliar application appeared to increase leaf boron concentration which influenced in vivo and in vitro pollen germination in many crops, increased fruit yield which might be due to transportation of applied B to the flowers where it exerted its influence of increased fruit set through an effect on pollen viability and/or pollen tube growth. The increase in fruit no and yield might be due to reduction in fruit drop where Nijjar (1985) [15] reported that Zn is required for prevention of abscission layer formation which thereby decrease the preharvest fruit drop. Perveen and Rehman (2000) [17] also concluded that spray of Zn, Mn and B helps in correcting the deficiency symptoms and improved the citrus fruit yield. B alone spray could not give satisfactory yield, but when it was applied in combination with Zn and Mn, yield was increased.

Table 1: Influence of micronutrients on fruit set, total fruit drop percent, total fruit retention percent and yield

Treatment	Fruit set (%)	Total fruit drop (%)	Total fruit retention (%)	Fruit yield (kg per tree)
T_1	58.37	42.66	57.34	12.21
T_2	57.08	40.65	59.35	11.96
T_3	58.10	42.90	57.10	12.23
T_4	56.66	44.74	55.26	10.26
T_5	58.74	38.75	61.25	13.51
T_6	57.55	43.12	56.88	11.25
T_7	60.97	36.71	63.29	16.87
T_8	58.74	39.96	60.04	13.20
T_9	59.25	40.58	59.42	13.65
T_{10}	61.30	40.72	59.28	14.73
T_{11}	59.89	36.38	63.62	15.90
T_{12}	59.96	35.64	64.36	17.38
T_{13}	62.13	34.17	65.83	19.99
T_{14}	60.96	37.69	62.31	15.19
T_{15}	59.86	35.72	64.28	19.74
T_{16}	54.07	49.10	50.90	8.98
SEm(±)	0.409	2.364	2.725	1.363
$CD_{(0.05)}$	1.183	6.829	7.870	3.937

Influence on number of fruits per plant and fruit physical properties

The data presented in Table 2 revealed that treatment which received micronutrient mixture of Zn + Cu + B (T_{13}) had maximum number of fruits per plant (140.55nos.) and minimum seed number (12.14nos.) Whereas, plants which received micronutrient mixture of Zn + Mn+ Cu + B (T_{15}) resulted in lowest peel weight (29.89g) and seed weight (1.12g). However, application of Zn + Mn + B (T_{12}) recorded maximum weight of fruit (153.25g). Due to the involvement of Zn and B in hormonal metabolism, increase in cell division, and cell wall expansion, fruit weight increased with the spray of $ZnSO_4$ and Boric acid. B stimulates rapid metabolization of water and sugar in the fruit thereby increasing accumulation of dry matter within the fruit (Bhatt *et al*., 2012) [6]. Tariq *et al*., (2007) [23] recorded minimum peel percentage with spray of Zn + Mn in Sweet Orange. Kazi *et al*., (2012) [10] reported in Sweet Orange that NPK bulk recommended dose + multi micronutrient observed number of fruits per tree significantly higher over other treatments. Singh *et al*., (2018) [20] supported our findings on his report on Sweet Orange that trees which received combined treatment of Zn+ B + Cu observed minimum number of seeds and minimum peel thickness.

Table 2: Influence of micronutrients on number of fruits per plant and fruit physical properties

Treatment	No of fruits per plant	Fruit weight(g)	Peel weight(g)	Seed No	Seed weight(g)
T_1	108.89	137.73	38.31	17.87	2.75
T_2	110.17	101.18	39.78	17.59	2.60
T_3	102.01	128.86	35.41	17.62	2.08
T_4	100.91	98.74	34.70	17.69	3.21
T_5	114.80	132.43	35.91	17.84	3.02
T_6	100.14	106.51	35.19	17.51	2.53
T_7	127.08	138.64	41.90	16.87	1.85
T_8	105.71	139.01	39.42	16.94	2.12
T_9	100.59	143.55	34.52	15.98	1.47
T_{10}	112.28	134.00	38.81	17.41	1.99
T_{11}	114.96	149.47	33.25	14.56	2.27
T_{12}	124.55	153.25	32.42	17.33	2.01
T_{13}	138.95	143.86	31.92	12.14	1.17
T_{14}	125.85	134.19	37.29	17.37	2.70
T_{15}	126.95	149.95	29.89	17.46	1.12
T_{16}	90.69	97.52	47.14	17.98	3.17
SEm(±)	1.247	1.164	2.329	0.667	0.278
$CD_{(0.05)}$	3.602	3.363	6.726	1.926	0.803

Influence on fruit biochemical properties

The data depicted in Table 3 revealed that application of micronutrients significantly differ in fruit quality. The spray of micronutrient mixture of Zn + Mn+ Cu + B (T_{15}) resulted in highest TSS (10.92 º Brix), while combination of Zn + Cu + B (T_{13}) recorded highest total sugar (9.18 %) highest ascorbic acid content (51.40mg/100mg of aril)and minimum acidity (0.49%). However, fruit juice content was observed highest (75.25ml) with spray of Zn + Mn + Cu (T_{11}). The findings are in line with Singh *et al*., (2018) [20] in Sweet Orange cv. Mosambi who reported that improved TSS, ascorbic acid, total sugar and minimum acidity were observed with treatment which contained Zinc+ Boron+ Cupper. Previous studies revealed that translocation of photosynthates to the fruit was efficient by regulation of copper, boron and zinc (Ullah *et al*., 2012) [24]. They also reported that acidity of Mandarin was reduced due to higher synthesis of nucleic acid. Cu (copper) increase photosynthetic activity and when combined with Zn and B it increased the sugar compounds and brought more accumulation of total soluble solids in fruit juice. The findings are in accordance with Babu and Yadav (2005) [5] in Khasi Mandarin. Mann *et al*., (1985) [13] found that micronutrients (Zn, Cu, Fe and Mn) application on the leaves of sweet orange resulted improved juice percentage, ascorbic acid content and reducing sugar .

Table 3: Influence of micronutrients on fruit biochemical properties

Treatment	Fruit juice content (ml)	TSS (ºBrix)	Acidity (%)	Total sugar (%)	Ascorbic acid (mg/100g of aril)
T_1	60.59	9.75	0.62	9.23	44.86
T_2	55.25	9.49	0.64	8.73	43.67
T_3	62.75	9.72	0.64	8.86	44.86
T_4	56.08	9.46	0.64	9.20	43.67
T_5	64.42	9.80	0.62	8.97	46.05
T_6	53.17	9.65	0.64	8.79	44.86
T_7	68.58	10.24	0.60	9.18	46.64
T_8	69.83	10.19	0.60	9.07	46.64
T_9	73.58	10.40	0.60	9.14	46.64
T_{10}	56.50	10.44	0.60	9.15	7.83
T_{11}	75.25	10.47	0.58	9.24	49.02
T_{12}	59.78	10.55	0.56	9.27	51.40
T_{13}	64.81	10.66	0.44	9.31	51.40
T_{14}	62.75	9.79	0.62	9.03	46.05
T_{15}	63.16	10.88	0.53	9.29	49.62
T_{16}	42.23	9.34	0.68	8.39	42.77
SEm(±)	2.106	0.198	0.024	0.177	0.871
$CD_{(0.05)}$	6.081	0.572	0.068	0.511	2.516

Conclusion

The investigation revealed that foliar application of combined micronutrients with treatment T_{13} [Zn (0.5%) + Cu (0.4%) + B(0.1%)] recorded highest fruit set %, number of fruits per plant, yield (kg per tree),total fruit retention percentage along with total sugar percentage and ascorbic acid content and minimum acidity, total fruit drop percentage and minimum seed number. While T_{15} [Zn (0.5%) + Mn (0.4%) + Cu (0.4%) + B (0.1%)] recorded maximum TSS and minimum peel weight and seed weight. Hence, it was concluded that the treatment T_{13} [Zn (0.5%) + Cu (0.4%) + B (0.1%)] was the best treatment in terms of fruit growth and development which was next with T_{15} [Zn (0.5%) + Mn (0.4%) + Cu (0.4%) + B (0.1%)] as compared with control plant (T_{16}).

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&	and
@	At the rate of
AMF	(Nutrilink- mixed strains of IARI)
Anon.	Anonymous
AZ	*Azotobacter*
B	Boron
BC	Benefit to cost ratio
°Brix	Degree brix
°C	Degree centigrade
cm	Centimeter
C	Carbon
cc	Cubic centimeter
CO_2	Carbon – di - oxide
CFU	Colony forming units
^{o} E	Degree east
EW	East West
Fig	Figure

FM	Filter mud (a by- product of sugar industry)
FYM	Farm Yard Manure
Fe	Iron
g	Gram (s)
ha	Hectare
ha^{-1}	Per Hectare
HCl	Hydrogen chloride
i.e	That is
INM	Integrated nutrient management
K	Potassium
Kg	Kilogram (s)
KSB	Potash Solubilizing Bacteria
lb	pound
MSS	Mean sum of square
mg	milligram
ml	Milliliter
m	Meter
m^3	Meter cube

Max	Maximum
Min	Minimum
mm	milimeter
Mn	Manganese
MOP	Muriate of Potash
MSL	Mean sea level
MT	Metric ton
^{o}N	Degree North
N	Nitrogen, Normal
NC	Neem cake
NEH	North Eastern Hills
NS	North- South, Non- significant
Nos.	Number
/	per
%	Per cent
P	Phosphorus
Plant^{-1}	Per plant
ppm	Parts per million
PSB	Phosphate solubilizing bacteria

RBD	Randomised Block Design
Rs.	Rupee
S.Em.	Standard error of mean
Sq.m	Square meter
SSP	Single Super Phosphate
t	Tonnes
t/ha	Tonnes per hectare
$Tree^{-1}$	Per Tree
TSS	Total soluble solids
Var	Variety
Viz	Namely
VC	Vermicompost
Vol	Volume
Wt	weight
$Year^{-1}$	Per year
Zn	Zinc

Chapter - 1

INTRODUCTION

Citrus which has a long lasting niche in International trade and World finance, is considered to be one of the most remunerative fruit crops, dominated by the northern hemisphere, followed by the southern hemisphere, and Mediterranean region contributing 45%, 35% and 20%, respectively (Srivastava and Singh, 2009). The role of citrus fruits in providing nutrients and medicinal value has been recognised since ancient times, *Citrus* belongs to the family Rutaceae, and are well known for their refreshing fragrance, thirst-quenching ability, and adequate vitamin C content (Ladaniya, 2008).Citrus fruits also contain several phytochemicals, which play the role of neutraceuticals, such as carotenoids, limonoids, flavonones (naringins and rutinoside), and vitamin –B complex and related nutrients (Ladaniya, 2008). The flavonoids from citrus juice are effective for improving blood circulation and also possess anti-allergic, anti-carcinogenic, and anti-viral properties (Filatova and Kolesnova, 1999). Consumption of the fresh juice is important because of more availability of the nutrients and health-promoting factors (especially antioxidants) which are immediately available to the body as compared to processed juice. Citrus is grown in more than 80 countries (Chang, 1992). Its cultivation generates employment besides its nutritive and therapeutic value. Citrus stands first among the fruit crops in the world with respect to production leaving behind grapes, apples and banana (Ladaniya, 2008). India ranks 5^{th} in Citrus production in the world after Brazil, China, United States and Mexico. Citrus production in India is 12.55 million tonnes from 1.003 million hectares (Anon., 2018a). The production of citrus fruit is 12.89 per cent of total fruit production in the country, India.

The most important citrus fruits grown on a commercial scale in India are Mandarin, Sweet Orange, Acid Lime and Lemon (Ladaniya, 2008; Singh, 2001). Grapefruit and Pummelo are grown in small orchards and homestead gardens only. Mandarin are commonly known as loose-skin oranges. Mandarin occupies a prime position among Citrus and has 40.66 % share of total citrus from an area of 428 thousand hectare with production of 5101 thousand tonnes and productivity of 11.92 t/ha (Anon., 2018a).

In India, there are five different Mandarin viz. ‘Nagpur’, ‘Coorg’, ‘Khasi’, ‘Darjeeling’ and ‘Kinnow’, which are popularly grown. ‘Nagpur’ is the popular cultivar in Maharashtra, whereas, ‘Coorg’ is commercially cultivated in Karnataka and Kerala (Ghosh *et al*., 2001).‘Kinnow’ mandarin is popularly grown in Punjab and ‘Darjeeling’ in West Bengal and Sikkim. ‘Khasi’ mandarin is commercially grown in North-East India, historically the region is believed to be the centre for the dissemination of citrus fruits to other parts of the World (Srivastava and Singh, 2006a). In North East India, its cultivation is confined up to an elevation of 1200m above mean sea level under a humid tropical climate (Srivastava, 2012). Khasi Mandarin fruits are depressed, globose to oblate, bright orange yellow in colour, surface smooth, glossy, stalk end even or obtuse, occasionally short necked; rind thick to medium, adherence slight, segments moderate in number; juice abundant, orange coloured with good sour-sweet blends; seeds 12-16, polymebryonic ; keeping quality good (Ghosh *et al*., 2001).

Cultivation of Khasi mandarin is confined to the North-East Himalayan (NEH) states of Assam, Manipur, Meghalaya, Nagaland, Mizoram and Tripura. NEH region holds 15.75% of the total area under mandarin cultivation with a production share of 12.75% in India. Assam is the leading Khasi Mandarin Producer in NEH region followed by Nagaland. However, Mizoram has the second highest area share under Khasi mandarin in NEH. Khasi mandarin is the second most important citrus crop in Mizoram after lime and lemon. It is cultivated in Rulpuihlim, Sakeibanglamual and Sailam; Tuitamzau, Darzo, Sethlun and Sekhum, Sialsir and Dawngzawl in the districts of Mamit, Aizawl, Kolasib, Lunglei and Serchhip districts, respectively. East Lungdar, North Vanlaiphai of Serchhip district; Khawhai of Champhai district, Thingdawl and Kawnpui of Kolasib district and Mamit district; Aizawl (Saitual), Lunglei (Vanlaiphai), Chhimtuipui (Saiha Tuipang), Champhai, North, South and West part of Mizoram, Chhimtuipui, Kolasib, Tawitaw, Aizawl, Thingdawl are the major Khasi mandarin growing belt in the state of Mizoram. Presently, Khasi mandarin production in Mizoram is 44.02 thousand tonnes with productivity of 2.69 t/ha from an area of 16.37 thousand hectare (Anon., 2018b). As per data of National Horticulture Board (2001-2002), Khasi mandarin production was 32.1 thousand tonnes from an area of 6.90 thousand hectare, which clearly showed that Khasi Mandarin production is declining at Mizoram even the area under cultivation has increased to 137%. Moreover, citrus productivity in NEH region (4.52 t ha^{-1}) is quite low than national average (8.9 t ha^{-1}) (Srivastava and Singh, 2002). Apart from the disease and pests problems, the major short coming in NEH citrus industry is improper management of soil fertility and plant nutrition (Srivastava, 2012). Proper management of nutrition and soil fertility is considered as pivotal in successful and remunerative cultivation of citrus fruit which unless otherwise develop an unhealthy orchard that becomes susceptible to diseases and pests infestations. Therefore, systematic management of nutrition in Khasi Mandarin is of immense importance for its successful cultivation with high productivity. Continuous fertilization has failed to sustain the yield expectancy on a long term basis and consequently, multiple nutrient deficiencies have emerged due to depletion of soil carbon (Srivastava and Singh, 2009). Citrus is a highly nutrient responsive crop, the productivity of plants depends largely on fruit nutrition. Judicious application of fertilizers is based on leaf and soil analysis and has been used as an analytical tool in knowing the nutritional requirements (Montanes *et al*.,1993). Inorder to meet the nutritional requirement of fruit trees, soil and foliar application plays an important role but their mobility in plants and soil differ their efficacy significantly. Redressing of nutrient deficiencies is more complex due to occurence of multiple nutrient deficiencies. If constraint specific fertilization is to be found out, classical progressive fertilization response studies would be followed. However, nutrient management studies irrespective of location specific would be a greater weightage over conventional. Simultaneously use of integrated approach viz., application of macronutrients in soil, foliar application of micronutrients; fertigation and integrated nutrient management (INM) fortified with biofertilizers have produced encouraging responses to improve production and productivity of crops. But, depending upon age of the orchard, type of soil and climatic conditions, fertilizer requirement study have generated a vast variation in their recommendations. However, fertigation reduced required amount of nutrients by 25-30%, which could also be effectively achieved through INM as well (Srivastava, 2013). Loss of soil health and productivity due to excessive soil erosion, associated plant nutrient losses, pollution of surface water and ground water by fertilizers and sediments, impending of non-renewable resources and low farm income due to high production costs and low benefit resulted non- sustainable conventional farming. Because of these problems, an alternate nutrient management system which is known as integrated plant nutrient management needs to play an important role by maintaining or adjusting soil fertility, plant nutrients supply to an optimum level for sustaining crop productivity through optimization of benefits from all possible sources of plant nutrients in an integrated manner. The adjustment of plant nutrient supply to an optimum level for sustaining the desired crop productivity is the basic concept of INM. It involves proper combination of chemical fertilizers, organic manure and biofertilizers suitable to the system of land use and ecological, social and economic conditions. Vermicompost is an ecofriendly natural manure prepared from biodegradable organic wastes rich in N fixers, P-solubilizers, cellulose decomposing micro-flora etc. which improve soil health, by improving soil structure, texture, aeration ,enhances the decomposition of other organic matter, increases water holding capacity and also prevents erosion of soil. It promotes better root growth and nutrient absorption (Ninama, 2013). In the process of intensive farming system, the environment has been treated in an unfriendly manner. The intensive production system has led to depletion of major and minor nutrients from the soil apart from damaging the soil health, productivity and also sustainability. The depletion of the major and minor nutrients limits the productivity of major crops. Most of the applied fertilizer is lost from soil-plant system by leaching, run-off, denitrification and volatilization and pollutes the soil, water bodies and the atmosphere. Heavy use of fertilizers turning the soil sick accompanied by hazardous residual effects, is posing great threat to human, animal and overall agricultural ecology. Nutrient imbalance, fast depletion in soil fertility and continuous deterioration in soil physical properties are some added disadvantages of chemical agriculture, lack of sustainability in production in recent years is becoming a major cause of concern. The future farming therefore requires judicious use of chemical fertilizers .Integrated nutrient management (INM) improves the economic yield in terms of fruit yield, quality, soil physico-chemical and microbial prospects. From other cultivated soils, soils under citrus differ with respect to fallow period of 3-6 months every year forcing depletion of soil organic matter in latter case (Bhargava, 2002). However, in contrast, biological oxidation of existing carbon (C) continues in soil covered under citrus (Srivastava *et al*., 2002). Multiple nutrient deficiencies are considered to have a profound effect on potential source of atmospheric carbon dioxide (CO_2). Hence, soil carbon stock is considered as an important criterion to determine the impact of INM in the longer version of impact assessment (He *et al*., 1997). Within the rhizosphere, the amount of accumulated C in soil does not continue to increase with time with increasing C outputs. The mechanism involved in C stabilization in soils should be clearly understood for controlling and enhancing soil C sequestration (Goh, 2004) under different modes of nutrient management. Yaseen and Ahmad (2010) reported that the use of multi-nutrient plant growth regulator formulation amended with appetizer is a new and innovative approach to develop a cost effective foliar spray “Micro Power” for improving citrus yield. Foliar application of micronutrients is a method for quick element supply which allows consumption of nutrients by the plant much faster than uptake from the soil by roots. Foliar application of micronutrients often gives a quicker response than soil application (Obreza *et al.*, 2010; Anees *et al.*, 2011) since the plants readily absorb the nutrients through the leaf surface. Despite of some shortcomings, it is regarded as the best under certain conditions (Marschner and Marschner, 2012). Micronutrients application help in uptake of macronutrients, helps in cell wall development, respiration, photosynthesis, chlorophyll formation, enzyme activity, hormone synthesis, nitrogen fixation and reduction (Das, 2003).

Scope of the Study

Citrus by its avid nutrition absorbing capacity, is considered a highly nutrient responsive perennial fruit crop (Srivastava, 2012). However, soil application of inorganic fertilizer has failed to sustain the high yield expectancy on a long term basis due to depletion of soil carbon stock and consequently emerged multiple nutrient deficiencies (Khehra, 2014). Moreover, high rainfall hilly areas are prone to nutrient loss through leaching and erosion. Therefore, proper management of plant nutrition involving inorganic coupled with organic nutrition inputs and use of bio fertilizer has strong basis for remunerative Khasi mandarin production. Following are some important scope of the present investigation:

i. Standardization of Integrated Nutrient Management (INM) package for Khasi Mandarin in Mizoram will enable to optimize and adapt the nutrient management practice for successful cultivation of Khasi mandarin in other growing areas of NEH region.

ii. Findings of the present investigation will help us to figure out the effect of INM on soil nutrient and microbial organism in Khasi mandarin orchard which will definitely help in nutrient management of other crops.

iii. Outcome of the present study will depict the soil and leaf tissue micronutrient (Fe, Mn, Cu, Zn, B) status of the Khasi mandarin orchard along with effect of foliar micronutrients on crop growth and yield which in turn will help Khasi mandarin industry of NEH region.

In view of this, there is a need for systematic work to study the nutrient management in Khasi Mandarin (*Citrus reticulata* Blanco) with the following objectives:

Objectives

i. To study the effect of INM on growth, yield, quality and production economics of Khasi mandarin.

ii. To evaluate the effect of foliar application of micronutrients on growth, yield, quality and production economics of Khasi mandarin.

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INTRODUCTION

Chapter-II

REVIEW OF LITERATURE

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MATERIALS AND METHOD

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SUMMARY AND CONCLUSION

Chapter – 3

MATERIALS AND METHODS

The details of the materials used and methods adopted during the course of the investigation are described below:-

3.1 Experimental Site

The experiments were carried out at farmer's field situated at Thiak, Aizawl district, Mizoram, situated at 23.47^{0}N latitude & 92.71^{0}E longitude having an altitude of 1070 m above mean sea level (MSL).

3.2 Soil status of the experimental site

Before undertaking the experiments, composite soil samples of the experimental sites were taken from the depth of 15 - 45 cm. The soil texture is loam to clay loam soil. The estimated values of initial soil composition are as follows:

Table 3.1: Initial soil composition of the experimental plot 1

Depth of soil (cm)	Soil pH	Organic Carbon (%)	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)
0-15	4.75	0.90	276.12	19.32	121.09
15-30	4.85	0.69	259.76	17.40	119.87
30-45	4.63	0.96	281.14	16.30	122.89

Table 3.2: Initial soil composition of the experimental plot 2

Depth of soil (cm)	Soil pH	Organic Carbon (%)	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)
0-15	4.96	0.87	365.12	34.12	155.21
15-30	4.97	0.91	386.21	19.23	165.23
30-45	4.91	0.86	371.32	24.15	171.29

Table 3.3: Methods employed for soil analysis

Soil pH	pH meter with glass electrode (Jackson,1973)
Organic Carbon	Walkey and Black method (Jackson, 1973)
Available N	Micro-Kjeldahl's method (Jackson, 1973)
Available P_2O_5	Colorimetric method (Dickman and Bray,1940)
Available K_2O	Flame photometric method(Jackson, 1973)
Fe	Atomic Absorption Spectrophotometry
Mn	Atomic Absorption Spectrophotometry
Cu	Atomic Absorption Spectrophotometry
Zn	Atomic Absorption Spectrophotometry
B	Atomic Absorption Spectrophotometry

3.3 Meteorological observations during the period of experimentations.

The climate of the site usually is subtropical and humid.

Table 3.4: Monthly records of temperature, relative humidity and total rainfall during the period of experimentation (2016)

Year & Month	Average temperature (◦C)		Average relative humidity (%)		Monthly annual total rainfall(mm)
	Maximum	**Minimum**	**Maximum**	**Minimum**	
2016					
January	23.8	6.4	96.4	81.4	0.03
February	27.2	9.6	92.7	82.1	0.4
March	30.2	12.4	80.8	88.5	2.6
April	29.3	12.7	89.2	93.5	4.1
May	28.1	13.1	93.7	87.9	11.3
June	27.8	14.1	95.2	90.4	13.2
July	27.2	12.2	96.7	93.2	9.4
August	28.5	12.8	95	90	10.6
September	28.0	12.3	97.1	92.9	12.7
October	28.4	12.0	96.2	89.2	3.4
November	25.7	8.2	94.2	85.3	3.0
December	24.9	7.0	91	81.4	0.0

Source: State Meteorological Centre, Directorate of Science & Technology

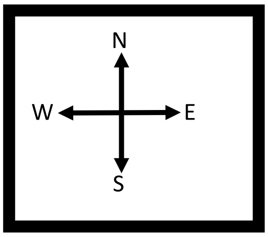
Table 3.5: Monthly records of temperature, relative humidity and total rainfall during the period of experimentation (2017)

Year & Month	Average temperature (◦C)		Average relative humidity (%)		Monthly annual total rainfall(mm)
	Maximum	Minimum	Maximum	Minimum	
2017					
January	26.3	5.7	89.3	79.6	0.0
February	28.4	8.2	79.9	89.1	0.7
March	27.1	8.5	90.7	82.0	3.1
April	30.0	10.6	91.1	84.5	4.8
May	30.3	13.8	92.7	86.4	7.0
June	28.4	12.2	96.5	93.6	24.8
July	29.1	12.6	97.5	95.1	12.1
August	29.4	12.613	97.8	96.7	15.5
September	29.9	14.1	97.5	95.9	8.0
October	29.7	15.6	96.0	92.4	10.6
November	28.8	13.9	92.1	85.3	0.3
December	25.3	11.4	91.7	84.4	1.2

Source: State Meteorological Centre, Directorate of Science & Technology

Fig.3.1. Layout of the Experimental Plot 1

R_1	R_2	R_3
T_1	T_7	T_{10}
T_2	T_8	T_{11}
T_3	T_9	T_{12}
T_4	T_{10}	T_{13}
T_5	T_{11}	T_1
T_6	T_{12}	T_2
T_7	T_{13}	T_3
T_8	T_1	T_4
T_9	T_2	T_5
T_{10}	T_3	T_6
T_{11}	T_4	T_7
T_{12}	T_5	T_8
T_{13}	T_6	T_9



3.4. Experiment 1: Integrated Nutrient management of Khasi Mandarin

Table 3.6: Details of the Experiment

a.	**Plant/variety**	**:**	**Khasi Mandarin (Local)**
b.	**Age of the Plant**	**:**	**8 years**
c.	**Spacing**	**:**	**3m X 3m**
d.	**Design of experiment**	**:**	**Randomised Block Design**
e.	**Number of treatments**	**:**	**13**
f.	**Number of replications**	**:**	**3**
g.	**Plants per replication**	**:**	**5**
h.	**Total no of Plants**	**:**	**195**
i.	**Plot size**	**:**	**1755sq.m**
j.	**Total experimental area**	**:**	**3195sq.m**

3.4.1 Treatment details

T_1: Recommended dose of fertilizer (RDF) as 100% inorganic

T_2: Farm Yard Manure (FYM) to supply 50% K+ 50% RDF

T_3: Vermi compost (VC) to supply 50% K+ 50% RDF

T_4: Neem Cake (NC) to supply 50% K+ 50% RDF

T_5: Farm Yard Manure (FYM) to supply 50% K+ 50% RDF+ Azotobacter (AZ) + Phosphate Solubilizing Bacteria (PSB) + Potash Solubilizing Bacteria (KSB)

T_6: VC to supply 50% K + 50% RDF+AZ+PSB+ KSB

T_7: NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB

T_8: FYM to supply 25% K + VC to supply 25% K+ 50% RDF+AZ+PSB+ KSB

T_9: FYM to supply 25% K + NC to supply 25% K+ 50% RDF+AZ+PSB+ KSB

T_{10}: VC to supply 25% K + NC to supply 25% K+ 50% RDF+AZ+PSB+ KSB

T_{11}: FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF

T_{12}: FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB

T_{13}: Control (no fertilizer)

Table3.7: Nutrient composition of the various organic matters before application

Organic matter	N (%)	P (%)	K (%)
Farm yard manure	0.68	0.21	0.50
Vermicompost	0.80	0.15	0.70
Neem cake	4.22	1.08	1.98

3.4.2Time and methods of application of fertilizers

Recommended dose of fertilizers was N: P: K (Nitrogen: Phosphorus: Potassium) 600:300:600 g plant^{-1} year^{-1} (Medhi *et al.*, 2007) in case of this experiment. Calculation of the amount of manures and fertilizers required were done based on RDF and the nutrient composition of the inputs (Table 3.7). Full dose of phosphorus and potassium and half split dose of nitrogen in the form of urea, SSP and MOP were applied in the month of March during flowering and the remaining half split dose of nitrogen were applied in the month of September. Biofertilizers (*Azotobacter, Phosphate Solubilizing Bacteria and Potash Solubilising Bacteria*) each at the rate of 100 g per plant were applied in single dose at March. FYM, Vermi compost and Neem Cake were also given in single dose during March to supply 50%

and 25% K. The manures and fertilizers were applied in the morning hours on the trenches dug around the trees.

3.4.3 Intercultural Operations

3.4.3.1Land preparation:

Before starting of the experiment, the experimental plot was cleaned from weeds, soil was loosened and ring basin were prepared for application of fertilizers and manures to prevent them from leaching and run off. Dead shoots, limbs, disease branches and water suckers were removed.

3.4.3.2 Plant protection:

After removing dead and disease branches, they were sprayed with0.1% dichlorvos and cypermethrin @ 2ml/l at regular interval for control of leaf miner and citrus butterfly.

3.4.3.3 Harvesting

Mandarin fruits were harvested by hand picking and from the tall branches fruits were harvested with bamboo stick when the skin become loose and green coloured skin turns orange yellow in colour.

3.4.4 Observations recorded

3.4.4.1 Plant growth and development

Following parameters were recorded at initial and on yearly interval during the period of experiment and expressed finally as per cent promotion of growth over initial.

a. Plant girth

Plant girth was measured at 30 cm height from soil surface with measuring tape and was expressed in centimetre.

b. Plant height

Plant height was measured with the help of meter scale taking soil surface as basal point and top of the tip as distal end.

c. Plant canopy spread (Canopy: North-South and East-West)

Canopy spread was measured from north to south and east to west and radius was worked out assuming the plant canopy spread to be circular in nature and expressed in meter.

3.4.4.2 Fruit growth and development

a. Days from fruit set to maturity

Days were counted from fruit set to maturity.

b. Fruit set (%)

Four branches from each plant at different direction (east, west, north, south) were tagged and the number of fruits that set from each branch were counted and expressed in percentage. The percentage of fruit set was calculated as follows:

Fruit set (%) = (Number of fruitlets per branch/ Total number of flower per branch) X 100

c. Fruit drop (%)

Data on fruit drop was recorded from date of fruit set to till harvest at specific interval and was expressed in percentage. The percentage of fruit drop was calculated as follows:

Fruit drop (%) = {(Fruit Set-Fruit Retention) / Fruit Set} X100

d. Fruit retention (%)

Data on the fruit retention was recorded under every treatment at the time of fruit harvesting as well as at specific interval within the growth period.

The percentage of fruit retention was computed by using the following formula:

Fruit retention (%) = {(Total number of fruit set – total no. of fruit drop) / Total no. of fruit set} X 100

e.No. of fruits / plant

Total number of fruits per plant was counted at harvest and expressed in number.

f.Yield

Yield per tree (kg $tree^{-1}$) was calculated by multiplying the average weight (50 fruits) of the fruits with total number of fruits per plant produced at harvest whereas, yield per ha (t ha^{-1}) was calculated by multiplying the yield per tree with the total number of trees ha^{-1}.

3.4.4.3 Fruit Physical and Biochemical Parameters

a. Physical Parameters

i. Fruit length

The length of four fruits were measured with the help of a digital slide calliper and their mean value was expressed in cm.

ii. Fruit diameter

By using a slide calliper the diameter was measured in the portion of the fruit where it was widest in case of four fruits and mean was expressed in cm.

iii. Fruit weight

The fruit weight was measured by taking 50 representative fruits at random from each replication; these were weighed and expressed in g (average fruit weight).

iv. Fruit volume

The volume of four fruits was determined by water displacement method and their mean value was expressed in cubic centimetre.

v. Specific gravity

The specific gravity of fruit was calculated by dividing the average fruit weight with average fruit volume.

vi. No. of seeds

Total number of seeds per fruit were counted for four fruits and mean value was expressed in number.

vii. Seed weight

The fruit was cut out and seeds were separated, washed with water and weighed. Average weight of twenty seeds per fruit were measured and expressed in g.

viii. Peel weight

Weight of the peel was measured using a digital balance and expressed in g.

ix. Peel thickness

Thickness of the peel was measured by using a slide caliper and expressed in cm.

x. Juice content

After peeling and extracting the seeds, fruit was squeezed to obtain juice and was measured using a measuring cylinder and expressed in ml.

b. Biochemical Parameters

i. Total Soluble Solids (TSS)

Total Soluble Solids content of freshly harvested matured fruit was measured by Refractrometer which was calibrated at 20^{o}C and expressed in terms of °Brix.

ii. Acidity

Total titratable acidity was determined by titrating the extracted juice against N/10 NaOH using phenolphthalein as indicator and expressed in percentage (AOAC, 1990).

iii. TSS/ acid ratio

The ratio was calculated by dividing TSS value by titratable acidity content of fruit.

iv. Total Sugar and reducing sugar

The total sugar and reducing sugar content of fruits were estimated by standard procedure of AOAC (1990) using Fehling's A and Fehlings B reagents with methylene blue as an indicator through copper reduction method.

Calculation

$$\%\ \text{Total sugar} = \frac{\text{mg of Dextrose X Volume made up X 100}}{\text{Titre X Weight of sample taken X 100}}$$

$$\%\ \text{Reducing sugar} = \frac{\text{mg of Dextrose X Volume made up X 100}}{\text{Titre X Weight of sample taken X 100}}$$

v. Ascorbic Acid

2,6 – dichlorophenol indophenol dye titration method was used to estimate the ascorbic acid content of the fruit (AOAC, 1990; Ranganna 1997) and expressed as mg / 100g of fruit.

Procedure

(a) Standardization of dye

Standard ascorbic acid solution 5ml was diluted with 5ml of 30% metaphosphoric acid. This was titrated against dye solution till pink colour persists for 10 seconds. The dye factor (mg of ascorbic acid per ml of dye) as follows-

Dye Factor (D.F.) = 0.5/Titre

(b) Preparation of sample and titration

- 5ml fruit juice + 25 ml metaphosphoric acid
- Titration against blue dye
- Reading was taken

(c) Calculation

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titre x Factor x volume made up x 100}}{\text{Volume of filtrate taken x wt.or vol.of sample taken}}$$

3.4.4.4. Soil analysis (N, P, K, Fe, Mn, Cu, Zn)

Preparation of soil samples:

Soil samples from each experimental plot were collected at 0-30 cm depthunder the canopy lineof the tree basinwith the help of a soil auger. The samples were thoroughly mixed,driedin shade, pulverized, to pass through 0.2mm sieve and kept in brown paper bag forchemical analysis.

Time:

Soil samples were collected before the initiation of the research work, one year and two years after installation of the treatment.

Area:

Soil samples were taken from the area where manures were applied, around therhizosphere of the plants.

Chemical analysis:

a. Total nitrogen content of soil was determined by micro-kjeldahl’s method (Jackson, 1973).

b. Available phosphorus of soil sample was determined colorimetrically following the procedure of Dickman and Bray (1940).

c. Available potassium of soil sample was determined by leaching the soil with neutral ammonium acetate and estimated by flame photometer (Jackson, 1973).

d. Micro nutrient viz. Fe, Mn, Cu and Zn of the soil sample was measured using Atomic Absorption Spectrophotometer.

3.4.4.5. Soil Microbial analysis (AZ, PSB and KSB)

Soil samples taken from the rhizosphere were used for microbial count of azotobacter, phosphate solubilising bacteria and potash mobilizers' population. Serial dilution plating method was followed for microbial population count (Vincent, 1970).

a. Isolation of *azotobacter* from treated soil:

Isolation of *azotobacter* was done by serial dilution up to 10^6 of soil samples with sterilized distilled water. Melted warm Jehnson's agar media was poured, solidified and1ml of the diluted aliquot was added on the petriplates and incubated at 28 ± 2^o C for 3 days and observations were taken by counting the colonies and expressed in colony forming units (cfu) per g of soil.

b. Isolation of phosphate solubilising bacteria and potash mobilizers from treated soil:

Soil samples were serially diluted up to 10^6 and then plated in the respective media for solubilisation test and identification and incubated at $28 \pm 2\ ^o$ C for 3 days and observations were taken by counting the colonies and expressed in colony forming units (cfu) per g of soil.

Composition of different media used for microbial count:

1. Jehnson's agar media for identification of *Azotobacter* colonies:

1.	Sucrose	20g
2.	K_2HPO_4	1.0g
3.	$MgSO_4.7H_2O$	0.5g
4.	NaCl	0.5g
5.	$FeSO_4$	0.1g
6.	$CaCO_3$	2.0g
7.	Agar	15.0g
8.	Distilled Water	1ltr.

2. Sreber's media for solubilisation test and identification of phosphate solubilising bacteria:

1.	Glucose	10g
2.	Soil extract/ tap water	250ml
3.	Stock solutionA(K_2HPO_4 10%)	20ml
4.	Stock solution B($CaCl_2$ 10%)	30ml
5.	$CaCl_2$	0.1g
6.	$MgSO_4$	0.2g
7.	Yeast extract	0.5g
8.	Agar Agar	20g
9.	Distilled water	750ml

Note: Stock solution A and B are prepared separately, autoclaved and added to the medium while plating at 60^{o}C

3. Media for potash mobilizers identification

1.	D – glucose	2.0
2.	Yeast extract	0.8
3.	Peptone	0.5
4.	Ethanol	0.3
5.	Calcium carbonate ($CaCO_3$)	0.3
6	Agar agar	2

3.4.4.6 Leaf analysis (N, P, K, Fe, Mn, Cu, Zn and C:N ratio)

Leaf sampling

1. It was made sure that the selected leaves represent the block being sampled.
2. It was walked diagonally through the orchard block, randomly identified sampling spot.
3. Sampling was done to cover a minimum of 10 % trees in an orchard.
4. Samples were collected from healthy trees only.
5. 5-7 months oldflush leaves from non-fruiting terminals at 1.5 to 1.8 m from the ground were used for sampling in the month of July-August.
6. Samples was collected from all direction (North, South, West and East)
7. Each leaf samples was consisting about 100 leaves.
8. Clean paper bags were used to store the sample.
9. Labelling was done with clear indication of location, altitude and date of collection.

10. Sample was hold in a cooler place until they were sent to the laboratory.

Precaution

1. Immature leaves were avoided for their rapidly changing composition.
2. Sampling was not done on abnormal-appearing trees. Also, trees at the block's edge or at the end of rows were not sampled.
3. Diseased, insect-damaged, or dead leaves were not included in a sample.

Digestion of leaf samples

The digestion of leaf samples (1 g) for the estimation of total nitrogen was carried out in concentrated H_2S0_4 in the presence of a digestion mixture of following chemicals: Potassium sulphate - 400 parts, Copper sulphate - 20 parts, Mercuric oxide - 3 parts, Selenium powder - 1 parts. For estimation of P, K, Ca, Mg, Fe, Cu, Zn and Mn, the leaf samples (0.5 g) were digested in di acid mixture prepared by mixing HNO_3 and $HC1O_4$ in the ratio of 4: 1 taking all precautions as suggested by Piper (1966).

Chemical analysis

a. The total nitrogen content (% dry weight basis) of the leaf sample was estimated by Micro-kjeldahl method as described by Black (1965).

b. Phosphorus content of leaf sample was estimated by Vanadomolybdate yellow colour method (Chapman and Pratt, 1961).

c. Potassium content was determined by standard procedure using flame photometer (Jackson, 1973).

d. Micro nutrient viz. Fe, Mn, Cu and Zn of the leaf sample were measured using Atomic Absorption Spectrophotometer.

e. Carbohydrate was calculated by following the methods of Hodge and Hofreiter (1962) and C/N ratio of leaf was calculated as the ratio of total carbohydrate to the total nitrogen.

Determination of total carbohydrate content of leaf

The leaf samples were kept in an oven and dried. Dried leaves were then crushed and 100mg taken into a boiling tube and hydrolysed in boiling water bath for three hours with 5ml of 2.5 N HCl and then cooled in room temperature. The hydrolysed sample was then neutalized with solid sodium carbonate until the effervescence ceases. The volume is made up to 100ml and centrifuged. The supernatant was collected and 0.5 and 1ml aliquots were taken for analysis. Standard curve was prepared by taking 0,0.2,0.4,0.6,0.8 and 1ml of the working standard. 0 served as blank. Volume was made up to 1ml in all the tubes including the sample tubes by adding distilled water,4ml of anthrone reagent added and the samples were heated for eight minutes in a boiling water bath and then made to cool. Readings of the green to dark green coloured samples was taken at 630nm in a spectrophotometer. Standard graph was drawn by plotting concentration of the standard on the X- axis versus absorbance on the Y- axis. The amount of carbohydrate present in the sample tube was determined from the graph and calculation was done as-

Amount of carbohydrate present in 100mg of the sample = (mg of glucose/ volume of the test sample) x 100.

3.4.4.7 Cost - Benefit analysis

The economics of different treatments and net return was calculated considering the valid rates of field worker wages, manures, fertilizers, biofertilizers, plant protection chemicals and market sale value of the harvested fruits and the net out turn per rupee of investment was worked out.

3.4.4.8 Statistical analysis

Data was analyzed for statistical inference following the statistical method for Randomized Block Design (RBD) described by Gomez and Gomez (1983).

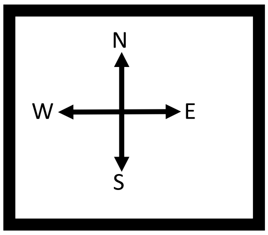
3.5.Experiment 2: Foliar application of micro nutrients on growth, development and fruit quality of Khasi Mandarin

Table 3.8 Details of the experiment

a.	**Plant/variety**	**:**	**Khasi Mandarin (Local)**
b.	**Age of the Plant**	**:**	**8 years**
c.	**Spacing**	**:**	**3m X 3m**
d.	**Design of experiment**	**:**	**Randomised Block Design**
e.	**Number of treatments**	**:**	**16**
f.	**Number of replications**	**:**	**3**
g.	**Plants per replication**	**:**	**5**
h.	**Total no of Plants**	**:**	**240**
i.	**Plot size**	**:**	**2160 sq.m**
j.	**Total experimental area**	**:**	**3195 sq.m**

Fig.3.2. Layout of the Experimental Plot 2

R_1	R_2	R_3
T_1	T_8	T_{11}
T_2	T_9	T_{12}
T_3	T_{10}	T_{13}
T_4	T_{11}	T_{14}
T_5	T_{12}	T_{15}
T_6	T_{13}	T_{16}
T_7	T_{14}	T_1
T_8	T_{15}	T_2
T_9	T_{16}	T_3
T_{10}	T_1	T_4
T_{11}	T_2	T_5
T_{12}	T_3	T_6
T_{13}	T_4	T_7
T_{14}	T_5	T_8
T_{15}	T_6	T_9
T_{16}	T_7	T_{10}



3.5.1 Treatments details

T_1: Foliar application of Zinc (Zn)

T_2: Foliar application of Manganese (Mn)

T_3: Foliar application of Copper (Cu)

T_4: Foliar application of Boron (B)

T_5: Foliar application of Zn + Mn

T_6: Foliar application of Zn + Cu

T_7: Foliar application of Zn + B

T_8: Foliar application of Mn + Cu

T_9: Foliar application of Mn + B

T_{10}: Foliar application of Cu +B

T_{11}: Foliar application of Zn + Mn + Cu

T_{12}: Foliar application of Zn + Mn + B

T_{13}: Foliar application of Zn + Cu + B

T_{14}: Foliar application of Mn + Cu + B

T_{15}: Foliar application of Zn + Mn + Cu + B

T_{16}: Control (no micro nutrients)

3.5.2 Time and methods of application of fertilizers

Recommended dose of fertilizers N:P:K (Nitrogen: Phosphorus: Potassium) 600:300:600 g plant^{-1} year^{-1} (Medhi *et al.*, 2007) were applied in all the plants. Full dose of phosphorus and potassium and half split dose of nitrogen in the form of urea, SSP and MOP were applied in the month of March during flowering and the remaining half split dose of nitrogen were applied in the month of September. Foliar spray of micronutrients were done twice during the month of April and October.

Dose of Foliar Micronutrients: Zn (Zinc, 0.5%), Mn (Manganese, 0.4%), Cu (Copper, 0.4%), B (Boron, 0.1%)

Form of Foliar Micronutrients: Zn ($ZnNO_3$, $6H_20$), Mn ($MnSO_4$), Cu ($CuSO_4$), B ($Na_2B_4O_7$, $10H_20$)

3.5.3 Intercultural Operations

3.5.3.1 Land preparation:

Before starting of the experiment, the experimental plot was cleaned from weeds, soil was loosened and ring basin were prepared for application of fertilizers and manures to prevent them from leaching and run off. Dead shoots, limbs, disease branches and water suckers were removed.

3.5.3.2 Plant protection:

After removing dead and disease branches, they were sprayed with 0.1% dichlorvos and cypermethrin @ 2ml/l at regular interval for control of leaf miner and citrus butterfly.

3**.5.3.3 Harvesting**

Mandarin fruits were harvested by hand picking and from the tall branches fruits were harvested with bamboo stick when the skin become loose and green coloured skin turns orange yellow in colour.

3.5.4 Observations recorded

3.5.4.1 Plant growth and development

Following parameters were recorded at initial and on yearly interval during the period of experiment and expressed finally as per cent promotion of growth over initial.

a. Plant girth

Plant girth was measured at 30 cm height from soil surface with measuring tape and was expressed in centimetre.

b. Plant height

Plant height was measured with the help of meter scale taking soil surface as basal point and top of the tip as distal end.

c. Plant canopy spread (Canopy: North-South and East-West)

Canopy spread was measured from north to south and east to west and radius was worked out assuming the plant canopy spread to be circular in nature and expressed in meter.

3.5.4.2 Fruit growth and development

a. Days from fruit set to maturity

Days were counted from fruit set to maturity.

b. Fruit set (%)

Four branches from each plant at different direction (east, west, north, south) were tagged and the number of fruits that set from each branch were counted and expressed in percentage. The percentage of fruit set was calculated as follows:

Fruit set (%) = (Number of fruitlets per branch/ Total number of flower per branch) X 100

c. Fruit drop (%)

Data on fruit drop was recorded from date of fruit set to till harvest at specific interval and was expressed in percentage. The percentage of fruit drop was calculated as follows:

Fruit drop (%) = {(Fruit Set-Fruit Retention) / Fruit Set} X100

d. Fruit retention (%)

Data on the fruit retention was recorded under every treatment at the time of fruit harvesting as well as at specific interval within the growth period.

The percentage of fruit retention was computed by using the following formula:

Fruit retention (%) = {(Total number of fruit set – total no. of fruit drop) / Total no. of fruit set} X 100

e.No. of fruits / plant

Total number of fruits per plant was counted at harvest and expressed in number.

f.Yield

Yield per tree (kg tree^{-1}) was calculated by multiplying the average weight (50 fruits) of the fruits with total number of fruits per plant produced at harvest whereas, yield per ha (t ha^{-1}) was calculated by multiplying the yield per tree with the total number of trees ha^{-1}.

3.5.4.3 Fruit Physical and Biochemical Parameters

a. Physical Parameters

i. Fruit length

The length of four fruits were measured with the help of a digital slide calliper and their mean value was expressed in cm.

ii. Fruit diameter

By using a slide calliper the diameter was measured in the portion of the fruit where it was widest in case of four fruits and mean was expressed in cm.

iii. Fruit weight

The fruit weight was measured by taking 50 representative fruits at random from each replication; these were weighed and expressed in g (average fruit weight).

iv. Fruit volume

The volume of four fruits was determined by water displacement method and their mean value was expressed in cubic centimetre.

v. Specific gravity

The specific gravity of fruit was calculated by dividing the average fruit weight with average fruit volume.

vi. No. of seeds

Total number of seeds per fruit were counted for four fruits and mean value was expressed in number.

vii. Seed weight

The fruit was cut out and seeds were separated, washed with water and weighed. Average weight of twenty seeds per fruit were measured and expressed in g.

viii. Peel weight

Weight of the peel was measured using a digital balance and expressed in g.

ix. Peel thickness

Thickness of the peel was measured by using a slide calliper and expressed in cm.

x. Juice content

After peeling and extracting the seeds, fruit was squeezed to obtain juice and was measured using a measuring cylinder and expressed in ml.

b. Biochemical Parameters

i. Total Soluble Solids (TSS)

Total Soluble Solids content of freshly harvested matured fruit was measured by Refractrometer which was calibrated at 20^{o}C and expressed in terms of °Brix.

ii. Acidity

Total titratable acidity was determined by titrating the extracted juice against N/10 NaOH using phenolphthalein as indicator and expressed in percentage (AOAC, 1990).

iii. TSS/ acid ratio

The ratio was calculated by dividing TSS value by titratable acidity content of fruit.

iv. Total Sugar and reducing sugar

The total sugar and reducing sugar content of fruits were estimated by standard procedure of AOAC (1990) using Fehling's A and Fehlings B reagents with methylene blue as an indicator through copper reduction method.

Calculation

$$\% \text{ Total sugar} = \frac{\text{mg of Dextrose X Volume made up X 100}}{\text{Titre X Weight of sample taken X 100}}$$

$$\% \text{ Reducing sugar} = \frac{\text{mg of Dextrose X Volume made up X 100}}{\text{Titre X Weight of sample taken X 100}}$$

v. Ascorbic Acid

2,6 – dichlorophenol indophenol dye titration method was used to estimate the ascorbic acid content of the fruit (AOAC, 1990; Ranganna 1997) and expressed as mg / 100g of fruit.

Procedure

(a) Standardization of dye

Standard ascorbic acid solution 5ml was diluted with 5ml of 30% metaphosphoric acid. This was titrated against dye solution till pink colour persists for 10 seconds. The dye factor (mg of ascorbic acid per ml of dye) as follows-

Dye Factor (D.F.) = 0.5/Titre

(b) Preparation of sample and titration

- 5ml fruit juice + 25 ml metaphosphoric acid
- Titration against blue dye
- Reading was taken

(c) Calculation

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titre x Factor x volume made up x 100}}{\text{Volume of filtrate taken x wt. or vol. of sample taken}}$$

3.5.4.4. Soil analysis (N, P, K, Fe, Mn, Cu, Zn)

Preparation of soil samples:

Soil samples from each experimental plot were collected at 0-30 cm depth under the canopy line of the tree basin with the help of a soil auger. The samples were thoroughly mixed, dried in shade, pulverized, to pass through 0.2mm sieve and kept in brown paper bag for chemical analysis.

Time:

Soil samples were collected before the initiation of the research work, one year and two years after installation of the treatment.

Area:

Soil samples were taken from the area where manures were applied, around the rhizosphere of the plants.

Chemical analysis:

a. Total nitrogen content of soil was determined by micro-kjeldahl's method (Jackson, 1973).

b. Available phosphorus of soil sample was determined colorimetrically following the procedure of Dickman and Bray (1940).

c. Available potassium of soil sample was determined by leaching the soil with neutral ammonium acetate and estimated by flame photometer (Jackson, 1973).

d. Micro nutrient viz. Fe, Mn, Cu and Zn of the soil sample was measured using Atomic Absorption Spectrophotometer.

3.5.4.5 Leaf analysis (N, P, K, Fe, Mn, Cu, Zn and C:N ratio)

Leaf sampling

1. It was made sure that the selected leaves represent the block being sampled.
2. It was walked diagonally through the orchard block, randomly identified sampling spot.
3. Sampling was done to cover a minimum of 10 % trees in an orchard.
4. Samples was collected from healthy trees only.
5. 5-7 months old flush leaves from non-fruiting terminals at 1.5 to 1.8 m from the ground were used for sampling in the month of July-August.
6. Samples was collected from all direction (North, South, West and East)
7. Each leaf samples was consisting about 100 leaves.
8. Clean paper bags were used to store the sample.
9. Labelling was done with clear indication of location, altitude and date of collection.

10. Sample was hold in a cooler place until they were sent to the laboratory.

Precaution

1. Immature leaves were avoided for their rapidly changing composition.
2. Sampling was not done on abnormal-appearing trees. Also, trees at the block's edge or at the end of rows were not sampled.
3. Diseased, insect-damaged, or dead leaves were not included in a sample.

Digestion of leaf samples

The digestion of leaf samples (1 g) for the estimation of total nitrogen was carried out in concentrated H_2S0_4 in the presence of a digestion mixture of following chemicals: Potassium sulphate - 400 parts, Copper sulphate - 20 parts, Mercuric oxide - 3 parts, Selenium powder - 1 parts. For estimation of P, K, Ca, Mg, Fe, Cu, Zn and Mn, the leaf samples (0.5 g) were digested in di-acid mixture prepared by mixing HNO_3 and $HC1O_4$ in the ratio of 4: 1 taking all precautions as suggested by Piper (1966).

Chemical analysis

a. The total nitrogen content (% dry weight basis) of the leaf sample was estimated by Micro-kjeldahl method as described by Black (1965).

b. Phosphorus content of leaf sample was estimated by Vanadomolybdate yellow colour method (Chapman and Pratt, 1961).

c. Potassium content was determined by standard procedure using flame photometer (Jackson, 1973).

d. Micro nutrient viz. Fe, Mn, Cu and Zn of the leaf sample were measured using Atomic Absorption Spectrophotometer.

e. Carbohydrate was calculated by following the methods of Hodge and

Hofreiter (1962) and C/N ratio of leaf was calculated as the ratio of total carbohydrate to the total nitrogen.

Determination of total carbohydrate content of leaf

The leaf samples were kept in an oven and dried. Dried leaves were then crushed and 100mg taken into a boiling tube and hydrolysed in boiling water bath for three hours with 5ml of 2.5 N HCl and then cooled in room temperature. The hydrolysed sample was then neutalized with solid sodium carbonate until the effervescence ceases. The volume is made up to 100ml and centrifuged. The supernatant was collected and 0.5 and 1ml aliquots were taken for analysis. Standard curve was prepared by taking 0,0.2,0.4,0.6,0.8 and 1ml of the working standard. 0 served as blank. Volume was made up to 1ml in all the tubes including the sample tubes by adding distilled water, 4ml of anthrone reagent added and the samples were heated for eight minutes in a boiling water bath and then made to cool. Readings of the green to dark green coloured samples was taken at 630nm in a spectrophotometer. Standard graph was drawn by plotting concentration of the standard on the X- axis versus absorbance on the Y- axis. The amount of carbohydrate present in the sample tube was determined from the graph and calculation was done as-

Amount of carbohydrate present in 100mg of the sample = (mg of glucose/ volume of the test sample) x 100.

3.5.4.6 Cost - Benefit analysis

The economics of different treatments and net return was calculated considering the valid rates of field worker wages, manures, fertilizers, biofertilizers, plant protection chemicals and market sale value of the harvested fruits and the net out turn per rupee of investment was worked out.

3.5.4.7 Statistical analysis

Data was analyzed for statistical inference following the statistical method for Randomized Block Design (RBD) described by Gomez and Gomez (1983).

Chapter - 4

RESULTS AND DISCUSSION

Experiment No.1: Integrated Nutrient Management of Khasi Mandarin

4.1. Results

4.1.1 Plant Growth and Development

The plant growth parameters were recorded at initial and on yearly interval during the period of experiment and expressed finally as per cent promotion of growth over initial.

4.1.1.1. Plant Height

It is evident from Table 4.1.1 and Figure 4.1.1 that plant height varied significantly among the treatments which varied from 4.84m to 5.43m in 2016 and 5.20m to 5.76m in 2017. Maximum plant height (5.43m) was observed in T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)followed by T_{11}(FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF)(5.40m) during 2016.Whereas, T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) recorded maximum plant height (5.76m) followed by T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) (5.74m) in 201. However, the pooled data of two consecutive years had shown that maximum plant height in T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) (5.59m) followed by T_{11} (FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF)(5.55m) while T_{13} (control) recorded minimum plant height (5.02m).

Calculating the promotion percentage over initial plant height, maximum plant height promotion percentage was observed in T_7 (6.45%) followed by T_4 (Neem Cake (NC) to supply 50% K+ 50% RDF) (6.11%) during 2016, whereas; T_{12} recorded maximum promotion percentage (15.13 %) and followed by T_7 (12.48%) in 2017 and pooled data also showed highest with T_{12} (10.45 %) followed by T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) (9.46%) while control (T_{13}) recorded the lowest value (5.64%).

4.1.1.2 .Stem girth

Table 4.1.1 and Figure 4.1.2 revealed that stem girth varied from 34.96cm to 51.94cm in 2016 and 36.38cm to 54.87cm in 2017 due to application of different combination of integrated nutrients. Maximum stem girth (51.94cm, 54.87cm), was observed in T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) which was statistically *at par* with T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) (51.01cm, 54.01cm), during 2016, 2017 and the pooled data of two consecutive years also showed maximum stem girth with T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) (53.41cm) which was also *at par* with T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) (52.51cm) which are significantly superior over T_{13} (Control)(35.67cm).

However, calculating promotion percentage over initial,T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB)showed maximum promotion percentage in both the years (10.60%, 17.11%), and pooled data(13.86 %) which was followed by T_{11}(FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF) (14.18%)in 2017 and 11.42% in pooled data while T_4(Neem Cake (NC) to supply 50% K+ 50% RDF)recorded second highest (9.85%) during 2016. T_{13} (Control) recorded minimum percentage promotion of stem girth in 2016, 2017 and pooled data (5.17%, 9.44%, 7.30%), respectively.

4.1.1.3. Plant Canopy Spread (North – South)

It is obvious from Table 4.1.2 that all treatments varied significantly over control with regard to plant canopy spread, North – South (N-S).The plant canopy spread varied from 2.19m to 2.76 m in 2016 and 2.31m to 3.12m in 2017. T_{11}(FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF) recorded maximum plant canopy spread (2.76m) in 2016 followed by T_7 (2.68m) during 2016. Whereas, T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) recorded maximum canopy spread (3.12m) in 2017. However, canopy spread at T_{11}(FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF) (3.11m) was at par with T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) during 2017.The pooled data also showed maximum spread in T_{11}(FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF) (2.94m) followed by T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)(2.90m). Minimum canopy spread (N-S) was recorded in Control (2.25m).

Table 4.1.1Effect of integrated nutrient management on plant height and stem girth

Treatment	Plant Height(m)			Percent Promotion over initial			Stem Girth(cm)			Percent Promotion over initial		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	5.14	5.50	5.32	2.37 (8.85)	9.49 (17.95)	5.93 (14.10)	35.98	37.94	36.96	6.11 (14.31)	11.90 (20.18)	9.00 (17.46)
T_2	5.12	5.49	5.31	3.62 (10.97)	10.99 (19.36)	7.30 (15.68)	39.17	41.26	40.22	6.13 (14.33)	11.80 (20.09)	8.96 (17.42)
T_3	5.10	5.43	5.27	3.22 (10.33)	9.85 (18.29)	6.53 (14.81)	37.72	39.81	38.77	6.03 (14.21)	11.91 (20.19)	8.97 (17.43)
T_4	5.36	5.63	5.50	6.11 (14.31)	11.42 (19.75)	8.76 (17.22)	45.67	46.70	46.19	9.85 (18.29)	12.34 (20.56)	11.09 (19.45)
T_5	5.10	5.43	5.27	4.70 (12.52)	11.43 (19.76)	8.06 (16.50)	39.52	41.79	40.65	6.12 (14.32)	12.21 (20.45)	9.16 (17.62)
T_6	5.05	5.38	5.22	4.75 (12.58)	11.54 (19.86)	8.15 (16.58)	40.63	42.83	41.73	6.24 (14.47)	12.01 (20.27)	9.13 (17.58)
T_7	5.43	5.74	5.59	6.45 (14.71)	12.48 (20.69)	9.46 (17.91)	51.94	54.87	53.41	6.93 (15.26)	12.97 (21.11)	9.95 (18.38)
T_8	5.15	5.47	5.31	5.29 (13.30)	11.79 (20.08)	8.54 (16.99)	41.30	42.94	42.12	6.15 (14.35)	10.37 (18.79)	8.26 (16.70)
T_9	5.18	5.50	5.34	5.05 (12.98)	11.49 (19.81)	8.27 (16.71)	44.47	46.98	45.72	6.96 (15.30)	13.00 (21.13)	9.98 (18.42)
T_{10}	5.25	5.51	5.38	5.61 (13.70)	10.79 (19.18)	8.20 (16.64)	42.53	44.88	43.70	6.30 (14.54)	12.18 (20.42)	9.24 (17.69)
T_{11}	5.40	5.69	5.55	6.07 (14.26)	11.72 (20.02)	8.89 (17.35)	46.26	48.61	47.44	8.65 (17.11)	14.18 (22.12)	11.42 (19.75)
T_{12}	5.29	5.76	5.53	5.77 (13.90)	15.13 (22.89)	10.45 (18.86)	51.01	54.01	52.51	10.60 (19.00)	17.11 (24.43)	13.86 (21.85)
T_{13}	4.84	5.20	5.02	1.87 (7.86)	9.40 (17.86)	5.64 (13.73)	34.96	36.38	35.67	5.17 (13.14)	9.44 (17.89)	7.30 (15.68)
SEm(±)	0.089	0.111	0.154	1.039	0.652	0.978	1.995	1.481	1.828	0.866	0.936	0.588
$CD_{(0.05)}$	0.261	0.325	0.449	3.033	1.902	2.854	5.822	4.322	5.334	2.527	2.731	1.715

*Angular transformed values are in parenthesis

supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF) (2.94m) followed by T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)(2.90m). Minimum canopy spread (N-S) was recorded in Control (2.25m).

Regarding promotion percentage of plant canopy spread N-S, T_{11} (FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF) recorded highest promotion percentage (13.73%) followed by T_7 (13.25%) in 2016. During 2017, T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) recorded highest (31.42%) followed by T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) (28.38%). However, it was statistically *at par* with T_{11} (FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF) (27.88%). The pooled data indicated that T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) was maximum (22.33%) followed by T_{11}(FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF)(20.81%) which was statistically *at par* with T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB)(20.59%) compared with control(T_{13}) (8.21%).

4.1.1.4. Plant Canopy Spread (East-West)

The data presented in Table 4.1.2 revealed that the plant canopy spread East-West (E-W) varied from 2.33m to 2.94m and 2.44m to 3.36m during 2016 and 2017, respectively. Maximum spread was observed in T_{11} (FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF) (2.94m) in 2016 followed by T_7 (2.85m).Whereas, T_{12} (FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) recorded maximum (3.36m) followed by

Table 4.1.2 Effect of integrated nutrient management on plant Canopy spread North-South (N-S) and East-West (E-W)

Treatment	Canopy spread NS(m)			Percent Promotion over initial			Canopy spread EW(m)			Percent Promotion over initial		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	2.25	2.39	2.32	6.12 (14.32)	12.62 (20.81)	9.37 (17.82)	2.39	2.52	2.45	6.80 (15.12)	12.72 (20.89)	9.76 (18.21)
T_2	2.29	2.51	2.40	6.99 (15.33)	17.18 (24.29)	12.09 (20.34)	2.46	2.66	2.56	9.18 (17.64)	17.92 (25.05)	13.55 (21.60)
T_3	2.26	2.41	2.33	6.59 (14.87)	13.57 (21.61)	10.08 (18.51)	2.40	2.56	2.48	7.47 (15.86)	14.51 (22.39)	10.99 (19.36)
T_4	2.60	2.90	2.75	12.54 (20.74)	25.44 (30.29)	18.99 (25.83)	2.77	3.14	2.95	14.30 (22.22)	29.22 (32.72)	21.76 (27.81)
T_5	2.35	2.56	2.46	8.73 (17.18)	18.13 (25.20)	13.43 (21.50)	2.52	2.70	2.61	10.61 (19.01)	18.39 (25.39)	14.50 (22.38)
T_6	2.33	2.62	2.48	8.05 (16.49)	21.19 (27.40)	14.62 (22.48)	2.50	2.79	2.65	9.98 (18.41)	22.60 (28.38)	16.29 (23.80)
T_7	2.68	3.12	2.90	13.25 (21.34)	31.42 (34.09)	22.33 (28.20)	2.85	3.21	3.03	14.76 (22.60)	29.14 (32.67)	21.95 (27.94)
T_8	2.38	2.64	2.51	9.76 (18.20)	21.44 (27.58)	15.60 (23.26)	2.55	2.81	2.68	11.58 (19.90)	22.83 (28.54)	17.21 (24.51)
T_9	2.45	2.81	2.63	11.04 (19.41)	27.04 (31.33)	19.04 (25.87)	2.62	3.01	2.82	12.77 (20.94)	29.42 (32.85)	21.10 (27.34)
T_{10}	2.52	2.73	2.63	11.48 (19.81)	20.48 (26.91)	15.98 (23.56)	2.69	2.95	2.82	13.15 (21.26)	23.96 (29.31)	18.56 (25.52)
T_{11}	2.76	3.11	2.94	13.73 (21.75)	27.88 (31.87)	20.81 (27.14)	2.94	3.29	3.11	15.32 (23.04)	29.02 (32.60)	22.17 (28.09)
T_{12}	2.63	3.00	2.82	12.80 (20.97)	28.38 (32.19)	20.59 (26.98)	2.80	3.36	3.08	14.36 (22.27)	37.10 (37.52)	25.73 (30.48)
T_{13}	2.19	2.31	2.25	5.48 (13.54)	10.94 (19.32)	8.21 (16.65)	2.33	2.44	2.39	6.24 (14.47)	11.13 (19.49)	8.69 (17.14)
SEm(±)	0.086	0.128	0.115	1.200	1.484	1.374	0.109	0.135	0.143	1.034	1.592	1.235
$CD_{(0.05)}$	0.252	0.375	0.334	3.503	4.332	4.010	0.318	0.394	0.416	3.018	4.648	3.604

*Angular transformed values are in parenthesis, NS (North-South); EW (East-West)

T_{11} (3.29m) during 2017. In pooled data, T_{11} recorded maximum (3.11m). However, T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB)(3.08m) was statistically at par with T_{11} (FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF) in pooled data.

The plant canopy spread (E-W) promotion percentage also varied significantly over control (T_{13}). Maximum promotion percentage was observed in T_{11} (FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF) (15.32%) followed by T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) (14.76%) in 2016. T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) recorded maximum (37.10%) followed by T_9 (29.42%) in 2017. However, the pooled data showed T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) as maximum percentage of canopy spread E-W (25.73) in pooled data of the two consecutive years compared with T_{13} (control) (8.69%).

4.1. 2.Fruit Growth and Development

4.1.2.1. Fruit Set %

Perusal of data in Table 4.1.3 revealed that all the treatments varied significantly with fruit set percentage. The fruit set percentage varied between 50.32% to 65.05% in 2016 and 49.68% and 63.47% in 2017. T_{12} (FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) recorded highest fruit set % (65.05% and 63.47%)in 2016 and 2017. However, it was followed by T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) (64.72%) during

2016. whereas, in 2017, T_{11} (FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF) showed second highest fruit set percentage (61.98%). The pooled data revealed that fruit set percentage was highest in T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB)(64.26%) which was followed by T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)(63.07%) whereas, control recorded the lowest value in both the years and at pooled analysis (50.32 %, 49.68 %, 50.00 %).

4.1.2.2. Days from fruit set to maturity

It is clear from the data presented in Table 4.1.3 that days from fruit set to maturity varied from 299.51 days to 308.79 days in 2016 and 296.89 days to 305.69 days in 2017. Treatments varied significantly with days from fruit set to maturity. Longest maturity days was observed in T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) (308.79 days and 305.69days), which was followed by T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) (307.44 days, 305.68 days) in both the years, 2016 & 2017.

The pooled data showed longest day to maturity with T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB)(307.24 days) followed by T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)(306.56 days), while shortest maturity day was observed in T_{13} (299.51 days, 296.89 days ,298.20 days) in 2016, 2017 and at pooled data, respectively.

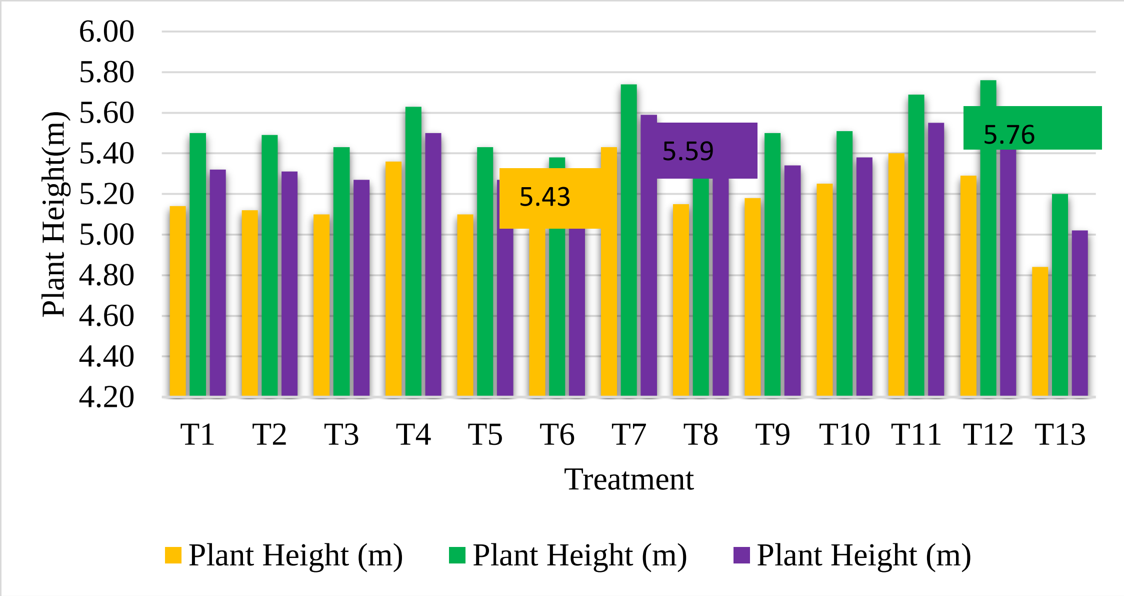


Fig. 4.1.1Effect of Integrated Nutrient Management on Plant Height

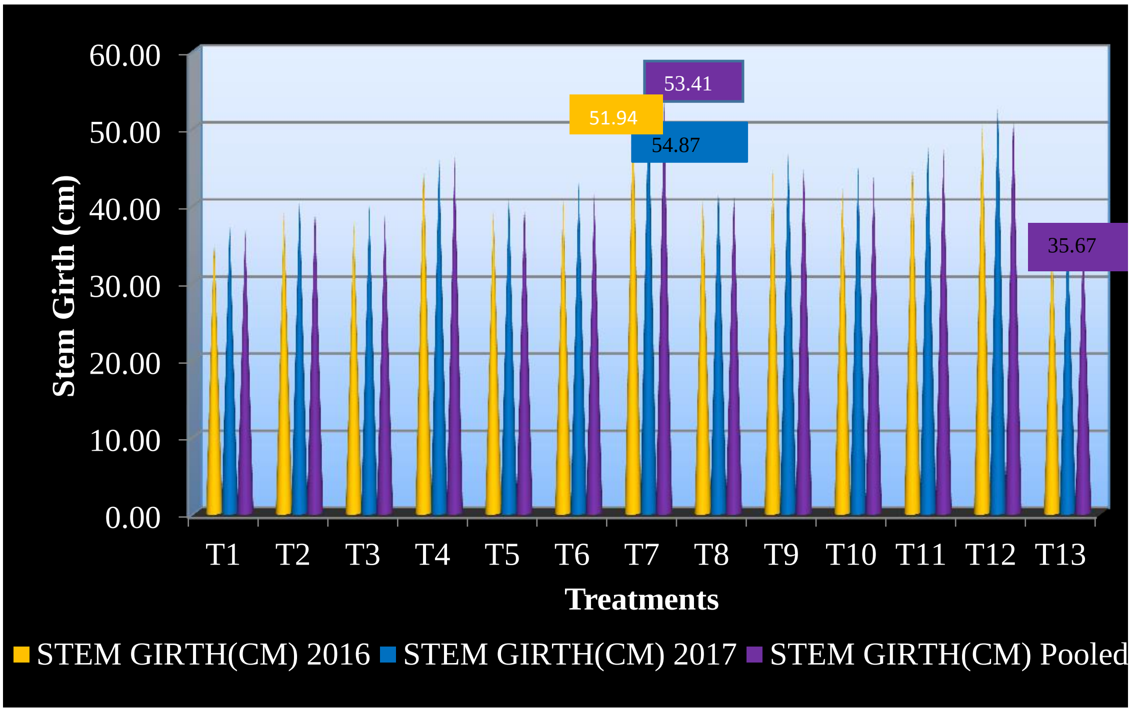


Fig.4.1.2 Effect of Integrated Nutrient Management on Stem girth

4.1.2.3. Fruit Drop %

In this experiment, it was found that fruit drop percentage significantly varied among the treatments in both the years. The data presented in Table 4.1.4 and Table 4.1.5 and Figure 4.1.3 clearly showed that fruit drop percentage consistently increased from 60 Days after fruit set (DAF) to 120DAFS and subsequently fallen on 180DAFS onwards in both the year of study. Fruit drop percentage ranged between 14.24 to 19.62 per cent in 2016 and 18.54 to 23.98 per cent in 2017 at 60DAFS which got increased and ranged between 16.23 to 24.18 per cent in 2016 and 20.19 to 28.16 per cent in 2017 at 120 DAFS.

Pooled data also revealed that fruit drop percentage which range between 16.39 to 21.80 per cent in 60 DAFS got increased and ranged between 18.21 and 26.17 per cent in 120 DAFS. From 180 DAFS to pre harvest situation, fruit drop percentage was found low (1.14 to 5.08%) in 2016; (1.84 to 7.02 %) in 2017 and (1.49 to 6.05 %) in pooled data. Further, it was observed that total fruit drop was significantly higher in 2017 (ranged between 47.58 to 64.19) compared with 2016 (ranged between 36.42 to 52.69). Perusal of the pooled data revealed that total fruit drop was found minimum in T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) (42.00%) followed by T_4 (Neem Cake (NC) to supply 50% K+ 50% RDF)(46.28%) and T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) (46.88%) compared with control(58.44%).

4.1.2.4. Fruit Retention %

Perusal of the data presented in Table 4.1.6 and Table 4.1.7, figure

4.1.4 showed that retention percentage of fruit significantly varied among the selected treatments in both 2016 and 2017 along with pooled data. Moreover, it was found that retention percentage of fruit gradually dropped from 60DAFS to pre harvest condition.in 2016 and was ranged between 80.38 to 85.76% at 60 DAFS, whereas, it ranged between 46.82 to 63.2% at pre harvest condition. Similarly, in 2017, it ranged between 76.02 to 81.46% in 60 DAFS, which further declined and ranged between 36.30 to 52.80 % at pre harvest condition. However, it was noted that the retention percentage was higher in 2016 (ranged between 46.82 to 63.20 %) compared with 2017 (ranged between 36.30 to 52.80 %). From the table 4.1.7, it is evident that in case of pooled data, final fruit retention was found highest in T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) (58.00%) followed by T_4 (Neem Cake (NC) to supply 50% K+ 50% RDF)(53.72%) and T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)(53.12%) compared with control (41.56 %).

4.1.2.5. Number of fruits per plant

Number of fruits per plant were recorded and indicated in Table 4.1.3. Data on average number of fruits per plant presented that there was a significant increase due to various treatments during the period of study. Maximum number of fruits was observed in T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) (242.74), which was *at par* with T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB)(239.53) in 2016.Whereas, T_6(VC to supply 50% K + 50% RDF+AZ+PSB+ KSB) recorded maximum number of fruits (250.28) which was *at par* with T_3(Vermi compost (VC) to supply 50% K+

50% RDF) (245.10)in 2017. However, in pooled analysis, the data showed that T_3 (Vermi compost (VC) to supply 50% K+ 50% RDF) recorded maximum number (232.27) which was *at par* with treatment T_6 (VC to supply 50% K + 50% RDF+AZ+PSB+ KSB) (231.69). It is observed that in pooled data, number of fruits per plant was also found high in T_2, T_4 & T_{12} (228.41, 228.31 and 227.36) compared with control (51.95).

4.1.2.6. Yield

Yield varied significantly with the application of integrated nutrients comprising of organic, inorganic and biofertilizers. It varied from 4.79 kg per tree or 5.32 t per ha to 37.33 kg per tree / 41.47 t per ha during 2016, whereas, in 2017 it varied 4.51kg per tree or 5.01t per ha to 34.63kg per tree or 38.47t per ha.

The treatment which recorded maximum yield during 2016 and 2017 was T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB)(37.33 kg per tree or 41.47t per ha and 34.63 kg per tree or 38.47 t per ha),respectively and was followed by T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)(33.98kg per tree or 37.75t per ha and 32.30kg per tree or 35.89 t per ha).The pooled analysis also revealed that T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB)was recorded with maximum yield (35.98kg per tree or 39.97t /ha) followed by T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)(33.14kg per tree and 36.82 t/ha) as compared with control (4.65kg/tree and 5.17 t/ ha) as shown in Table 4.1.8 and Figure 4.1.5.

Table 4.1.3 Effect of integrated nutrient management on fruit set %, days from fruit set to maturity, number of fruits per plant

Treatment	Fruit set %			Days from fruit set to maturity			Number of fruits per plant		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	56.63	53.14	54.88	296.54	297.35	296.95	106.27	107.43	106.85
T_2	58.71	56.16	57.44	297.65	299.47	298.56	222.51	234.31	228.41
T_3	57.31	55.69	56.50	295.69	298.65	297.17	219.44	245.10	232.27
T_4	61.72	61.47	61.59	299.60	300.12	299.86	227.77	228.85	228.31
T_5	61.85	59.32	60.59	305.01	301.97	303.49	208.67	221.81	215.24
T_6	60.91	58.45	59.68	299.78	298.46	299.12	213.10	250.28	231.69
T_7	64.72	61.42	63.07	307.44	305.68	306.56	242.74	198.18	220.46
T_8	59.39	57.98	58.68	302.16	300.16	301.16	193.85	218.09	205.97
T_9	63.20	61.09	62.14	306.87	303.65	305.26	219.63	225.03	222.33
T_{10}	64.31	61.04	62.68	304.15	304.09	304.12	211.57	209.89	210.73
T_{11}	63.78	61.98	62.88	307.85	304.09	305.97	225.35	198.69	212.02
T_{12}	65.05	63.47	64.26	308.79	305.69	307.24	239.53	215.19	227.36
T_{13}	50.32	49.68	50.00	299.51	296.89	298.20	46.93	56.97	51.95
SEm(±)	0.896	1.011	0.732	0.954	1.303	0.788	1.761	2.003	1.442
$CD_{(0.05)}$	2.616	2.950	2.136	2.785	3.802	2.299	5.141	5.847	4.208

Table 4.1.4 Effect of integrated nutrient management on fruit drop percentage at 60, 120 and 180 days after fruit set (DAFS)

	Fruit drop% at 60DAFS			Fruit drop% at 120DAFS			Fruit drop% at 180DAFS		
Treatment	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
T_1	18.77	22.12	20.44	22.14	26.72	24.43	1.96	2.91	2.44
T_2	17.48	21.47	19.48	18.14	22.19	20.17	1.77	2.92	2.34
T_3	16.86	20.86	18.86	18.02	22.17	20.10	1.80	2.96	2.38
T_4	15.94	19.94	17.94	18.41	22.50	20.46	1.84	2.04	1.94
T_5	17.23	21.23	19.23	22.13	27.00	24.56	1.81	2.59	2.20
T_6	16.28	20.28	18.28	18.45	22.91	20.68	1.91	2.87	2.39
T_7	15.17	19.17	17.17	20.14	25.18	22.66	1.65	1.84	1.75
T_8	17.99	22.03	20.01	23.47	27.22	25.34	1.14	3.01	2.07
T_9	16.04	20.05	18.05	22.30	27.43	24.87	1.05	1.94	1.49
T_{10}	16.86	20.56	18.71	24.09	28.05	26.07	1.81	2.12	1.97
T_{11}	15.33	19.49	17.41	21.87	26.07	23.97	1.58	2.03	1.81
T_{12}	14.24	18.54	16.39	16.23	20.19	18.21	1.66	2.04	1.85
T_{13}	19.62	23.98	21.80	24.18	28.16	26.17	2.18	3.02	2.60
SEm(±)	0.972	0.931	0.765	1.155	1.696	0.779	0.189	0.261	0.129
$CD_{(0.05)}$	2.837	2.719	2.234	3.370	4.951	2.273	0.551	0.762	0.376

Table 4.1.5 Effect of integrated nutrient management on fruit drop percentage at 240DAFS, Pre harvest drop and total fruit drop percentage

	Fruit drop% at 240DAFS			Fruit drop% at pre harvest			Total Fruit drop%		
Treatment	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
T_1	3.68	5.01	4.34	2.93	3.21	3.07	49.48	59.97	54.72
T_2	2.71	3.21	2.96	3.97	4.18	4.07	44.06	53.97	49.02
T_3	3.76	4.05	3.90	2.97	3.78	3.37	43.41	53.82	48.61
T_4	2.46	4.01	3.24	2.50	2.91	2.71	41.16	51.40	46.28
T_5	3.55	4.03	3.79	2.81	3.01	2.91	47.53	57.86	52.69
T_6	2.94	4.06	3.50	3.32	4.01	3.67	42.90	54.13	48.51
T_7	2.84	3.06	2.95	2.01	2.69	2.35	41.81	51.94	46.88
T_8	3.48	4.03	3.76	2.26	3.01	2.63	48.34	59.30	53.82
T_9	2.15	3.02	2.59	1.78	2.01	1.90	43.33	54.45	48.89
T_{10}	2.61	3.01	2.81	2.71	3.47	3.09	48.08	57.21	52.64
T_{11}	2.39	3.03	2.71	2.96	3.06	3.01	44.14	53.68	48.91
T_{12}	1.40	2.94	2.17	2.89	3.87	3.38	36.42	47.58	42.00
T_{13}	5.08	7.02	6.05	1.64	2.01	1.82	52.69	64.19	58.44
SEm(±)	0.464	0.487	0.486	0.411	0.465	0.409	1.450	1.070	1.135
$CD_{(0.05)}$	1.355	1.422	1.418	1.201	1.358	1.193	4.232	3.122	3.313

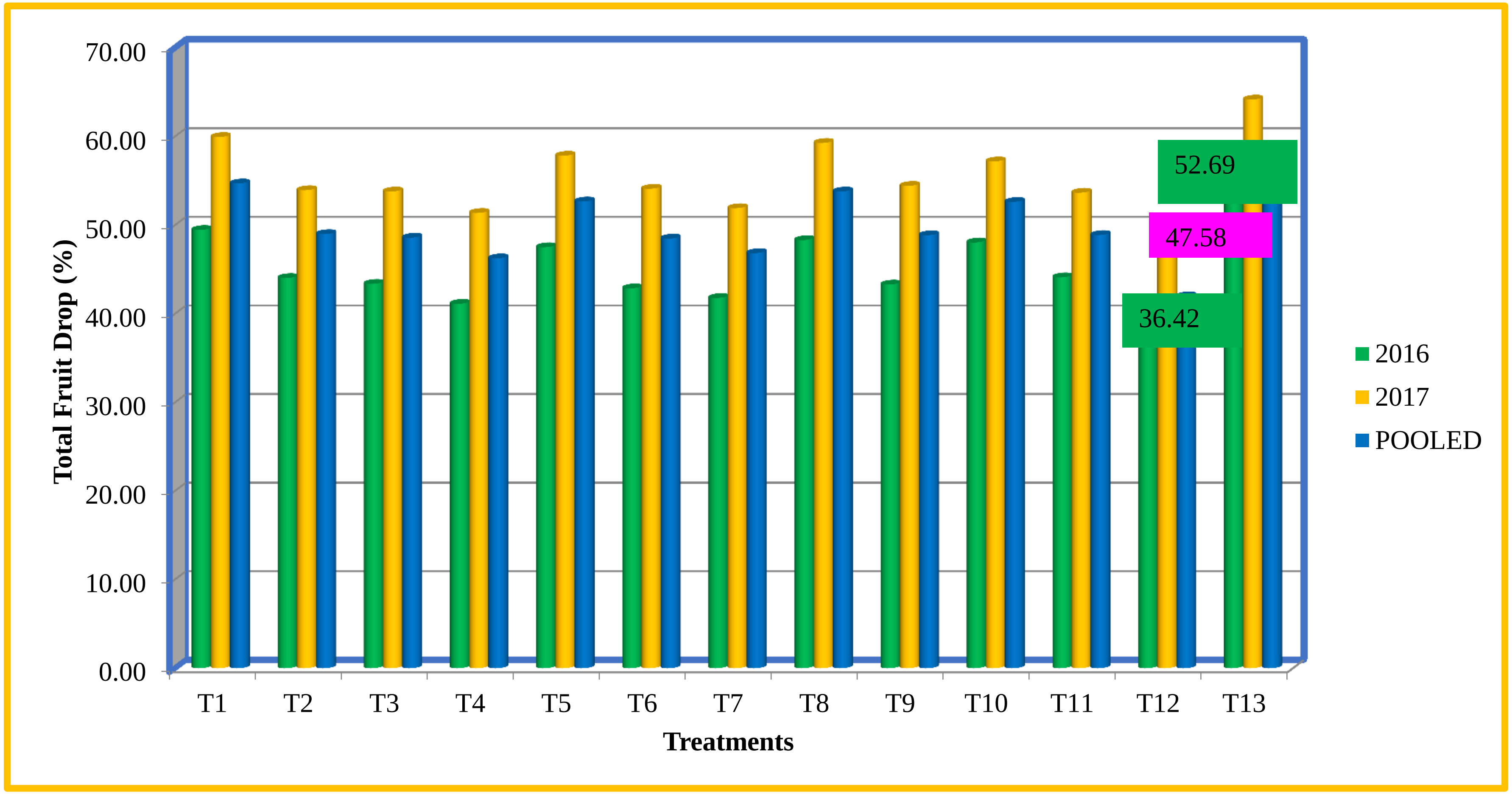


Fig. 4.1.3 Effect of Integrated Nutrient Management on Total Fruit Drop Percentage

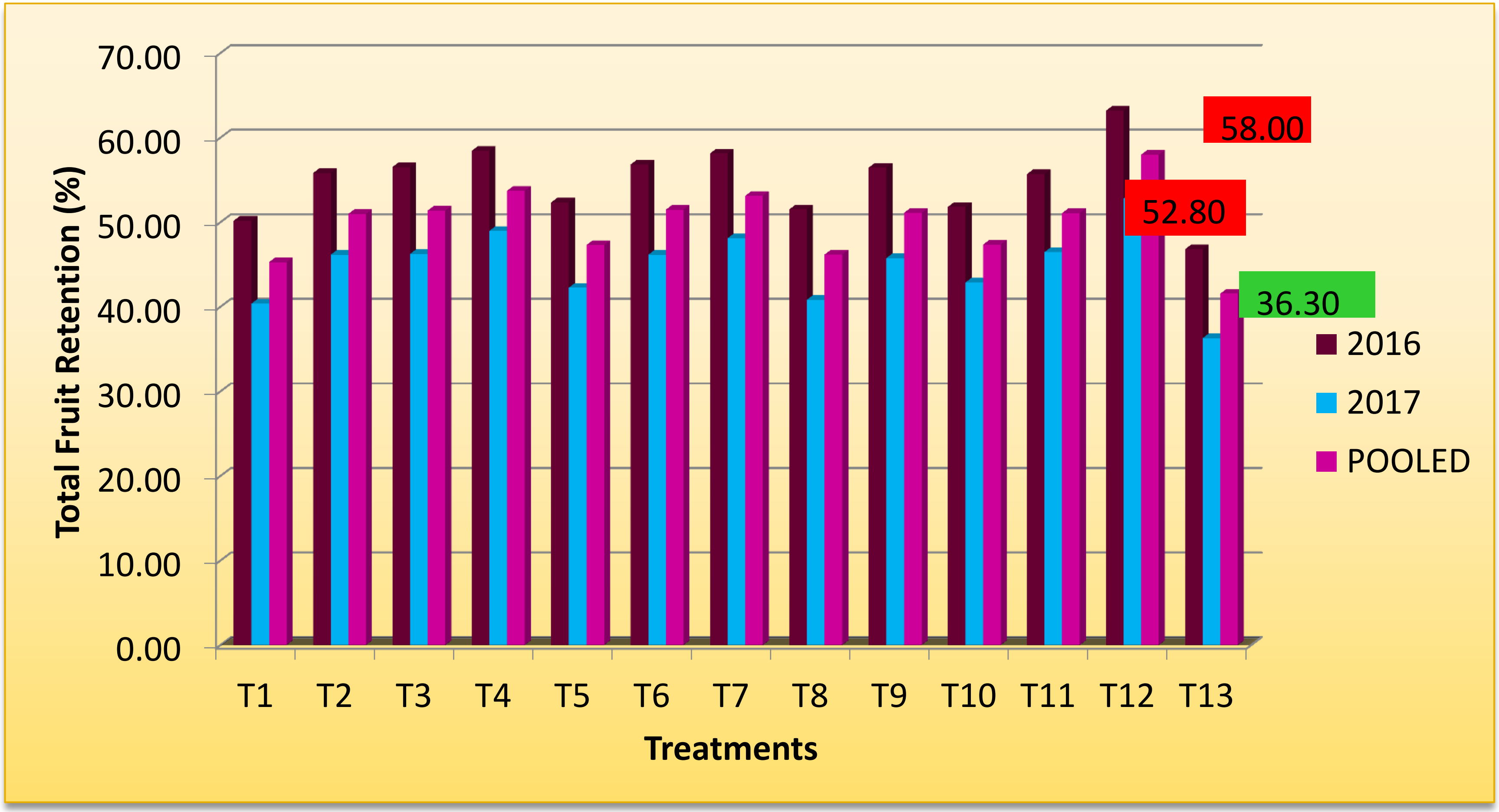


Fig. 4.1.4 Effect of Integrated Nutrient Management on Total Fruit Retention Percentage

Table 4.1.6 Effect of integrated nutrient management on fruit retention percentage at 60, 120 and 180 days after fruit set (DAFS)

Treatment	Fruit retention% at 60DAFS			Fruit retention% at 120DAFS			Fruit retention% at 180DAFS		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	81.23	77.88	79.56	59.09	51.16	55.13	57.13	48.25	52.69
T_2	82.52	78.53	80.52	64.38	56.34	60.36	62.61	53.42	58.02
T_3	83.14	79.14	81.14	65.12	56.97	61.04	63.32	54.01	58.67
T_4	84.06	80.06	82.06	65.65	57.56	61.60	63.81	55.52	59.66
T_5	82.77	78.77	80.77	60.64	51.77	56.21	58.83	49.18	54.01
T_6	83.72	79.72	81.72	65.27	56.81	61.04	63.37	53.94	58.65
T_7	84.83	80.83	82.83	64.69	55.65	60.17	63.04	53.81	58.42
T_8	82.01	77.97	79.99	58.54	50.75	54.65	57.40	47.74	52.57
T_9	83.96	79.95	81.95	61.66	52.52	57.09	60.61	50.58	55.59
T_{10}	83.14	79.44	81.29	59.05	51.39	55.22	57.24	49.27	53.25
T_{11}	84.67	80.51	82.59	62.80	54.44	58.62	61.22	52.41	56.81
T_{12}	85.76	81.46	83.61	69.53	61.27	65.40	67.87	59.23	63.55
T_{13}	80.38	76.02	78.20	56.20	47.86	52.03	54.02	44.84	49.43
SEm(±)	0.931	0.846	0.793	1.450	1.281	1.230	1.488	1.667	1.163
$CD_{(0.05)}$	2.719	2.470	2.314	4.232	3.739	3.589	4.343	4.866	3.394

Table 4.1.7 Effect of integrated nutrient management on fruit retention percentage at 240DAFS, Pre harvest retention and total fruit retention percentage

	Fruit retention% at 240DAFS			Fruit retention% at pre harvest			Total Fruit retention%		
Treatment	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
T_1	52.78	43.24	48.01	50.18	40.37	45.28	50.18	40.37	45.28
T_2	59.65	50.21	54.93	55.81	46.16	50.98	55.81	46.16	50.98
T_3	59.42	49.96	54.69	56.52	46.25	51.39	56.52	46.25	51.39
T_4	60.57	51.51	56.04	58.46	48.98	53.72	58.46	48.98	53.72
T_5	55.04	45.15	50.10	52.35	42.26	47.31	52.35	42.26	47.31
T_6	59.87	49.88	54.87	56.82	46.15	51.49	56.82	46.15	51.49
T_7	60.09	50.75	55.42	58.13	48.11	53.12	58.13	48.11	53.12
T_8	53.64	43.71	48.68	51.52	40.84	46.18	51.52	40.84	46.18
T_9	58.02	47.56	52.79	56.46	45.76	51.11	56.46	45.76	51.11
T_{10}	54.43	46.26	50.34	51.82	42.89	47.36	51.82	42.89	47.36
T_{11}	58.51	49.38	53.94	55.70	46.48	51.09	55.70	46.48	51.09
T_{12}	65.70	56.29	60.99	63.20	52.80	58.00	63.20	52.80	58.00
T_{13}	47.97	37.82	42.90	46.82	36.30	41.56	46.82	36.30	41.56
SEm(±)	1.591	1.495	1.213	1.838	1.606	1.278	1.838	1.606	1.278
$CD_{(0.05)}$	4.645	4.364	3.541	5.366	4.688	3.729	5.366	4.688	3.729

Table 4.1.8 Effect of integrated nutrient management on fruit yield

Treatment	Yield (kg per tree)			Yield (tonnes per hectare)		
	2016	2017	Pooled	2016	2017	Pooled
T_1	11.67	9.15	10.41	12.97	10.17	11.57
T_2	24.66	21.90	23.28	27.40	24.33	25.86
T_3	24.33	21.79	23.06	27.03	24.21	25.62
T_4	31.20	29.22	30.21	34.66	32.46	33.56
T_5	26.75	24.95	25.85	29.72	27.72	28.72
T_6	25.63	23.79	24.71	28.47	26.43	27.45
T_7	33.98	32.30	33.14	37.75	35.89	36.82
T_8	24.64	24.10	24.37	27.38	26.78	27.08
T_9	29.62	27.86	28.74	32.91	30.95	31.93
T_{10}	28.21	26.21	27.21	31.34	29.12	30.23
T_{11}	33.50	31.64	32.57	37.22	35.15	36.19
T_{12}	37.33	34.63	35.98	41.47	38.47	39.97
T_{13}	4.79	4.51	4.65	5.32	5.01	5.17
SEm(±)	1.450	1.296	1.190	1.450	1.257	1.183
$CD_{(0.05)}$	4.232	3.782	3.475	4.232	3.669	3.453

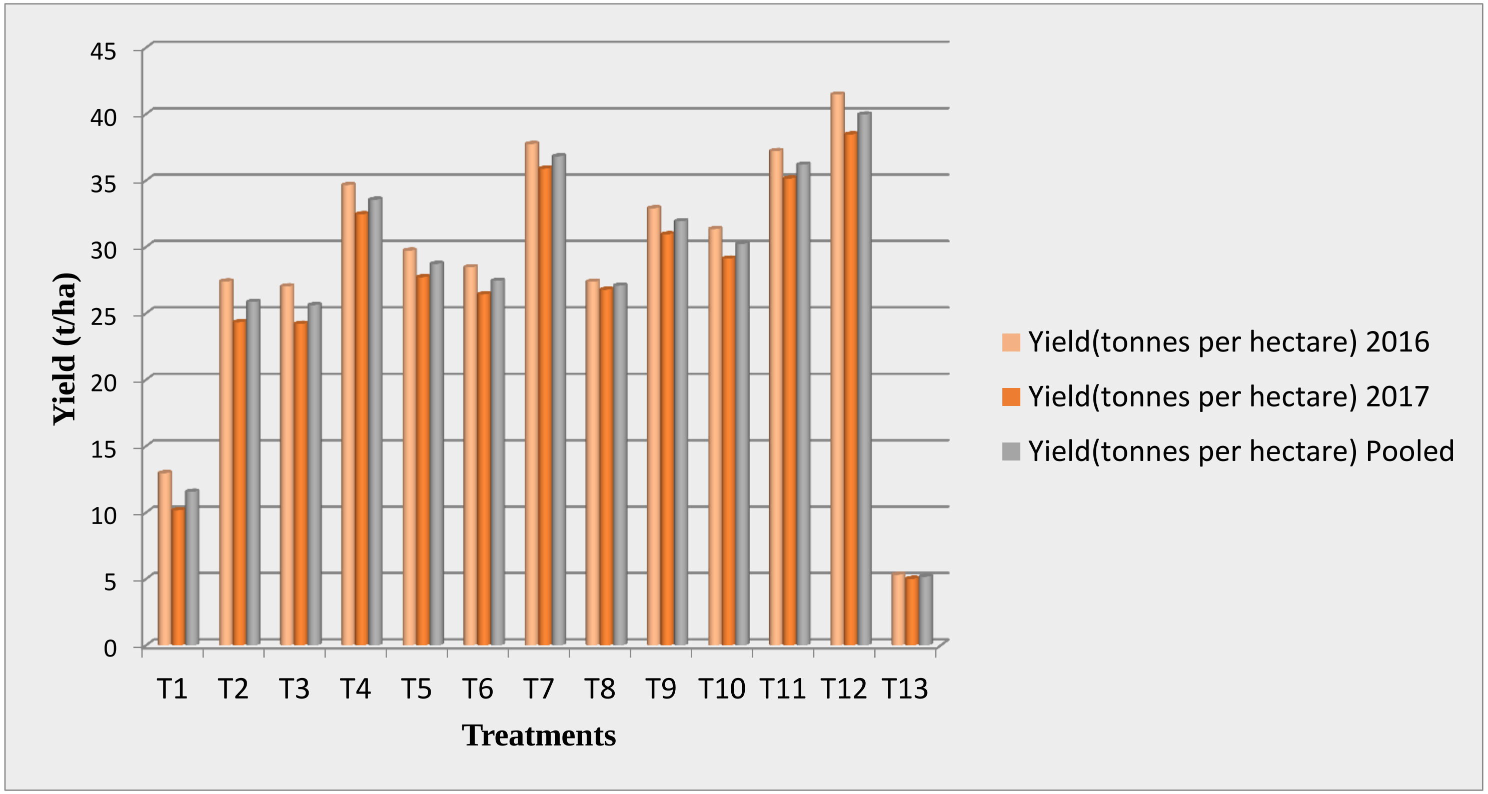


Fig. 4.1.5 Effect of Integrated Nutrient Management on Fruit Yield

4.1.3. Fruit Physical Parameters

4.1.3.1. Fruit Length (cm)

The data pertaining to fruit length shown in Table 4.1.9 indicated that significant increase was observed with fruit length, which ranged from 5.14cm to 5.85cm in the year 2016 and 4.67cm to 6.27cm in 2017.

Maximum fruit length was observed with T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)(5.85cm) which was statistically *at par* with T_4(Neem Cake (NC) to supply 50% K+ 50% RDF)(5.83cm) followed by T_{11}(FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF)(5.68cm) during 2016. In the year 2017, maximum fruit length was obtained with T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB)(6.27cm) followed by T_{11}(6.09cm) which was statistically *at par* with T_7(6.04cm).However, the pooled data of two consecutive years had shown that maximum fruit length was observed in T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)(5.95cm) which was *at par* with T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB)(5.93cm) followed by T_{11}(FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF)(5.88cm) compared with control(4.91cm).

4.1.3.2. Fruit Diameter (cm)

Perusal of the data in Table 4.1.9 and Figure 4.1.6 revealed that significant difference was observed among treatments with fruit diameter. The data varied from 6.00cm to 6.93cm and 5.11cm to 7.81cm during 2016 and 2017 respectively.

T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) recorded maximum fruit diameter (6.93cm), followed by T_4 (Neem Cake (NC) to supply 50% K+ 50% RDF) (6.82cm) followed by T_{12} (6.80cm) in the year 2016. T_{12} (FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) recorded maximum (7.81cm) followed by T_7 (7.24cm), in 2017 and the pooled data of the two experimental years also revealed that T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) had maximum fruit diameter (7.30cm) followed by T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)(7.08cm) compared with control (5.55cm).

4.1.3.3. Fruit weight (g)

The result of the present investigation revealed that fruit weight was significantly influenced by application of integrated nutrients. The fruit weight varied from 102.03g to 155.83g and 76.99g to 160.67g during 2016 and 2017 respectively as presented in Table 4.1.10.

Significantly heaviest fruit weight was observed in T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB)(155.83g) ,followed by T_{11} (148.58g), in the first year (2016) study while in the second year (2017) study, T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB recorded heaviest fruit (160.67g) but was *at par* with T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)(160.66g) and

T_{11}(158.66g).The pooled data indicated that fruit weight was maximum in T_{12} (158.25g) which was followed by T_{11}(FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF)(153.62g) over control(89.51g).

4.1.3.4. Fruit Volume (cc)

It is clear from the Table 4.1.9 that significant variation was observed in both the years and pooled data for average fruit volume of Khasi Mandarin. The data ranged from 109.17 cc to 150.83cc in 2016 and 67.67cc to 196.67cc in the year 2017.

Maximum fruit volume was obtained in T_{11}(FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF)(150.83cc) followed by T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)(149.17cc) in 2016, whereas, T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) was found highest (196.67cc), followed by T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)(158.33cc) in 2017 and the pooled data also revealed highest fruit volume in T_{12} (170.83cc) followed by T_7 (153.75cc) .However, control plant T_{13} observed lowest value (88.42cc) in pooled analysis.

4.1.3.5. Specific Gravity

The present studies indicated in Table 4.1.10 showed that specific gravity ranged from 0.89 to 1.07 during first year and varied from 0.82 to 1.21 during second year of experiment.

In the first year study, T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) recorded maximum specific

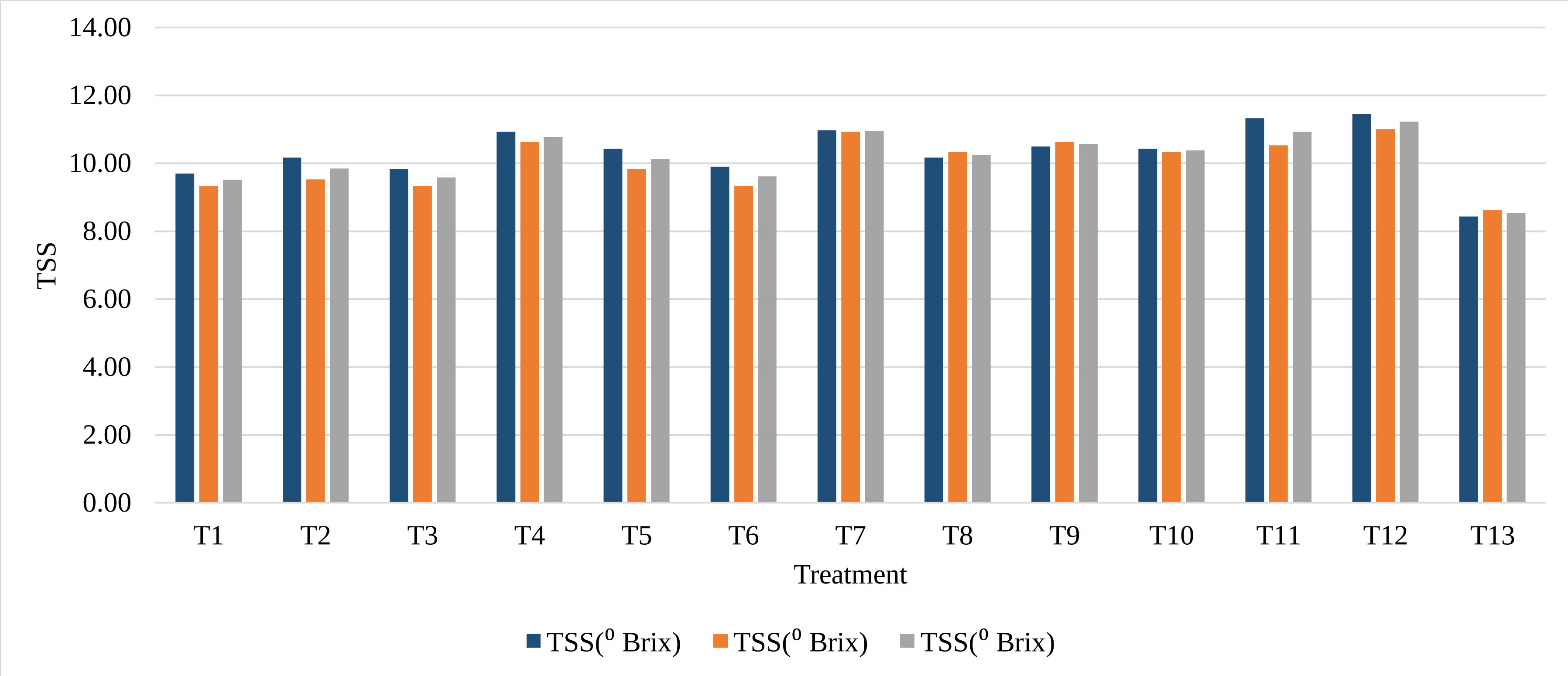


Fig. 4.1.6 Effect of Integrated Nutrient Management on Fruit Diameter

Table 4.1.9 Effect integrated nutrient management on fruit diameter, fruit length and fruit volume

Treatment	Fruit diameter(cm)			Fruit length (cm)			Fruit volume (cc)		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
T_1	6.16	5.32	5.74	5.21	4.80	5.00	115.00	70.00	92.50
T_2	6.33	5.46	5.90	5.28	4.86	5.07	124.17	83.33	103.75
T_3	6.38	5.45	5.92	5.25	5.08	5.17	123.33	85.00	104.17
T_4	6.82	6.39	6.61	5.83	5.82	5.83	145.00	140.67	142.83
T_5	6.46	6.12	6.29	5.42	5.16	5.29	135.00	111.67	123.33
T_6	6.42	5.75	6.08	5.37	5.09	5.23	127.50	90.00	108.75
T_7	6.93	7.24	7.08	5.85	6.04	5.95	149.17	158.33	153.75
T_8	6.38	6.09	6.24	5.40	5.08	5.24	129.17	106.67	117.92
T_9	6.61	6.33	6.47	5.57	5.66	5.61	129.17	123.33	126.25
T_{10}	6.55	6.26	6.41	5.58	5.10	5.34	140.83	120.00	130.42
T_{11}	6.80	6.73	6.76	5.68	6.09	5.88	150.83	146.67	148.75
T_{12}	6.80	7.81	7.30	5.60	6.27	5.93	145.00	196.67	170.83
T_{13}	6.00	5.11	5.55	5.14	4.67	4.91	109.17	67.67	88.42
SEm(±)	0.121	0.445	0.345	0.164	0.344	0.230	1.484	1.566	1.050
$CD_{(0.05)}$	0.353	1.299	1.006	0.478	1.005	0.671	4.330	4.572	3.066

Table 4.1.10 Effect of integrated nutrient management on juice content of fruit, fruit weight and fruit specific gravity

	Juice content (ml)			Fruit weight (g)			Specific gravity		
Treatment	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
T_1	49.14	30.03	39.58	109.85	85.01	97.43	0.96	1.21	1.08
T_2	63.27	35.06	49.17	110.84	93.00	101.92	0.89	1.12	1.00
T_3	54.16	35.01	44.58	110.89	87.67	99.28	0.90	1.03	0.97
T_4	74.55	40.03	57.29	136.97	127.67	132.32	0.94	0.91	0.93
T_5	65.42	37.40	51.41	128.19	112.01	120.10	0.95	1.00	0.98
T_6	60.24	35.01	47.63	120.29	93.01	106.65	0.94	1.03	0.99
T_7	69.98	50.04	60.01	139.98	160.66	150.32	0.94	1.01	0.98
T_8	61.64	37.53	49.58	127.13	109.51	118.32	0.98	1.03	1.01
T_9	70.77	40.06	55.42	134.87	123.67	129.27	1.04	1.00	1.02
T_{10}	67.89	62.53	65.21	133.33	124.91	129.12	0.95	1.04	0.99
T_{11}	70.33	40.09	55.21	148.58	158.66	153.62	0.99	1.08	1.03
T_{12}	68.74	62.51	65.63	155.83	160.67	158.25	1.07	0.82	0.95
T_{13}	46.25	25.33	35.79	102.03	76.99	89.51	0.93	1.14	1.04
SEm(±)	1.424	1.383	1.348	1.902	1.133	1.312	0.034	0.038	0.025
$CD_{(0.05)}$	4.155	4.037	3.935	5.552	3.308	3.829	0.099	0.110	0.072

gravity (1.07) followed by T_9(FYM to supply 25% K + NC to supply 25% K+ 50% RDF+AZ+PSB+ KSB) (1.04). From second year (2017) analysis of the experiment, it was found that fruits of the plants at T_1 (Recommended dose of fertilizer (RDF) as 100% inorganic) had maximum specific gravity (1.21) followed by T_{13} (1.14).The pooled data also resulted that fruits at T_1 (Recommended dose of fertilizer (RDF) as 100% inorganic had maximum specific gravity (1.08) followed by T_{13} (1.04).

4.1.3.6. Number of seeds

Number of seeds per fruit as observed in Table 4.1.12 varied significantly from 14.70 to 30.70 in 2016 and from 6.50 to 20.50 in 2017.

The pooled data of the experimental years resulted that T_{13} (Control) with largest number of seeds (23.80) while lowest number of seed (10.60) was observed in T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) followed by T_{12} (FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) (11.90).

4.1.3.7. Seed weight (g)

The weight of seed varied from 1.41g to 3.37g and 0.63g to 2.99g during first and second year of study, respectively. Minimum seed weight was observed in T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB)(1.41g) followed by T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)(1.49g) compared to control (3.15g) in 2016.Whereas, in 2017, it was found minimum in T_{12} (0.63g) followed by T_7 (0.81g) compared with control (2.99g). The pooled data also showed that fruits at T_{12} had minimum seed weight (1.02g) followed by T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) (1.15g) compared with T_{13} (3.07g) as shown in Table 4.1.11.

4.1.3.8. Peel Weight (g)

It is clear from the Table 4.1.11 that peel weight differed significantly with the treatments compared with control. It varied from 26.80g to 40.00g in 2016 and 16.50g to 58.50g in the year 2017.

The pooled data recorded minimum peel weight in T_{11} (FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF) (22.28g) followed by T_4 (Neem Cake (NC) to supply 50% K+ 50% RDF) (24.40g) compared with control (49.25g). However, T_4(Neem Cake (NC) to supply 50% K+ 50% RDF)recorded minimum peel weight (26.80g) followed by T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB)(27.27g) during the first year (2016) study. As observed in the pooled analysis, T_{11}(FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF)was found minimum with peel weight (16.50g) followed by T_4(Neem Cake (NC) to supply 50% K+ 50% RDF) (22g) compared with control (58.50g) during the second year (2017) study.

4.1.3.9. Peel Thickness (cm)

It is observed from Table 4.1.11 that Peel thickness varied significantly from 0.22cm to 0.35cm in the year 2016, whereas, in the year 2017, it ranged from 0.18cm to 0.32cm.

The observation indicated that minimum peel thickness was observed in T_4

(Neem Cake (NC) to supply 50% K+ 50% RDF)(0.22cm) which was statistically *at par* with T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) (0.23cm) in the year 2016 compared with control (0.35cm).Whereas, in the year 2017, T_{11}(FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF) was observed with minimum peel thickness (0.18cm) followed by T_4 (0.19cm) while T_1(Recommended dose of fertilizer (RDF) as 100% inorganic) recorded maximum peel thickness (0.32cm). However, the pooled analysis resulted that T_4(Neem Cake (NC) to supply 50% K+ 50% RDF) recorded minimum thickness (0.21cm) which was *at par* with T_{11}(FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF)(0.21cm) but, T_1(Recommended dose of fertilizer (RDF) as 100% inorganic) recorded maximum peel thickness (0.33cm) which was followed by control (0.30cm).

4.1.3.10. Juice content (ml)

It is evident from Table 4.1.10 that the juice content varied significantly from 46.25ml to 74.55ml in the first year (2016) study and varied from 25.33 to 62.53ml in the second year (2017) study.

T_4 (Neem Cake (NC) to supply 50% K+ 50% RDF) recorded highest juice content (74.55ml), followed by T_9 (FYM to supply 25% K + NC to supply 25% K+ 50% RDF+AZ+PSB+ KSB) (70.77ml) during 2016. Whereas, T_{10}(VC to supply 25% K + NC to supply 25% K+ 50% RDF+AZ+PSB+ KSB) was found highest with juice content (62.53ml) followed by T_{12} (FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB)62.51ml) compared with control (25.33ml) during 2017. However, the pooled data of the two experimental years resulted that T_{12} recorded highest juice content (65.63ml) which was statistically *at par* with T_{10}(65.21ml) compared with control(35.79ml).

4.1.4. Biochemical parameters

4.1.4.1. Total Soluble Solids (TSS)

Table 4.1.12 is showing that significant variation in total soluble solids content of fruit in both the experimental years and pooled analysis. Data ranged from 8.43^{o}Brix to 11.45 ^{o}Brix during 2016 and varied from 8.63 ^{o}Brix to 11.01 ^{o}Brix in 2017. Fruits at T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) was found as highest (11.45 ^{o}Brix, 11.01 ^{o}Brix) among all treatments compared with control (8.43 ^{o} Brix, 8.63^{o} Brix) during first and second year study followed by T_{11} (FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF)(11.33 ^{o} Brix) during 2016. However, T_{12} (11.01 ^{o}Brix) was *at par* with T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)(10.93 ^{o} Brix) followed by T_9(FYM to supply 25% K + NC to supply 25% K+ 50% RDF+AZ+PSB+ KSB) (10.63 ^{o} Brix) in 2017. The pooled data also showed T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB)as maximum (11.23^{o} Brix) followed by T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) (10.95 ^{o} Brix) compared with control (8.53^{o} Brix).

4.1.4.2. Acidity (%)

It is evident from Table 4.1.12 that significant variation was observed in fruit acidity which ranged between 0.64% to 0.87% in 2016 and 0.68% to 0.92% in 2017.

Table 4.1.11 Effect of integrated nutrient management on peel weight, peel thickness and seed weight of fruit

Treatment	Peel Weight (g)			Peel Thickness (cm)			Seed Weight(g)		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	39.33	43.50	41.42	0.33	0.32	0.33	3.37	2.01	2.69
T_2	33.40	41.50	37.45	0.28	0.28	0.28	3.01	2.01	2.51
T_3	32.58	38.00	35.29	0.28	0.28	0.28	3.19	1.99	2.59
T_4	26.80	22.00	24.40	0.22	0.19	0.21	2.19	1.01	1.60
T_5	29.74	32.50	31.12	0.27	0.25	0.26	2.82	1.50	2.16
T_6	37.64	35.00	36.32	0.30	0.25	0.28	2.67	2.01	2.34
T_7	28.79	22.50	25.65	0.25	0.21	0.23	1.49	0.81	1.15
T_8	30.52	34.00	32.26	0.27	0.25	0.26	2.93	1.51	2.22
T_9	28.98	33.00	30.99	0.26	0.25	0.26	2.27	1.49	1.88
T_{10}	32.20	30.50	31.35	0.28	0.23	0.26	2.78	1.50	2.14
T_{11}	28.07	16.50	22.28	0.25	0.18	0.21	1.67	1.01	1.34
T_{12}	27.27	27.00	27.13	0.23	0.21	0.22	1.41	0.63	1.02
T_{13}	40.00	58.50	49.25	0.35	0.25	0.30	3.15	2.99	3.07
SEm(±)	1.375	1.768	1.248	0.025	0.026	0.017	0.440	0.367	0.364
$CD_{(0.05)}$	4.013	5.159	3.643	0.073	0.077	0.049	1.283	1.071	1.062

Table 4.1.12 Effect of integrated nutrient management on number of seeds, TSS and acidity content of fruit

Treatment	Number of Seeds			TSS(^{0} Brix)			Acidity (%)		
	2016	2017	2016	2016	2017	Pooled	2016	2017	Pooled
T_1	26.60	19.00	22.8	9.70	9.33	9.52	0.81	0.86	0.83
T_2	22.90	20.50	21.7	10.17	9.53	9.85	0.74	0.85	0.80
T_3	25.40	16.00	20.7	9.83	9.33	9.58	0.79	0.88	0.83
T_4	18.70	11.50	15.1	10.93	10.63	10.78	0.68	0.73	0.71
T_5	22.30	13.00	17.6	10.43	9.83	10.13	0.72	0.83	0.77
T_6	22.80	15.00	18.9	9.90	9.33	9.62	0.76	0.90	0.83
T_7	14.70	6.50	10.6	10.97	10.93	10.95	0.66	0.69	0.67
T_8	22.40	15.00	18.7	10.17	10.33	10.25	0.74	0.78	0.76
T_9	20.80	15.50	18.2	10.50	10.63	10.57	0.70	0.71	0.71
T_{10}	20.50	12.00	16.3	10.43	10.33	10.38	0.74	0.81	0.78
T_{11}	19.60	10.00	14.8	11.33	10.53	10.93	0.64	0.75	0.70
T_{12}	15.80	8.00	11.9	11.45	11.01	11.23	0.64	0.68	0.66
T_{13}	30.70	17.00	23.8	8.43	8.63	8.53	0.87	0.92	0.89
SEm(±)	2.337	1.614	1.216	0.385	0.347	0.422	0.043	0.050	0.040
$CD_{(0.05)}$	6.820	4.712	3.549	1.123	1.013	1.232	0.126	0.146	0.118

Lowest fruit acidity was observed in T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) (0.64%) which was statistically *at par* with T_{11}(FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF)(0.64%) followed by T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)(0.66%) compared with control (0.87%) in the first year (2016) study. In the second year (2017) study, it was found that acidity was lowest in T_{12} (0.68%) which was *at par* with T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)(0.69%) followed by T_9(FYM to supply 25% K + NC to supply 25% K+ 50% RDF+AZ+PSB+ KSB)(0.71%) compared with control (0.92%).

The pooled data of two consecutive years has shown that T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) recorded lowest fruit acidity level (0.66%) followed by T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)(0.67%) compared with control (0.89%)

4.1.4.3. TSS/Acid Ratio

Significant variation was observed in fruit TSS/Acid ratio which varied from 9.68 to 17.99 during 2016 and from 9.41 to 16.19 during 2017, among the treatments. Maximum TSS/Acid ratio of fruits was found in T_{12} (FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) (17.99) followed by T_{11} (FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF) (17.81) compared with control (9.68) during the first year (2016) experiment. Similarly, it was observed in 2017 that T_{12} recorded highest TSS/Acid ratio (16.19) which was *at par* with T_7 (NC to supply 50% K+ 50 %

RDF+AZ+PSB+ KSB) (15.87) followed by T_9 (14.96) compared with control (9.41) shown in Table 4.1.13. However, the pooled analysis indicated that Khasi Mandarin fruits at T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) was highest in TSS/Acid ratio (17.09) followed by T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) (16.24) over control (9.55).

4.1.4.4. Total Sugar (%)

It is evident from Table 4.1.13 that significant variation was observed among the treatments in regard to total sugar content of the fruits and varied from 6.06 % to 8.82 % in the first year (2016) study while it ranged from 5.85% to 8.68% in the second year (2017) reading. Highest total sugar content of fruit was observed in T_4 (8.82%) followed by T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB)(8.79%) compared with control (6.06%) during 2016. Whereas, in the year 2017, T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) recorded highest total sugar content (8.68%) which was *at par* with T_4(Neem Cake (NC) to supply 50% K+ 50% RDF) (8.67%) followed by T_{12} (8.65%) compared with control (5.85%). However, the pooled analysis had shown that Khasi Mandarin fruits at T_4 (Neem Cake (NC) to supply 50% K+ 50% RDF) recorded highest total sugar content (8.75%) followed by T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) (8.72%) which was *at par* with T_{12} (8.72%) compared with control (5.96%).

4.1.4.5. Reducing Sugar (%)

It is clear from Table 4.1.13 that reducing sugar content of Khasi Mandarin fruits varied significantly during the experimental period. It varied from 4.97% to 7.13% in 2016 while it varied from 4.77% to 6.81% in 2017. Fruits at T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) recorded maximum reducing sugar (7.13%) followed by T_4 (Neem Cake (NC) to supply 50% K+ 50% RDF) (7.08%) compared with control (4.97%) in 2016. But, in the year 2017, Khasi Mandarin fruits at T_{12} were found highest in reducing sugar percentage (6.81%) followed by T_4 (6.57%) compared with control (4.77%). The pooled data resulted that fruits at T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) recorded highest reducing sugar (6.91%) followed by T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)(6.84%) which was statistically *at par* with T_4(Neem Cake (NC) to supply 50% K+ 50% RDF)(6.83%) compared with control (4.87%).

4.1.4.6. Ascorbic acid (mg/100g)

The data presented in Table 4.1.13 revealed that ascorbic acid content of fruit varied significantly among the treatments compared with control and ranged from 27.48mg/100g of pulp to 52.81mg/100g of pulp during 2016. In the second year study, it varied from 26.74 to 50.53mg/100g pulp of mandarin fruit. Highest ascorbic acid content of fruits was found with T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)(52.81mg/100g pulp) followed by T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) (52.04mg/100g pulp) compared with control (27.48mg/100g pulp) in the first year study. Whereas, in the second year observation, fruits at T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) recorded

Table 4.1.13 Effect of integrated nutrient management on TSS/Acid, Ascorbic acid, Total Sugar, Reducing Sugar content of fruit

Treatment	TSS/Acid			Ascorbic acid (mg/100g of fruit pulp)			Total Sugar (%)			Reducing Sugar (%)		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	12.02	10.89	11.45	45.67	42.25	43.96	8.46	8.39	8.43	6.34	6.23	6.29
T_2	13.68	11.18	12.43	47.45	43.51	45.48	8.47	8.45	8.46	6.36	6.32	6.34
T_3	12.51	10.64	11.58	46.86	42.84	44.85	8.49	8.41	8.45	6.38	6.25	6.32
T_4	16.10	14.54	15.32	51.32	49.42	50.37	8.82	8.67	8.75	7.08	6.57	6.83
T_5	14.46	11.89	13.17	49.01	45.39	47.20	8.53	8.52	8.53	6.43	6.41	6.42
T_6	12.95	10.41	11.68	47.98	44.36	46.17	8.51	8.42	8.47	6.39	6.27	6.33
T_7	16.62	15.87	16.24	52.81	50.29	51.55	8.76	8.68	8.72	7.13	6.54	6.84
T_8	13.68	13.20	13.44	46.97	45.04	46.01	8.56	8.51	8.54	6.46	6.38	6.42
T_9	14.99	14.96	14.97	48.64	46.68	47.66	8.59	8.56	8.58	6.51	6.48	6.50
T_{10}	14.04	12.80	13.42	49.10	48.06	48.58	8.71	8.59	8.65	6.53	6.49	6.51
T_{11}	17.81	13.97	15.89	50.87	49.28	50.08	8.63	8.62	8.63	6.59	6.51	6.55
T_{12}	17.99	16.19	17.09	52.04	50.53	51.29	8.79	8.65	8.72	7.01	6.81	6.91
T_{13}	9.68	9.41	9.55	27.48	26.74	27.11	6.06	5.85	5.96	4.97	4.77	4.87
SEm(±)	1.256	1.144	1.217	1.968	1.041	1.451	0.417	0.507	0.461	0.351	0.282	0.316
$CD_{(0.05)}$	3.666	3.339	3.553	5.743	3.040	4.235	1.217	1.481	1.346	1.026	0.822	0.921

highest ascorbic acid content (50.53mg/100g pulp) followed by T_7 (50.29mg/100g pulp) over control (26.74mg/100g pulp).

However, the pooled analysis revealed that fruits at T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) were the best in ascorbic acid content (51.55mg/100g pulp), followed by T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB)(51.29mg/100g pulp) compared with control (27.11mg/100g pulp).

4.1.5. Soil nutrient analysis

4.1.5.1. Total Nitrogen (kg/ha)

Total nitrogen content in the experimented soil are depicted in Table 4.1.14 and Figure 4.1.7.Total nitrogen content among the treatments varied significantly between 287.85 to 1098kg/ha in 2016 and 225.59 to 1262.97kg/ha in 2017. Highest total nitrogen content of soil was observed in T_{12} (FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF + AZ+ PSB+ KSB) (1098kg/ha) followed by T_{11}(FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF)(956.93kg/ha) compared with control (287.85kg/ha) in 2016. The same treatment T_{12} also recorded highest in total N content of soil (1262.97kg/ha) followed by T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) (1175.80kg/ha) while the least was recorded in control (225.59kg/ha) in 2017.

Similarly for the consecutive two years, the pooled analysis again resulted that highest total soil nitrogen content at T_{12} (1180.49kg/ha) which was followed by T $_7$ (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) (1060.40kg/ha) while control recorded the least (256.72kg/ha).

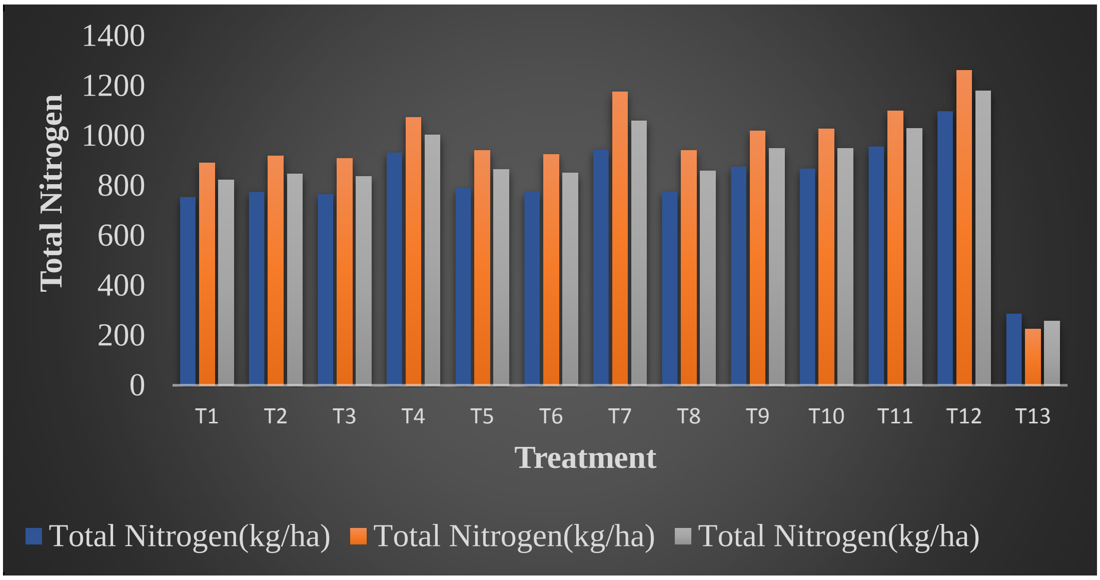


Fig.4.1.7 Effect of INM on Soil Total Nitrogen

4.1.5.2. Available Phosphorus (kg/ha)

It was found that soil phosphorus content was significantly varied over control in all the treatments as depicted in table 4.1.14. Available soil phosphorus varied from 23.24 to 63.12kg/ha during 2016 and 14.44 to 82.11kg/ha in 2017.

Available soil phosphorus was found highest in T_1 (Recommended dose of fertilizer (RDF) as 100% inorganic) (63.12kg/ha) while control recorded minimum (23.24kg/ha) in the first year (2016) study, whereas, T_{12} recorded highest available soil phosphorus (82.11kg/ha) followed by T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)(77.23 kg/ha) while control plant recorded the lowest value (14.44 kg/ha) during 2017.

Similarly to 2017 observation, pooled analysis also recorded highest available soil P content (69.53kg/ha) with T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB), but it was statistically *at par* with T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) and T_1(Recommended dose of fertilizer (RDF) as 100% inorganic)(67.63kg/ha). However, the least available soil phosphorus was obtained in control plot (18.84kg/ha).

4.1.5.3. Available Potassium (kg/ha)

The data presented in Table 4.1.14 revealed that there was significant variation among treatments with respect to soil available potassium, in both the years. Available soil potassium varied from 126.76kg/ha to 560.09 kg/ha in 2016 and 82.38kg/ha to 638.97kg/ha in 2017. In the year 2016, highest available soil potassium was observed with T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+KSB) (560.09kg/ha). Similarly in the second year also, T_7 recorded maximum available soil potassium content (638.97kg/ha) which was followed by T_{12} (FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) (608.68kg/ha) and control recorded minimum (126.76 and 82.38 kg/ha)in both the years. Pooled data revealed that available soil potassium content was significantly higher in T_7 than all the treatments (600.03kg/ha) followed by T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB)(570.40kg/ha), while control plot recorded the least amount (104.57kg/ha).

4.1.5.4. Soil Manganese (mg/kg)

It is clear from the Table 4.1.15 that soil manganese (Mn) content varied significantly from 18.12 mg/kg to 23.65mg/kg during 2016 and 15.36mg/kg to 25.07mg/kg during 2017. T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) recorded highest amount of soil Manganese (23.65mg/kg) followed by T_4 (23.12mg/kg) over control (18.12mg/kg) during first year (2016) study. In the year 2017, T_7 recorded highest amount of soil Mn (25.07mg/kg) which was statistically *at par* with T_{12} (24.63mg/kg) compared with control (15.36mg/kg).

The pooled data of two consecutive years had shown that T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) recorded the highest soil Mn (24.36mg/kg) followed by T_4(Neem Cake (NC) to supply 50% K+ 50% RDF) (23.86mg/kg) which was *at par* with T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB)(23.75mg/kg) while control plot had the lowest amount of soil Manganese (16.74 mg/kg).

4.1.5.5. Soil Copper (mg/kg)

Copper content of the soil varied significantly among the selected treatments and ranged between 1.58 to 1.90mg/kg in the year 2016 and 1.49 to 1.94mg/kg in the year 2017. During the experimental years, T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) recorded highest soil copper content among all treatments compared with control, it was recorded 1.90mg/kg and 1.94mg/kg in 2016 and 2017 respectively which was followed by T_4(Neem Cake (NC) to supply 50% K+ 50% RDF) (1.85 and 1.89mg/kg respectively) in both the years but was *at par* with T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB)(1.86mg/kg) during 2017.

The pooled analysis revealed that T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) had the highest level of Copper content in soil (1.92mg/kg) which was followed by T_4(Neem Cake (NC) to supply 50% K+ 50% RDF) (1.87mg/kg) compared with control plot (1.56mg/kg) as described in table 4.1.15.

4.1.5.6. Soil Zinc (mg/kg)

The Zinc content of experimental soil varied differently in all the treatments compared with control. It varied from 2.75 to 4.69 mg/kg during 2016 and 2.59 to 4.87 mg/kg during 2017. The highest level of soil Zinc was obtained in T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) (4.69 and 4.87mg/kg) in 2016 and 2017 respectively and was followed by T_4 (Neem Cake (NC) to supply 50% K+ 50% RDF)(4.49mg/kg in 2016, 4.63 mg/kg in 2017). The pooled analysis also indicated that highest soil zinc was observed in T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) (4.78 mg/kg) which was followed by T_4(Neem Cake (NC) to supply 50% K+ 50% RDF)(4.56mg/kg) while T_{13} (control) recorded the minimum soil Zinc in 2016, 2017 and pooled analysis (2.75, 2.59, 2.67mg/kg, respectively) as shown in Table 4.1.15.

4.1.5.7. Soil Iron (mg/kg)

It is evident from Table 4.1.15 that soil Fe content varied significantly over control and ranged between 91.13 to 115.76 mg/kg during 2016 and 88.15 to

Table 4.1.14 Effect of integrated nutrient management on major nutrients of soil

Treatment	Total Nitrogen(kg/ha)			Available Phosphorus (kg/ha)			Available Potassium(kg/ha)		
	2016	2017	2016	2016	2017	Pooled	2016	2017	Pooled
T_1	754.98	891.08	823.03	63.12	72.13	67.63	355.00	448.00	401.50
T_2	775.45	920.05	847.75	36.58	50.15	43.36	349.18	458.62	403.90
T_3	765.91	908.78	837.34	33.14	51.34	42.24	355.20	431.14	393.17
T_4	932.89	1073.41	1003.15	52.25	63.13	57.69	470.89	562.21	516.55
T_5	789.98	940.56	865.27	45.47	61.23	53.35	432.12	491.98	462.05
T_6	776.98	925.08	851.03	40.79	59.12	49.96	395.50	448.00	421.75
T_7	945.00	1175.80	1060.40	58.03	77.23	67.63	560.09	638.97	600.03
T_8	776.92	941.52	859.22	34.93	55.21	45.07	402.45	469.75	436.10
T_9	876.90	1020.11	948.51	47.85	62.12	54.99	455.46	514.54	485.00
T_{10}	868.94	1028.07	948.51	30.14	45.65	37.89	446.78	521.26	484.02
T_{11}	956.93	1100.51	1028.72	57.91	71.45	64.68	459.23	548.77	504.00
T_{12}	1098.00	1262.97	1180.49	56.95	82.11	69.53	532.12	608.68	570.40
T_{13}	287.85	225.59	256.72	23.24	14.44	18.84	126.76	82.38	104.57
SEm(±)	3.741	4.448	2.863	1.931	1.345	1.383	2.442	1.972	2.180
$CD_{(0.05)}$	10.920	12.983	8.357	5.637	3.926	4.035	7.126	5.755	6.361

116.92 mg/kg in 2017. Highest Iron content of soil was observed in T_4 (Neem Cake (NC) to supply 50% K+ 50% RDF) in both the years (115.76 and 116.92 mg/kg in 2016 and 2017, respectively) which was followed by T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB**)** in both the years (114.89 mg/kg and 115.83mg/kg, irrespective of 2016 and 2017) compared with control (91.13 and 88.15 mg/kg in 2016 and 2107, respectively).

The pooled data indicated that T_4 (Neem Cake (NC) to supply 50% K+ 50% RDF) had highest content of soil Iron (116.34mg/kg) followed by T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) (115.36 mg/kg) compared with control (89.64 mg/kg).

4.1.6. Leaf nutrient analysis

4.1.6.1. Total Nitrogen (%)

Leaf Nitrogen content showed significant variation among all treatments compared with control. It varied from 1.64% to 2.45 % during 2016 and 1.56 % to 2.88 % in 2017. T_{12} (FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) was found highest in leaf Nitrogen content (2.45%) during 2016, whereas, T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) recorded highest (2.88%) in 2017, while control was found minimum (1.64 and 1.56 %) in both the years of study.

The pooled data presented that leaf Nitrogen content was highest in T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF+AZ+PSB+ KSB)(2.63%) while T_{13}(control) recorded minimum (1.60%) as presented in Table 4.1.16 and Figure 4.1.7.

4.1.6.2. Available Phosphorus (%)

The phosphorus content of leaf varied significantly over control from 0.07% to 0.14% in 2016 and 0.06% to 0.19% in 2017. T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) and T_{11}(FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF) recorded highest amount of leaf Phosphorus percentage (0.14%) followed by T_{12} (0.13%) compared with control (0.08%) in 2016.

T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) recorded maximum leaf phosphorus content (0.19%) in 2017followed by T_4(Neem Cake (NC) to supply 50% K+ 50% RDF) (0.18%) which was *at par* with T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)(0.18%) while control recorded the least available leaf phosphorus (0.06%).

Pooled analysis reported that T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) and T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) were high in leaf phosphorus content (0.16%) followed by T_{11}(FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF)(0.15%) while control recorded minimum concentration of leaf Phosphorus (0.07%) as shown in Table 4.1.16.

4.1.6.3. Available Potassium (%)

It is evident from the Table 4.1.16 that available potassium content of leaf varied significantly among the treatments and ranged between 0.77 % to 1.61 % in 2016 and 0.45 % to 1.80% in 2017. T_7 (NC to supply 50% K+ 50 %

Table 4.1.15 Effect of integrated nutrient management on soil micronutrients

Treatment	Mn (mg/kg)			Cu(mg/kg)			Zn(mg/kg)			Fe(mg/kg)		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	18.23	19.61	18.92	1.59	1.63	1.61	2.87	2.79	2.83	93.89	95.23	94.56
T_2	18.34	20.14	19.24	1.58	1.68	1.63	2.77	2.97	2.87	95.11	96.77	95.94
T_3	19.03	20.61	19.82	1.63	1.73	1.68	3.08	3.24	3.16	95.12	97.84	96.48
T_4	23.12	24.6	23.86	1.85	1.89	1.87	4.49	4.63	4.56	115.76	116.92	116.34
T_5	18.34	20.88	19.61	1.64	1.66	1.65	2.87	3.03	2.95	95.45	97.01	96.23
T_6	19.65	21.91	20.78	1.72	1.74	1.73	3.38	3.54	3.46	100.02	102.44	101.23
T_7	23.65	25.07	24.36	1.90	1.94	1.92	4.69	4.87	4.78	114.89	115.83	115.36
T_8	19.24	21.04	20.14	1.69	1.73	1.71	3.18	3.24	3.21	98.65	99.65	99.15
T_9	20.31	22.41	21.36	1.75	1.78	1.76	3.67	3.89	3.78	102.13	104.83	103.48
T_{10}	21.56	23.4	22.48	1.74	1.76	1.75	3.89	3.99	3.94	104.65	106.25	105.45
T_{11}	22.23	24.19	23.21	1.75	1.81	1.78	4.19	4.23	4.21	102.76	104.48	103.62
T_{12}	22.87	24.63	23.75	1.76	1.86	1.81	4.29	4.35	4.32	113.24	115.1	114.17
T_{13}	18.12	15.36	16.74	1.63	1.49	1.56	2.75	2.59	2.67	91.13	88.15	89.64
SEm(±)	1.233	1.025	1.267	0.062	0.058	0.067	0.40	0.421	0.396	1.771	2.233	2.681
$CD_{(0.05)}$	3.600	2.992	3.698	0.182	0.170	0.196	1.18	1.229	1.155	5.170	6.518	7.825

RDF+AZ+PSB+ KSB) was found highest in leaf Potassium content (1.61%) while control was the least (0.77%) during 2016. Whereas, in the year 2017, T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) recorded highest leaf potassium content (1.80%) whereas, T_{13} (control) recorded the lowest amount (0.45%).

Similarly, the pooled analysis showed that highest leaf potassium was recorded in T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB)(1.64%) followed by T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) (1.62%) while lowest was observed in control (0.61%).

4.1.6.4. Leaf Manganese (ppm)

It is evident from Table 4.1.17 that leaf manganese content varied significantly over control from 65.83ppm to 80.98ppm during 2016 and from 63.73ppm to 81.67ppm in 2017. Highest leaf manganese content was observed in T_{11} (FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF) (80.98ppm), in the year 2016 which was followed by T_{12} (FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) (80.87 ppm) compared with control (65.83ppm). Whereas, in the year 2017, T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) recorded highest leaf Mn (81.67ppm) which was *at par* with T_{11} (81.48ppm) whereas, T_{13} (control) recorded the lowest amount (63.73ppm).

The pooled data also indicated that T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) with highest content of leaf manganese (81.27ppm) which was *at par* with T_{11}(FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF)(81.23ppm) followed by T_4(Neem Cake (NC) to supply 50% K+ 50% RDF)(80.45ppm) compared with control (64.78ppm).

4.1.6.5. Leaf Copper (ppm)

The data presented in Table 4.1.17 revealed that leaf copper content varied significantly between 12.48ppm to 20.12ppm in 2016 and 11.98ppm to 20.94ppm in 2017. T_4(Neem Cake (NC) to supply 50% K+ 50% RDF) was found highest in leaf copper content (20.12ppm) which was *at par* with T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) (19.87ppm) while control was the least (12.48ppm) during 2016. Similarly, in the year 2017, T_4 (Neem Cake (NC) to supply 50% K+ 50% RDF) recorded highest leaf copper content (20.94ppm) followed by T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) (20.69ppm) whereas, T_{13} (control) recorded the lowest amount (11.98ppm).

Similarly, the pooled analysis resulted that highest leaf copper was recorded in T_4 (Neem Cake (NC) to supply 50% K+ 50% RDF) (20.53ppm) followed by T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) (20.28ppm) while lowest was observed in control (12.23ppm).

4.1.6.6. Leaf Zinc (ppm)

Table 4.1.17 revealed that all treatments varied significantly over control with leaf zinc content. It ranged from 14.23ppm to 28.98ppm in 2016 and 12.98ppm to 29.46ppm in 2017. T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+

KSB) recorded highest amount of leaf zinc content in both the year (28.98ppm and 29.46ppm, respectively) followed by T_4(Neem Cake (NC) to supply 50% K+ 50% RDF)(27.01ppm and 27.89 ppm) which was *at par* with T_{11}(FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF)(26.43ppm and 27.31ppm).

Similarly, data presented at pooled analysis showed that highest leaf zinc content was recorded in T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) (29.22ppm) followed by T_4(Neem Cake (NC) to supply 50% K+ 50% RDF)(27.45ppm) which was *at par* with T_{11}(FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF) (26.87ppm) while lowest was observed in control (13.87ppm).

4.1.6.7. Leaf Iron (ppm)

Table 4.1.17 revealed that leaf iron content varied significantly among all the treatments. It ranged from 111.23ppm to 227.10ppm in 2016 and 110.67ppm to 228.00ppm in 2017. T_7 recorded highest in both the year 2016 and 2017 (227.10ppm and 228.00ppm, respectively) followed by T_4 (212.02ppm and 212.88ppm) compared with control (111.23 and 110.67ppm).

Similarly, the pooled analysis showed that highest leaf iron content was recorded in T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) (227.55ppm) followed by T_4 (Neem Cake (NC) to supply 50% K+ 50% RDF) (212.45ppm) while lowest was observed in control (110.95ppm).

Table 4.1.16 Effect of integrated nutrient management on major nutrients content of leaf

Treatment	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	1.75	1.97	1.86	0.07	0.11	0.09	1.04	1.22	1.13
T_2	1.84	2.05	1.94	0.09	0.11	0.10	1.14	1.42	1.28
T_3	1.82	2.16	1.99	0.08	0.12	0.10	1.19	1.25	1.22
T_4	1.97	2.67	2.32	0.10	0.18	0.14	1.45	1.75	1.60
T_5	2.01	2.23	2.12	0.11	0.13	0.12	1.45	1.49	1.47
T_6	1.94	2.15	2.04	0.09	0.13	0.11	1.32	1.40	1.36
T_7	1.91	2.88	2.39	0.14	0.18	0.16	1.61	1.63	1.62
T_8	2.01	2.33	2.17	0.10	0.12	0.11	1.41	1.57	1.49
T_9	2.14	2.34	2.24	0.11	0.17	0.14	1.52	1.64	1.58
T_{10}	2.18	2.21	2.19	0.12	0.14	0.13	1.57	1.59	1.58
T_{11}	2.12	2.42	2.27	0.14	0.16	0.15	1.54	1.64	1.59
T_{12}	2.45	2.81	2.63	0.13	0.19	0.16	1.48	1.80	1.64
T_{13}	1.64	1.56	1.60	0.08	0.06	0.07	0.77	0.45	0.61
SEm(±)	0.128	0.228	0.162	0.014	0.024	0.018	0.158	0.205	0.191
$CD_{(0.05)}$	0.374	0.664	0.474	0.041	0.069	0.052	0.460	0.598	0.558

Table 4.1.17 Effect of integrated nutrient management on leaf micro nutrients content

Treatment	Fe(ppm)			Mn (ppm)			Cu (ppm)			Zinc (ppm)		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	152.01	152.67	152.34	67.26	68.18	67.72	13.65	13.97	13.81	14.23	15.09	14.66
T_2	161.01	161.51	161.26	69.01	69.81	69.41	13.64	14.28	13.96	15.45	16.19	15.82
T_3	179.02	179.40	179.21	73.45	74.41	73.93	14.98	15.44	15.21	17.56	18.14	17.85
T_4	212.02	212.88	212.45	80.01	80.89	80.45	20.12	20.94	20.53	27.01	27.89	27.45
T_5	167.04	168.02	167.53	70.23	70.73	70.48	14.71	15.11	14.91	16.45	17.23	16.84
T_6	197.06	198.04	197.55	76.54	77.02	76.78	17.56	18.00	17.78	18.21	18.91	18.56
T_7	227.10	228.00	227.55	74.03	74.73	74.38	19.87	20.69	20.28	28.98	29.46	29.22
T_8	180.98	181.18	181.08	74.01	74.75	74.38	16.23	16.53	16.38	18.21	19.17	18.69
T_9	195.21	196.13	195.67	78.02	78.72	78.37	18.24	19.04	18.64	20.46	21.36	20.91
T_{10}	198.45	199.11	198.78	78.78	79.26	79.02	17.98	18.48	18.23	22.42	22.92	22.67
T_{11}	208.56	209.24	208.90	80.98	81.48	81.23	19.12	19.8	19.46	26.43	27.31	26.87
T_{12}	207.01	207.75	207.38	80.87	81.67	81.27	18.76	19.72	19.24	24.46	25.26	24.86
T_{13}	111.23	110.67	110.95	65.83	63.73	64.78	12.48	11.98	12.23	14.76	12.98	13.87
SEm(±)	3.990	4.273	3.722	2.830	2.444	3.330	1.151	1.601	1.724	1.799	1.662	1.813
$CD_{(0.05)}$	11.646	12.472	10.864	8.261	7.133	9.719	3.359	4.674	5.033	5.250	4.852	5.291

4.1.6.8. Leaf Carbohydrate

It was evident from table 4.1.18 that leaf carbohydrate content varied significantly over control and it was ranged from 4.64% to 8.76% during 2016 and 3.80 % to 7.72 % during 2017. During the first and second year study, T_{12} recorded the highest leaf carbohydrate content (8.76%, 7.72%) which was followed by T_4(Neem Cake (NC) to supply 50% K+ 50% RDF)(8.03%)in the first year (2016) whereas, T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) recorded the second highest value (7.53%) during 2017 compared with control (4.64%, 3.80% in 2016 and 2017, respectively).

The pooled data of both the years revealed that T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) recorded the highest carbohydrate content(8.24%) which was followed by T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) (7.64%) over control (4.22%).

4.1.6.9. Leaf Carbohydrate: Leaf Nitrogen Ratio

Table 4.1.18 indicated that Leaf C:N ratio varied significantly among the treatments and ranged from 2.83 to 4.08 during 2016 and 2.43 to 3.02 during 2017.The C:N ratio was found maximum in T_4(Neem Cake (NC) to supply 50% K+ 50% RDF)(4.08) followed by T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)(4.06) during 2016 whereas, T_9(FYM to supply 25% K + NC to supply 25% K+ 50% RDF+AZ+PSB+ KSB) recorded the maximum C:N ratio (3.02) which was followed by T_{10} (VC to supply 25% K + NC to supply 25% K+ 50% RDF+AZ+PSB+ KSB)(2.97) during 2017. However, the pooled data indicated that

Table 4.1.18 Effect of integrated nutrient management on leaf carbohydrate and leaf C: N Ratio

Treatment	Carbohydrate (%)			Carbohydrate: Nitrogen Ratio		
	2016	2017	Pooled	2016	2017	Pooled
T_1	5.38	5.19	5.28	3.07	2.63	2.85
T_2	5.53	5.37	5.45	3.01	2.62	2.81
T_3	5.91	5.67	5.79	3.25	2.62	2.93
T_4	8.03	7.09	7.56	4.08	2.65	3.36
T_5	7.04	6.23	6.63	3.50	2.80	3.15
T_6	7.06	6.12	6.59	3.64	2.85	3.24
T_7	7.75	7.53	7.64	4.06	2.62	3.34
T_8	7.03	6.41	6.72	3.50	2.75	3.12
T_9	7.19	7.09	7.14	3.36	3.02	3.19
T_{10}	7.23	6.56	6.90	3.32	2.97	3.14
T_{11}	8.01	6.45	7.23	3.78	2.66	3.22
T_{12}	8.76	7.72	8.24	3.58	2.75	3.16
T_{13}	4.64	3.80	4.22	2.83	2.43	2.63
SEm(±)	0.600	0.517	0.567	0.247	0.104	0.124
$CD_{(0.05)}$	1.751	1.509	1.654	0.720	0.303	0.361

T_4 (Neem Cake (NC) to supply 50% K+ 50% RDF) recorded maximum C: N ratio (3.36) which was followed by T_7 (3.34) compared with control (2.63).

4.1.7. Soil microbial analysis

4.1.7.1. *Azotobacter*

It is summarized from Table 4.1.19 that soil *Azotobacter* content varied significantly among the treatments and ranged between 5.87 x 10^6 CFU/g of soil and 30.98 x 10^6 CFU/g of soil during first year (2016) which gradually increased and ranged between 7.27 x 10^6 CFU/g of soil and 98.69 x 10^6 CFU/g of soil in the following year (2017). Maximum *Azotobacter* count of soil was observed in T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)(30.98 x 10^6 CFU/g of soil) followed by T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB)(30.43 x 10^6 CFU/g of soil) in the first year (2016) while T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) recorded maximum soil *Azotobacter* count (98.69x106 CFU/g of soil) followed by T_7 (93.92 x 10^6 CFU/g of soil) during the second year (2017). As per pooled analysis, the maximum soil *Azotobacter* population (64.56 x 10^6 CFU/g of soil) was recorded in T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) which was followed by T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)(62.45x 10^6 CFU/g of soil) compared with rhizosphere soil of control trees(T_{13}) (6.57 x 10^6 CFU/g of soil).

4.1.7.2. Phosphorus Solubilizing Bacteria (PSB)

Phosphorus solubilizing bacterial count of the soil varied significantly among the treatments as presented in table 4.1.19. The highest phosphorus solubilizing bacterial count (35.65 and 108.59 x10^6 CFU/g of soil) was observed in T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) in both the years (2016 and 2017) .It was followed by T_{12} (FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) having phosphorus solubilizing bacterial count of 33.41 X 10^6 CFU/g of soil which was *at par* with T_9(FYM to supply 25% K + NC to supply 25% K+ 50% RDF+AZ+PSB+ KSB)(32.09 x 10^6 CFU/g of soil) in the year of 2016. Even in the second year analysis, T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) recorded second highest in phosphorus solubilizing bacteria (104.49 x10^6 CFU/g of soil).The pooled analysis of both the years revealed that T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) recorded highest soil PSB count (72.12x10^6 CFU/g of soil) and was followed by T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB)(68.95 x10^6 CFU/g of soil) while the lowest population (6.89, 8.27 and 7.58 x 10^6 CFU/g of soil) was observed T_1 (Recommended dose of fertilizer (RDF) as 100% inorganic)in both the years of study and in pooled analysis.

4.1.7.3. Potassium Solubilizing Bacteria (KSB)

The data presented in Table 4.1.19 showed that Potassium solubilizing bacterial count of the soil varied significantly among the treatments. The highest Potassium solubilizing bacterial count (51.09 x10^6 CFU/g of soil) was observed in T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB), and was followed by T_{12} (FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF

Table 4.1.19 Effect of integrated nutrient management on soil microbial population

Treatment	*Azotobacter* (X 10^6 cfu/ g of soil)			PSB (X 10^6 cfu/ g of soil)			KSB (X 10^6 cfu/ g of soil)		
	2016	2017	2016	2016	2017	Pooled	2016	2017	Pooled
T_1	7.92	9.92	8.92	6.89	8.27	7.58	22.14	24.76	23.45
T_2	11.84	13.86	12.85	12.79	14.33	13.56	23.87	25.69	24.78
T_3	12.32	12.38	12.35	14.98	16.98	15.98	27.91	29.21	28.56
T_4	14.87	15.61	15.24	16.54	19.18	17.86	30.09	32.95	31.52
T_5	23.63	74.21	48.92	29.06	92.42	60.74	45.78	137.66	91.72
T_6	22.65	69.99	46.32	27.98	85.00	56.49	46.12	141.50	93.81
T_7	30.98	93.92	62.45	35.65	108.59	72.12	51.09	162.55	106.82
T_8	20.54	65.10	42.82	26.98	90.50	58.74	23.89	133.99	78.94
T_9	25.43	84.29	54.86	32.09	99.37	65.73	31.78	165.74	98.76
T_{10}	24.78	79.50	52.14	28.76	96.90	62.83	35.98	153.26	94.62
T_{11}	12.87	14.03	13.45	18.79	19.89	19.34	34.19	36.73	35.46
T_{12}	30.43	98.69	64.56	33.41	104.49	68.95	47.98	156.70	102.34
T_{13}	5.87	7.27	6.57	10.13	12.37	11.25	11.89	13.45	12.67
SEm(±)	2.766	3.618	2.261	2.073	2.986	2.187	1.076	2.224	1.364
$CD_{(0.05)}$	8.075	10.559	6.599	6.050	8.715	6.383	3.141	6.492	3.981

+AZ+PSB+ KSB) having potassium solubilizing bacterial count of 47.98 X 10^6 CFU/g of soil in the first year (2016) study. Whereas, in the second year (2017), T_9(FYM to supply 25% K + NC to supply 25% K+ 50% RDF+AZ+PSB+ KSB) recorded highest in potassium solubilizing bacteria (165.74 x10^6 CFU/g of soil) followed by T_7 (162.55 x10^6 CFU/g of soil). However, the pooled analysis manifested that T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) had highest Potassium solubilizing bacterial count(106.82 x10^6 CFU/g of soil) followed by T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB)(102.34 X 10^6 CFU/g of soil) . However, the lowest population (11.89, 13.45 and 12.67 x 10^6 CFU/g of soil) was observed in control (T_{13}) in both the years of study and in pooled analysis.

4.1.8. Cost - Benefit analysis

Perusal of the data presented in Table 4.1.20 revealed that highest Gross Expenditure was obtained with T_6(VC to supply 50% K + 50% RDF+AZ+PSB+ KSB)(Rs 8,35,180.60) followed by T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB)(Rs 8,27,197.91) while lowest gross expenditure was observed with T_{13} (Rs 1,59,650.92). Regarding gross income, the highest gross income was observed in T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB)(Rs 31,97,600.00) followed by T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) (Rs 29,45,600.00)while the lowest gross income was observed in Control (Rs 4,13,600. 00). Therefore, the highest net income was obtained with T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF

+AZ+PSB+ KSB)(Rs 23,70,402.09) followed by T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)(Rs 23,50,775.37) while T_{13} (control) recorded lowest net income (Rs 2,53,949.08). Comparing all the treatments, highest Benefit to Cost ratio was obtained in T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) (3.95) which was followed by T_4 (Neem Cake (NC) to supply 50% K+ 50% RDF) (3.93) while control plant recorded the lowest value of Benefit : Cost ratio (1.59).

Table 4.1.20 Effect of integrated nutrient management on Cost: Benefit Ratio

Treatment	Gross expenditure(Rs)	Gross income(Rs)	Net income(Rs)	B:C ratio
T_1	252,376.86	925,600.00	673,223.14	2.67
T_2	477,003.08	2,068,800.00	1,591,796.92	3.34
T_3	784,685.65	2,049,600.00	1,264,914.35	1.61
T_4	544,329.68	2,684,800.00	2,140,470.32	3.93
T_5	527,498.03	2,297,600.00	1,770,101.97	3.36
T_6	835,180.60	2,196,000.00	1,360,819.40	1.63
T_7	594,824.63	2,945,600.00	2,350,775.37	3.95
T_8	681,271.99	2,166,400.00	1,485,128.01	2.18
T_9	561,161.33	2,554,400.00	1,993,238.67	3.55
T_{10}	714,935.29	2,418,400.00	1,703,464.71	2.38
T_{11}	776,702.96	2,895,200.00	2,118,497.04	2.73
T_{12}	827,197.91	3,197,600.00	2,370,402.09	2.87
T_{13}	159,650.92	413,600.00	253,949.08	1.59

* Calculated based on one hectare land.

Experiment No.2: Foliar application of micro nutrients on growth, development and fruit quality of Khasi Mandarin

4.2. Results

4.2.1. Plant Growth and Development

The plant growth parameters were recorded at initial and on yearly interval during the period of experiment and expressed finally as per cent promotion of growth over initial.

4.2.1.1. Plant height

It is evident from Table 4.2.1 that plant height varied significantly among the treatments and it ranged from 4.98m to 5.41m in 2016 and 5.21m to 5.70m in 2017. Maximum plant height (5.41m and 5.70m) was observed in T_{13} (Foliar application of Zn + Cu + B) followed by T_1 [Foliar application of Zinc (Zn)] (5.38m, 5.63m) during both the study years (2016 and 2017). Similarly, T_{13} (Foliar application of Zn + Cu + B) recorded maximum plant height (5.56m) followed by T_1 [Foliar application of Zinc (Zn)] (5.51m) in pooled analysis compared with other treatments.

Calculating the promotion percentage over initial plant height, it was found that maximum plant height promotion percentage was observed in T_{13} (Foliar application of Zn + Cu + B) (6.29%, 11.98%) followed by T_{12} (Foliar application of Zn + Mn + B) (6.06%, 11.11%) during 2016 and 2017. Similarly, T_{13} (Foliar application of Zn + Cu + B) recorded maximum height promotion percentage (9.14 %) and followed by T_{12} (Foliar application of Zn + Mn + B) (8.59%) while control

(T_{16}) recorded the lowest value (5.91%) in pooled data as shown in Table 4.2.1 and figure 4.2.1.

4.2.1.2. Stem girth

Table 4.2.1 revealed that stem girth varied from 35.89cm to 50.96cm in 2016 and 37.89cm to 53.91cm in 2017 due to application of different combination of foliar micronutrients. Maximum stem girth (50.96cm, 53.91cm), was observed in T_{13}(Foliar application of Zn + Cu + B) which was followed by T_{12}(Foliar application of Zn + Mn + B)(47.98cm, 50.11cm), during 2016 and 2017, and in case of the pooled data of two consecutive years it was found maximum stem girth with T_{13}(Foliar application of Zn + Cu + B)(52.44cm) followed by T_{12}(Foliar application of Zn + Mn + B)(49.05cm) which were significantly superior over T_{16}(Control)(36.89cm).

However, calculating promotion percentage over initial, T_{12}(Foliar application of Zn + Mn + B) showed maximum promotion percentage in the first year (2016) study (11.27%) followed by T_{15}(Foliar application of Zn + Mn + Cu + B)(11.23%), whereas,T_{13}(16.97%) was found highest which was followed by T_1 [Foliar application of Zinc (Zn)] (16.36%)in 2017 and the pooled data showed that highest stem girth promotion with T_{13}(Foliar application of Zn + Cu + B)(13.77%) followed by T_{12}(Foliar application of Zn + Mn + B)(13.74%).T_{16}(Control) recorded minimum percentage promotion of stem girth in 2016, 2017 and pooled data (5.84%,11.74%,8.79%) respectively.

4.2.1.3. Plant Canopy Spread North – South (N-S)

It is obvious from Table 4.2.2 that all treatments varied significantly over control with regard to plant canopy spread N-S. The plant canopy spread varied from 2.24m to 2.74 m in 2016 and 2.36m to 3.09m in 2017. Plant at T_{13}(Foliar application of Zn + Cu + B) recorded maximum plant canopy spread (2.74m,3.09m) in 2016 and 2017 followed by T_{12}(Foliar application of Zn + Mn + B)(2.73m,3.08m).The pooled data also showed maximum canopy spread in T_{13} (Foliar application of Zn + Cu + B) (2.92m) followed by T_{12} (2.91m) and minimum was recorded in Control (2.30m).

Regarding promotion percentage of plant canopy spread N-S, T_9 (Foliar application of Mn + B) recorded highest promotion percentage (14.95%) followed by T_8 (Foliar application of Mn + Cu) (14.93%) in 2016. During 2017, T_{12} (Foliar application of Zn + Mn + B) recorded highest promotion percentage of plant canopy spread (28.33%) followed by T_{13} (Foliar application of Zn + Cu + B) (28.22%). The pooled data indicated that T_{12} (Foliar application of Zn + Mn + B) had maximum promotion percentage of plant canopy spread (N-S) (21.04%) followed by T_{13} (20.95%) whereas, control (T_{16}) recorded lowest value (9.05%).

4.2.1.4. Plant Canopy Spread East – West (E-W)

The data presented in Table 4.2.2 revealed that the Plant canopy spread (E-W) varied from 2.37m to 2.91m and 2.49m to 3.24m during 2016 and 2017, respectively. Maximum canopy spread (E-W) was observed in T_{13} (Foliar application of Zn + Cu + B) (2.91m, 3.24m) followed by T_{12} (Foliar application of Zn + Mn + B) (2.89m, 3.23m) in 2016 and 2017. Similarly, plants at T_{13} (Foliar

Table 4.2.1Effect of foliar micronutrients spray on plant height and stem girth

	Plant Height(m)			Percent Promotion over initial			Stem Girth(cm)			Percent Promotion over initial		
Treatment	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
T_1	5.38	5.63	5.51	5.96 (14.14)	10.85 (19.23)	8.41 (16.85)	46.65	49.01	47.83	10.75 (19.14)	16.36 (23.86)	13.56 (21.60)
T_2	4.98	5.28	5.13	3.53 (10.84)	9.77 (18.22)	6.65 (14.95)	39.89	41.61	40.75	9.35 (17.80)	14.06 (22.02)	11.71 (20.01)
T_3	4.98	5.21	5.09	5.04 (12.98)	9.92 (18.35)	7.48 (15.87)	41.39	43.04	42.22	10.26 (18.68)	14.65 (22.51)	12.45 (20.66)
T_4	5.16	5.39	5.28	5.95 (14.12)	10.68 (19.07)	8.32 (16.76)	43.65	45.54	44.60	10.65 (19.04)	15.44 (23.41)	13.04 (21.17)
T_5	5.26	5.49	5.38	5.41 (13.45)	10.02 (18.45)	7.72 (16.13)	42.56	44.16	43.36	10.43 (18.84)	14.58 (22.45)	12.51 (20.71)
T_6	5.01	5.24	5.12	5.25 (13.25)	9.98 (18.41)	7.62 (16.02)	41.50	43.45	42.48	10.11 (18.54)	15.28 (23.01)	12.70 (20.87)
T_7	5.23	5.47	5.35	5.98 (14.16)	10.95 (19.33)	8.47 (16.92)	45.98	48.26	47.12	10.69 (19.08)	16.18 (23.72)	13.43 (21.50)
T_8	5.24	5.48	5.36	5.65 (13.74)	10.48 (18.89)	8.06 (16.50)	42.74	44.61	43.68	10.58 (18.98)	15.42 (23.12)	13.00 (21.14)
T_9	5.19	5.43	5.31	5.70 (13.82)	10.59 (18.99))	8.15 (16.58)	45.29	47.28	46.29	10.52 (18.92)	15.37 (23.08)	12.95 (21.09)
T_{10}	5.14	5.38	5.26	6.00 (14.18)	10.93 (19.30))	8.46 (16.91)	45.26	47.39	46.33	10.53 (18.93)	15.73 (23.36)	13.13 (21.24)
T_{11}	5.14	5.38	5.26	5.98 (14.15)	10.93 (19.30))	8.45 (16.90)	45.29	47.15	46.22	10.81 (19.20)	15.37 (23.08)	13.09 (21.21)
T_{12}	5.25	5.50	5.38	6.06 (14.25)	11.11 (19.47)	8.59 (17.04)	47.98	50.11	49.05	11.27 (19.62)	16.21 (23.74)	13.74 (21.76)
T_{13}	5.41	5.70	5.56	6.29 (14.52)	11.98 (20.25)	9.14 (17.59)	50.96	53.91	52.44	10.57 (18.97)	16.97 (24.32)	13.77 (21.78)
T_{14}	5.37	5.60	5.48	5.61 (13.70)	10.24 (18.66)	7.92 (16.35)	43.12	44.98	44.05	10.54 (18.94)	15.30 (23.03)	12.92 (21.07)
T_{15}	5.31	5.56	5.44	5.99 (14.16)	10.98 (19.35)	8.48 (16.93)	45.96	47.99	46.98	11.23 (19.58)	16.14 (23.69)	13.69 (21.71)
T_{16}	5.11	5.46	5.29	2.40 (8.92)	9.42 (17.87)	5.91 (14.07)	35.89	37.89	36.89	5.84 (13.98)	11.74 (20.03)	8.79 (17.24)
SEm(±)	0.073	0.064	0.063	0.942	0.317	0.556	1.131	1.942	2.202	0.628	0.665	0.540
$CD_{(0.05)}$	0.211	0.184	0.181	2.722	0.915	1.607	3.266	5.608	6.360	1.814	1.922	1.559

*Angular transformed values are in parenthesis

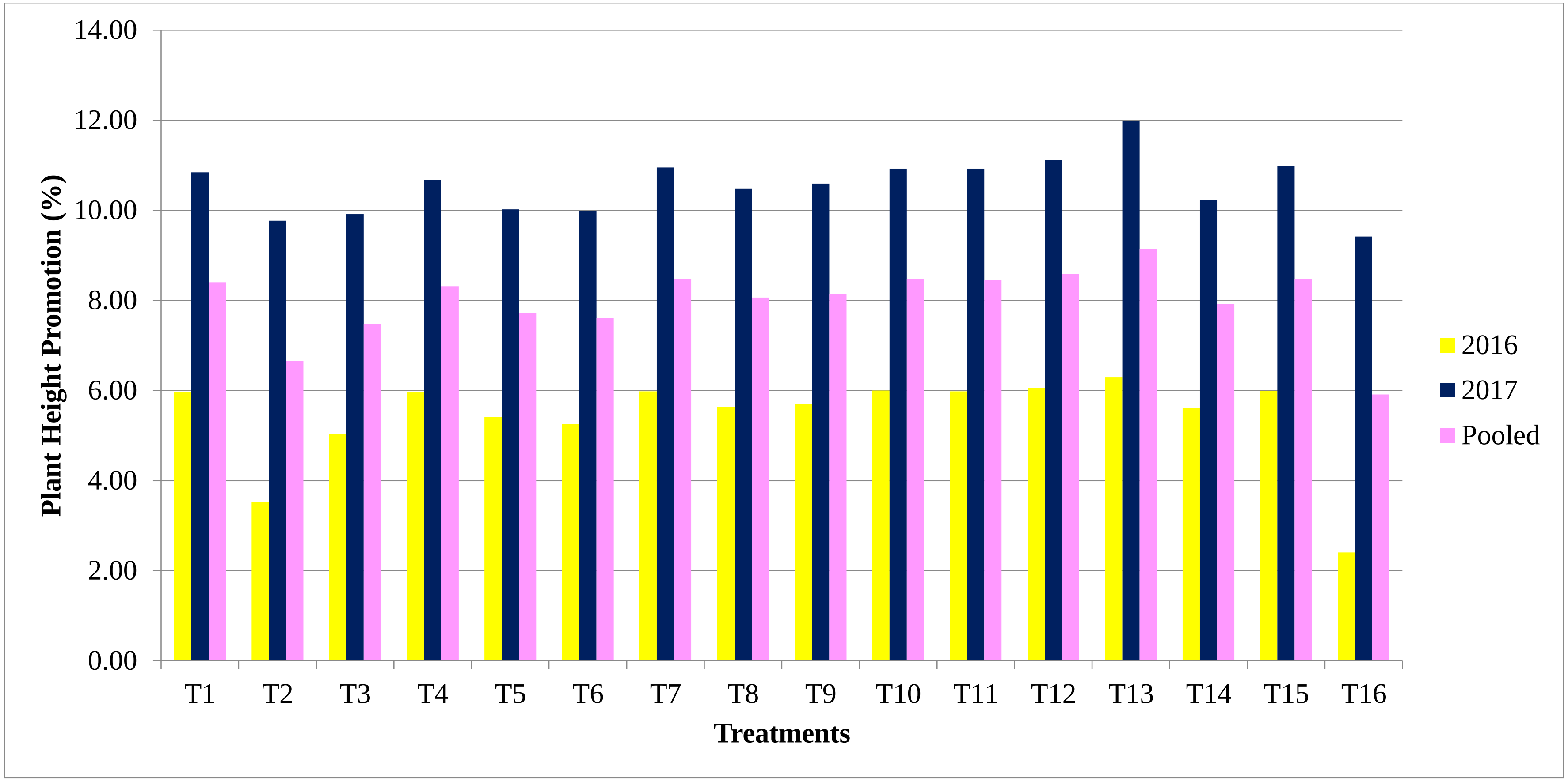


Fig. 4.2.1 Effect of foliar micronutrients spray on Plant Height Promotion Percentage

Table 4.2.2 Effect of foliar micronutrients spray on plant canopy spread North-South (N-S) and East-West (E-W)

Treatment	Canopy spread NS(m)			Percent Promotion over initial			Canopy spread EW(m)			Percent Promotion over initial		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	2.68	2.97	2.83	14.29	26.65	20.47	2.75	3.04	2.90	13.17	25.10	19.14
				(22.21)	(31.08)	(26.90)				(21.28)	(30.07)	(25.94)
T_2	2.49	2.56	2.53	12.26	15.42	13.84	2.54	2.79	2.67	8.55	19.23	13.89
				(20.50)	(23.12)	(21.84)				(17.00)	(26.01)	(21.88)
T_3	2.54	2.69	2.62	13.09	19.77	16.43	2.57	2.82	2.70	9.83	20.51	15.17
				(21.21)	(26.40)	(23.91)				(18.27)	(26.93)	(22.92)
T_4	2.67	2.93	2.80	14.15	25.27	19.71	2.74	3.01	2.88	13.69	24.90	19.29
				(22.10)	(30.18)	(26.36)				(21.72)	(29.93)	(26.06)
T_5	2.54	2.74	2.64	13.14	22.05	17.59	2.61	2.87	2.74	10.13	21.10	15.61
				(21.25)	(28.01)	(24.80)				(18.56)	(27.34)	(23.27)
T_6	2.61	2.76	2.69	11.30	17.70	14.50	2.59	2.85	2.72	10.21	21.28	15.74
				(19.64)	(24.88)	(22.38)				(18.64)	(27.47)	(23.38)
T_7	2.72	3.06	2.89	13.43	27.61	20.52	2.89	3.21	3.05	15.14	27.89	21.51
				(21.50)	(31.70)	(26.93)				(22.90)	(31.88)	(27.63)
T_8	2.64	2.84	2.74	14.93	23.64	19.29	2.68	2.92	2.80	12.13	22.18	17.15
				(22.73)	(29.09)	(26.05)				(20.39)	(28.09)	(24.47)
T_9	2.66	2.89	2.78	14.95	24.89	19.92	2.68	2.97	2.83	12.61	24.79	18.70
				(22.75)	(29.93)	(26.51)				(20.80)	(29.86)	(25.62)
T_{10}	2.69	3.03	2.86	13.12	27.42	20.27	2.83	3.19	3.01	14.11	28.63	21.37
				(21.24)	(31.58)	(26.76)				(22.07)	(32.35)	(27.53)
T_{11}	2.69	3.01	2.85	13.74	27.27	20.51	2.81	3.10	2.96	14.23	26.02	20.12
				(21.76)	(31.48)	(26.93)				(22.16)	(30.67)	(26.65)
T_{12}	2.73	3.08	2.91	13.75	28.33	21.04	2.89	3.23	3.06	14.17	27.17	20.67
				(21.77)	(32.16)	(27.30)				(22.12)	(31.41)	(27.04)
T_{13}	2.74	3.09	2.92	13.69	28.22	20.95	2.91	3.24	3.08	15.02	28.06	21.54
				(21.72)	(32.09)	(27.24)				(22.80)	(31.99)	(27.65)
T_{14}	2.59	2.78	2.69	14.35	22.74	18.54	2.64	2.89	2.77	11.39	21.94	16.67
				(22.26)	(28.48)	(25.51)				(19.73)	(27.93)	(24.09)
T_{15}	2.71	3.04	2.88	13.45	27.73	20.59	2.86	3.19	3.03	14.86	28.11	21.49
				(21.51)	(31.78)	(26.98)				(22.67)	(32.02)	(27.62)
T_{16}	2.24	2.36	2.30	6.16	11.94	9.05	2.37	2.49	2.43	6.76	12.16	9.46
				(14.37)	(20.22)	(17.51)				(15.07)	(20.41)	(17.91)
SEm(±)	0.067	0.132	0.111	0.988	1.498	1.712	0.076	0.133	0.117	1.204	1.551	1.686
$CD_{(0.05)}$	0.194	0.380	0.321	2.853	4.327	4.946	0.219	0.384	0.338	3.476	4.480	4.870

*Angular transformed values are in parenthesis

application of Zn + Cu + B) was recorded maximum canopy spread (E-W) (3.08m) followed by T_{12} (Foliar application of Zn + Mn + B) (3.06m) while control T_{16} (2.43m) recorded minimum, in pooled data.

The plant canopy spread (E-W) promotion percentage also varied significantly over control (T_{16}). Maximum promotion percentage was found in T_7 (Foliar application of Zn + B) (15.14%) followed by T_{13} (15.02%) in 2016. T_{10} (Foliar application of Cu +B) recorded maximum (28.63%) followed by T_{15} (Foliar application of Zn + Mn + Cu + B) (28.11%) in 2017. However, the pooled data showed plant at T_{13} (Foliar application of Zn + Cu + B) had maximum promotion percentage of canopy spread (E-W) (21.54%) followed by T_7 (Foliar application of Zn + B) (21.51%) in pooled data of the two consecutive years. However, minimum promotion percentage of canopy spread (E-W) spread was observed in T_{16}, Control plant (9.46%) in pooled data.

4.2.2 Fruit Growth and Development

4.2.2.1. Fruit Set %

Perusal of data presented in Table 4.2.3 revealed that there was significant variation in fruit set percentage among the treatments. The fruit set percentage varied between 54.07% to 61.89% in 2016 and 51.87% to 58.01% in 2017. Plants at T_{13} (Foliar application of Zn + Cu + B) recorded highest fruit set percentage (61.89%) followed by T_{10} (Foliar application of Cu +B) (61.30%) during 2016. whereas, in 2017, plant at T_{15} (Foliar application of Zn + Mn + Cu + B) showed highest fruit set percentage (58.01%) followed by T_{13} (Foliar application of Zn + Cu + B) (57. 91%).

The pooled data revealed that fruit set percentage was highest in T_{13} (Foliar application of Zn + Cu + B) (59.90%) which was followed by T_7 (Foliar application of Zn + B) (58.97%) whereas, control recorded the lowest value in both the years and pooled analysis (54.07%, 51.87%, and 52.97%).

4.2.2.2. **Days from fruit set to maturity**

It is clear from the data presented in Table 4.2.3 that days from fruit set to maturity varied among the treatment and ranged from 296.02 days to 308.64 days in 2016 and 294.10 days to 307.64 days in 2017. Longest maturity days was observed in T_{12} (Foliar application of Zn + Mn + B) (308.64 days and 307.64days), which was followed by T_{13} (Foliar application of Zn + Cu + B) (307.12 days, 306.76 days) in both the years (2016 and 2017). The pooled data also showed longest day to maturity with T_{12} (Foliar application of Zn + Mn + B) (308.14 days) followed by T_{13} (Foliar application of Zn + Cu + B) (306.94 days) compared with other treatments.

4.2.2.3. Fruit Drop %

In the experiment, it was found that fruit drop percentage significantly varied among the treatments in both the years. The data presented in Table 4.2.5 and Table 4.2.6 clearly showed that fruit drop percentage consistently increased from 60 (days after fruit set (DAFS) to 120 DAFS subsequently fallen on 180DAFS onwards in both the year of study. Fruit drop percentage ranged between 13.75 to 17.44 per cent in 2016 and 17.94 to 23.14 per cent in 2017 at 60DAFS which got increased and ranged between 16.35 to 24.28 per cent in 2016 and 20.36 to 30.16 per cent in 2017 at 120 DAFS. Pooled data also revealed that fruit drop percentage which range between 15.85 to 20.29 per cent in 60DAFS, got increased and ranged between 18.45 and 27.22 per cent in 120 DAFS. From 180 DAFS to pre harvest situation, fruit drop percentage was found low (0.77 to 3.66%) in 2016; (1.11 to 6.25 %) in 2017 and (0.94 to 4.82 %) in pooled data. Further, it was observed that total fruit drop was significantly higher in 2017 (ranged between 46.15 to 67.22%) compared with 2016 (ranged between 34.17 to 49.10%). Perusal of the pooled data revealed that total fruit drop was found minimum in T_{13} (Foliar application of Zn + Cu + B) (40.16%) followed by T_{12}(Foliar application of Zn + Mn + B)(41.93%) and T_{15}(Foliar application of Zn + Mn + Cu + B) (42.11%) compared with control (58.16%).

4.2.2.4. Fruit Retention %

Perusal of the data presented in Table 4.2.7 and Table 4.2.8 showed that retention percentage of fruit significantly varied among the selected treatments in both 2016 and 2017 along with pooled data. Moreover, it was found that retention percentage of fruit gradually dropped from 60DAFS to pre harvest condition. In 2016, it ranged between 82.56 to 86.25% at 60 DAFS, whereas, it ranged between 50.32 to 65.40% at pre harvest condition. Similarly, in 2017, it ranged between 76.86 to 82.06% in 60 DAFS, which further declined and ranged between 33.36 to 54.28 % at pre harvest condition. However, it was noted that the final retention percentage of fruit was higher in 2016 (ranged between 50.32 to 65.40 %) compared with 2017 (ranged between 33.36 to 54.28 %). From the table 4.2.8, it is evident that in case of pooled data, final fruit retention was found highest in T_{13} (Foliar application of Zn + Cu + B)(59.84%) followed by T_{12}(Foliar application of Zn + Mn + B) (58.07%) and

T_{15}(Foliar application of Zn + Mn + Cu + B) (57.89%) compared with control (41.84%).

4.2.2.5. Number of fruits per plant

Number of fruits per plant were recorded and presented in Table 4.2.3. Data on mean number of fruits per plant revealed that there was a significant variation due to different treatments during the period of study. Maximum number of fruits was observed in T_{13} (Foliar application of Zn + Cu + B)(140.55 and145.48) during both the years (2016 and 2017) of study; however, second highest fruit number was observed in T_7(Foliar application of Zn + B)(127.08) in 2016,whereas,plants at T_{14}(Foliar application of Mn + Cu + B) recorded second maximum fruit number (133.35) in 2017. However, in pooled data it was found that plants at T_{13} (Foliar application of Zn + Cu + B) recorded maximum no. of fruits (143.02) which was followed by T_7 (Foliar application of Zn + B)(130.09) compared with control (93.30).

4.2.2.6. Yield

Yield varied significantly with the application of foliar micronutrients in the present experiment. It varied from 8.98 kg per tree (9.98 t per ha) to 19.99 kg per tree (22.21 t per ha) during 2016, and in 2017 it varied 8.80kg per tree (9.78t per ha) to 18.06kg per tree (20.09t per ha) among the different treatments.

The treatment which recorded maximum yield during 2016 was T_{13} (Foliar application of Zn + Cu + B) (19.99 kg per tree and 22.21t per ha) which was followed by T_{15} (Foliar application of Zn + Mn + Cu + B) (19.74kg per tree and

21.93t per ha). However, during 2017, T_{15} recorded highest yield (18.08kg per tree and 20.09t/ha) followed by T_{13} (Foliar application of Zn + Cu + B)(18.06kg per tree and 20.07t/ha).The pooled analysis also revealed that plants at T_{13}(Foliar application of Zn + Cu + B) was recorded with maximum yield(19.03kg per tree and 21.14t/ha) followed by T_{15}(Foliar application of Zn + Mn + Cu + B)(18.91kg per tree and 21.01 t/ha) as shown in Table 4.2.4 and Figure 4.2.2.

4.2.3. Fruit Physical Parameters

4.2.3.1. Fruit Length (cm)

The data pertaining to fruit length shown in Table 4.2.9 and Figure 4.2.3 indicated that significant increase was observed with fruit length during the study and it ranged from 5.71cm to 6.09cm in the year 2016 and 5.67cm to 5.99cm in 2017. Maximum fruit length was observed with T_{13} (Foliar application of Zn + Cu + B) (6.09cm) which was followed by T_{12} (Foliar application of Mn + Cu + B) (6.05cm) during 2016. In the year 2017, maximum fruit length was obtained with T_{15} (Foliar application of Zn + Mn + Cu + B) (5.99cm) followed T_9 (Foliar application of Mn + B)(5.96cm). However, the pooled data of two consecutive years had shown that maximum fruit length was recorded in T_{15} (Foliar application of Zn + Mn + Cu + B) (6.01cm) which was followed by T_{13} (Foliar application of Zn + Cu + B) (5.99cm) whereas, minimum fruit length was recorded in control (5.69 cm).

4.2.3.2. Fruit Diameter (cm)

Perusal of the data presented in Table 4.2.9 and Figure 4.2.4 revealed that significant difference was observed among treatments in fruit diameter. Average fruit diameter varied from 5.90cm to 7.00cm and 4.50cm to 7.03cm during 2016 and 2017, respectively.

Fruits of the plants at T_{13} (Foliar application of Zn + Cu + B) recorded maximum fruit diameter (7.00cm), followed by T_{12} (6.98cm) in the year 2016. T_{15} (Foliar application of Zn + Mn + Cu + B) recorded maximum fruit diameter (7.03cm) followed by T_{13} (Foliar application of Zn + Cu + B) (6.41cm), in 2017. The pooled data of the two experimental years also revealed that fruits at T_{15} (Foliar application of Zn + Mn + Cu + B) had maximum fruit diameter (6.98cm) followed by T_{13} (Foliar application of Zn + Cu + B) (6.71cm) compared with control (5.20cm)

4.2.3.3. Fruit weight (g)

The result of the present investigation revealed that fruit weight was significantly influenced by application of foliar micronutrients across the treatments. It was found that among the treatments, average fruit weight varied from 97.52g to 153.25g and 79.22g to 145.67g during 2016 and 2017, respectively as presented in Table 4.2.10.

Significantly heaviest fruit weight was observed in T_{12}(Foliar application of Zn + Mn + B)(153.25g) ,followed by T_{15} (149.95g), in the first year (2016) study while in the second year (2017) study, T_{15}(Foliar application of Zn + Mn + Cu + B) recorded heaviest fruit (145.67g) which was followed by T_{13}(Foliar application of Zn + Cu + B)(124.17g).The pooled data indicated that fruit weight was maximum in T_{15}(Foliar application of Zn + Mn + Cu + B)(147.81g) which was followed by T_{12}(Foliar application of Zn + Mn + B)(134.96g) over control (95.32g).

4.2.3.4. Fruit Volume (cc)

It is clear from the Table 4.2.9 that significant variation was observed in both the years and pooled data. Fruit volume among the treatments ranged from 94.67 cc to 159.58 cc in 2016 and 66.68 cc to 128.33 cc in the year 2017.

Maximum fruit volume was obtained in T_{15} (Foliar application of Zn + Mn + Cu + B) (159.58cc) followed by T_{13} (152.50cc) in 2016, whereas, fruits at T_{12} (Foliar application of Zn + Mn + B) got maximum fruit volume (128.33cc) followed by T_{13} (Foliar application of Zn + Cu + B) (124.12cc), in 2017. The pooled data showed that fruit volume was highest in T_{13} (Foliar application of Zn + Cu + B) (138.31cc) followed by T_{12} (Foliar application of Zn + Mn + B) (135.83cc) .However, control plant T_{16} observed lowest fruit volume (93.39cc).

4.2.3.5. Specific Gravity

Data presented in Table 4.2.10 showed that specific gravity ranged from 0.71 to 1.24 during first year (2016) and varied from 0.62 to 1.65 during second year (2017) of experiment. In the first year (2016) study, specific gravity of fruit was highest (1.24) in T_1 [Foliar application of Zinc (Zn)] while T_5 (Foliar application of Zn + Mn) resulted second highest (1.18). From second year (2017) analysis of the data, it was found that fruits at T_4 [Foliar application of Boron (B)] was having maximum specific gravity (1.65) followed by T_7 (Foliar application of Zn + B)(1.57).The pooled data also resulted with maximum specific gravity for fruits at T_7 (1.32) followed by T_{11}(Foliar application of Zn +Mn+ Cu)(1.23) compared with other treatments.

4.2.3.6. Number of seeds

Number of seeds per fruit as observed in Table 4.2.12 varied significantly among treatments and ranged from 12.14 to 17.98 in 2016 and from 11.01 to 17.93 in 2017.

The pooled data of the experimental years resulted in maximum number of seeds (17.91) in fruits at T_{16} (control) while lowest number of seed (11.58) was observed in fruits at T_{13} (Foliar application of Zn + Cu + B) followed by T_{15} (Foliar application of Zn + Mn + Cu + B) (15.89).

4.2.3.7. Seed weight (g)

The weight of seed of Khasi Mandarin fruits varied from 1.12g to 3.17g and 1.09g to 3.50g during first and second year (2016 and 2017) study, respectively. Minimum seed weight was observed in fruits at T_{15}(Foliar application of Zn + Mn + Cu + B)(1.12g) followed by T_{13}(Foliar application of Zn + Cu + B)(1.17g) compared to control (3.17g) in 2016.Whereas, in 2017, fruits at T_{11} (Foliar application of Zn + Mn + Cu) and T_{15}(Foliar application of Zn + Mn + Cu + B) were found minimum seed weight (1.09g) followed by T_{12}(Foliar application of Zn + Mn + B)(1.14g) compared with control(3.50g). The pooled data also showed fruits at T_{15}(Foliar application of Zn + Mn + Cu + B) with minimum seed weight (1.11g) followed by T_{13} (Foliar application of Zn + Cu + B)(1.53g) compared with T_{16} (3.34g) as shown in Table 4.2.11.

4.2.3.8. Peel Weight (g)

It is evident from the Table 4.2.11 that peel weight differed significantly among the treatments compared with control. Average peel weight of fruits ranged from 29.89g to 47.14g in 2016 and 21.00g to 37.67g in the year 2017.

The first year (2016) data recorded minimum peel weight in case of fruits at T_{15} (Foliar application of Zn + Mn + Cu + B) (29.89g) followed by T_{13} (Foliar application of Zn + Cu + B) (31.92g) compared with control (47.14g). However, fruits at T_{13} (Foliar application of Zn + Cu + B) recorded minimum peel weight (21.00g) followed by T_{12} (Foliar application of Zn + Mn + B) (21.50g) during the second year (2017) study. As observed in the pooled analysis, T_{13} (Foliar application of Zn + Cu + B) was found minimum in fruit peel weight (26.46g) followed by T_{15} (Foliar application of Zn + Mn + Cu + B) (26.94g) compared with control (42.40g).

4.2.3.9. Peel Thickness (cm)

It is observed from Table 4.2.11 that peel thickness of Khasi Mandarin fruits varied significantly among the treatments and was ranged from 0.23cm to 0.32cm in the year 2016, whereas, in the year 2017, it ranged from 0.18cm to 0.32cm. The observation indicated that minimum peel thickness of fruit was observed in T_{15} (Foliar application of Zn + Mn + Cu + B)(0.23cm) which was statistically *at par* with T_{13}(Foliar application of Zn + Cu + B)(0.24cm) in the year 2016 compared with control (0.32cm).Whereas, in the year 2017, T_{13}(Foliar application of Zn + Cu + B) was observed with minimum fruit peel thickness (0.18cm) followed by T_{12}(Foliar application of Zn + Mn + B)(0.21cm). However, the pooled analysis resulted that T_{13} (Foliar application of Zn + Cu + B) recorded minimum thickness of fruit peel (0.21cm) which was *at par* with T_{15} (Foliar application of Zn + Mn + Cu + B)(0.23cm) while T_{16}(control) recorded maximum peel thickness (0.32cm) of fruits.

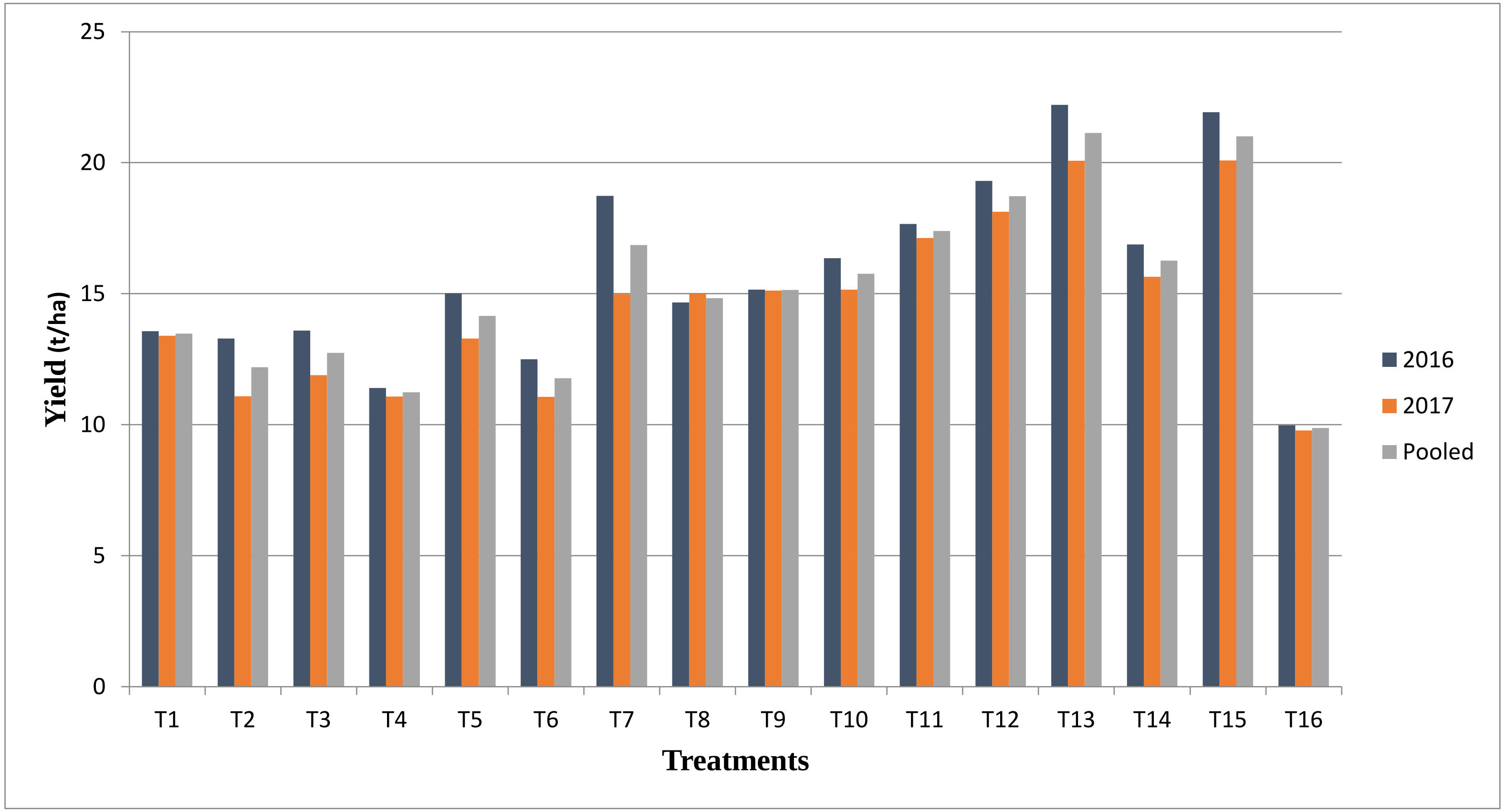


Fig.4.2.2 Effect of foliar micronutrients spray on fruit yield

Table 4.2.3 Effect of foliar micronutrients spray on fruit set %, days from fruit set to maturity, number of fruits per plant

	Fruit set %			Days from fruit set to maturity			No of fruits per plant		
Treatment	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	58.37	56.37	57.37	303.94	303.00	303.47	108.89	114.82	111.85
T_2	57.08	55.74	56.41	296.18	294.10	295.14	110.17	113.39	111.78
T_3	58.10	55.87	56.99	296.09	294.85	295.47	102.01	104.27	103.14
T_4	56.66	54.45	55.56	296.02	296.90	296.46	100.91	105.31	103.11
T_5	58.74	56.52	57.63	305.97	305.01	305.49	114.80	118.96	116.88
T_6	57.55	54.23	55.89	305.03	304.91	304.97	100.14	103.14	101.64
T_7	60.97	56.98	58.97	302.13	300.77	301.45	127.08	133.10	130.09
T_8	58.74	56.75	57.75	299.36	297.58	298.47	105.71	112.22	108.96
T_9	59.25	56.57	57.91	296.18	298.00	297.09	100.59	103.65	102.12
T_{10}	61.30	55.96	58.63	299.78	298.50	299.14	112.28	119.33	115.80
T_{11}	59.89	57.82	58.86	302.09	301.87	301.98	114.96	120.00	117.48
T_{12}	59.96	57.85	58.90	308.64	307.64	308.14	124.55	125.15	124.85
T_{13}	61.89	57.91	59.90	307.12	306.76	306.94	140.55	145.48	143.02
T_{14}	60.96	56.69	58.82	299.32	297.98	298.65	125.85	133.35	129.60
T_{15}	59.86	58.01	58.93	303.02	302.28	302.65	126.95	128.93	127.94
T_{16}	54.07	51.87	52.97	296.12	297.90	297.01	90.69	95.91	93.30
SEm(±)	0.910	0.818	1.118	1.501	1.751	1.337	2.474	2.202	2.746
$CD_{(0.05)}$	2.628	2.362	3.230	4.336	5.057	3.862	7.146	6.359	7.932

Table 4.2.4 Effect of foliar micronutrients spray on fruit yield

	Yield (kg per tree)			Yield (tonnes per hectare)		
Treatment	2016	2017	Pooled	2016	2017	Pooled
T_1	12.21	12.05	12.13	13.57	13.39	13.48
T_2	11.96	9.98	10.97	13.29	11.09	12.19
T_3	12.23	10.70	11.47	13.59	11.89	12.74
T_4	10.26	9.97	10.12	11.40	11.08	11.24
T_5	13.51	11.96	12.74	15.01	13.29	14.15
T_6	11.25	9.95	10.60	12.50	11.06	11.78
T_7	16.87	13.48	15.18	18.74	14.98	16.86
T_8	13.20	13.49	13.35	14.67	14.99	14.83
T_9	13.65	13.61	13.63	15.16	15.12	15.14
T_{10}	14.73	13.65	14.19	16.36	15.16	15.76
T_{11}	15.90	15.41	15.65	17.66	17.12	17.39
T_{12}	17.38	16.32	16.85	19.31	18.13	18.72
T_{13}	19.99	18.06	19.03	22.21	20.07	21.14
T_{14}	15.19	14.08	14.64	16.88	15.64	16.26
T_{15}	19.74	18.08	18.91	21.93	20.09	21.01
T_{16}	8.98	8.80	8.89	9.98	9.78	9.88
SEm (±)	1.363	1.499	1.313	1.474	1.393	1.845
$CD_{(0.05)}$	3.937	4.330	3.793	4.258	4.023	5.329

Table 4.2.5 Effect of foliar micronutrients spray on fruit drop percentage at 60, 120 and 180 days after fruit set (DAFS)

Treatment	Fruit drop% at 60DAFS			Fruit drop% at 120DAFS			Fruit drop% at 180DAFS		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	14.97	18.98	16.98	20.54	24.54	22.54	1.03	2.87	1.95
T_2	16.74	20.75	18.75	18.88	22.92	20.90	1.60	4.54	3.07
T_3	15.83	19.98	17.90	20.81	24.98	22.89	1.60	4.41	3.00
T_4	16.72	21.65	19.19	20.99	25.19	23.09	3.36	5.01	4.19
T_5	14.58	18.95	16.77	19.05	23.09	21.07	1.05	3.06	2.05
T_6	16.61	20.21	18.41	19.71	23.97	21.84	2.96	5.13	4.04
T_7	14.56	19.65	17.10	16.98	21.53	19.26	1.26	2.09	1.67
T_8	16.01	19.47	17.74	18.28	22.45	20.36	1.02	3.01	2.01
T_9	16.46	20.31	18.39	18.58	23.65	21.11	1.21	2.14	1.68
T_{10}	16.39	19.54	17.97	18.82	22.47	20.64	1.38	2.36	1.87
T_{11}	15.63	19.87	17.75	16.50	20.96	18.73	1.45	3.65	2.55
T_{12}	14.87	18.63	16.75	16.55	20.36	18.45	1.50	2.45	1.98
T_{13}	13.75	17.94	15.85	16.35	21.03	18.69	0.94	2.01	1.47
T_{14}	14.85	18.93	16.89	17.11	21.63	19.37	1.46	2.24	1.85
T_{15}	14.55	18.24	16.39	17.19	21.86	19.52	1.01	2.21	1.61
T_{16}	17.44	23.14	20.29	24.28	30.16	27.22	1.74	4.76	3.25
SEm(±)	0.700	0.458	0.612	1.285	1.466	1.290	0.353	0.606	0.366
$CD_{(0.05)}$	2.022	1.323	1.766	3.712	4.234	3.727	1.018	1.752	1.058

Table 4.2.6 Effect of foliar micronutrients spray on fruit drop percentage at 240DAFS, Pre harvest drop and total fruit drop percentage

	Fruit drop% at 240DAFS			Fruit drop% at pre harvest			Total Fruit drop%		
Treatment	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	3.36	4.21	3.78	2.76	4.12	3.44	42.66	54.72	48.69
T_2	1.28	3.27	2.27	2.16	6.25	4.20	40.65	57.73	49.19
T_3	3.08	5.09	4.09	1.58	3.47	2.52	42.90	57.93	50.41
T_4	1.39	3.96	2.67	2.27	3.54	2.91	44.74	59.35	52.04
T_5	1.89	5.87	3.88	2.17	3.54	2.85	38.75	54.51	46.63
T_6	1.84	4.78	3.31	2.01	3.14	2.57	43.12	57.23	50.18
T_7	1.89	2.94	2.42	2.01	3.96	2.99	36.71	50.17	43.44
T_8	3.04	5.01	4.02	1.61	3.79	2.70	39.96	53.73	46.85
T_9	2.93	4.03	3.48	1.40	4.01	2.71	40.58	54.14	47.36
T_{10}	2.75	4.03	3.39	1.39	2.65	2.02	40.72	51.05	45.89
T_{11}	1.29	2.06	1.67	1.51	3.02	2.27	36.38	49.56	42.97
T_{12}	1.61	3.65	2.63	1.11	3.13	2.12	35.64	48.22	41.93
T_{13}	2.36	4.06	3.21	0.77	1.11	0.94	34.17	46.15	40.16
T_{14}	2.62	4.12	3.37	1.66	2.69	2.17	37.69	49.61	43.65
T_{15}	1.95	3.14	2.54	1.02	3.05	2.04	35.72	48.50	42.11
T_{16}	3.66	5.98	4.82	1.98	3.18	2.58	49.10	67.22	58.16
SEm(±)	0.350	0.490	0.467	0.325	0.520	0.402	2.364	2.008	1.939
$CD_{(0.05)}$	1.011	1.416	1.349	0.939	1.502	1.160	6.829	5.798	5.600

4.2.3.10. Juice content (ml)

It is evident from Table 4.2.10 that the juice content varied significantly among treatments and ranged from 42.23ml to 75.25ml in the first year study and varied from 38.00 to 64.20ml in the second year (2017) study.

T_{11} (Foliar application of Zn + Mn + Cu) recorded highest juice content of fruit (75.25ml), followed by T_9 (Foliar application of Mn + B) (73.58ml) during 2016. Whereas, fruits at T_{13} was found highest with juice content (64.20ml) followed by T_{15} (Foliar application of Zn + Mn + Cu + B) (63.10ml) compared with control (38.00ml). However, the pooled data of the two experimental years resulted that T_{13} (Foliar application of Zn + Cu + B) recorded highest juice content of fruit (64.48ml) followed by T_{11} (Foliar application of Zn + Mn + Cu) (63.88ml) compared with control (40.12ml).

4.2.4. Biochemical parameters

4.2.4.1. Total Soluble solids (TSS)

Table 4.2.12 and Figure 4.2.5 is showing that significant variation is observed in fruit TSS content in both the experimental years and pooled analysis. It was found that TSS content of fruit ranged from 9.34^{o}Brix to 10.92^{o}Brix during 2016 and varied from 9.31^{o}Brix to 10.74^{o}Brix in 2017. T_{15} (Foliar application of Zn + Mn + Cu + B) was found to be highest (10.92^o Brix, 10.74^o Brix) in TSS content of fruit among all treatments during first (2016) and second (2017) year study followed by T_{13} (Foliar application of Zn + Cu + B)(10.66^o Brix) during 2016 and by T $_{12}$(Foliar application of Zn + Mn + B)(10.54) during 2017. The pooled data also showed that

Table 4.2.7 Effect of foliar micronutrients spray on fruit retention percentage at 60, 120 and 180 days after fruit set (DAFS)

Treatment	Fruit retention% at 60DAFS			Fruit retention% at 120DAFS			Fruit retention% at 180DAFS		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	85.03	81.02	83.02	64.49	56.48	60.48	63.46	53.61	58.53
T_2	83.26	79.25	81.25	64.38	56.33	60.35	62.78	51.79	57.29
T_3	84.17	80.02	82.10	63.37	55.04	59.20	61.77	50.63	56.20
T_4	83.28	78.35	80.81	62.29	53.16	57.72	58.93	48.15	53.54
T_5	85.42	81.05	83.23	66.36	57.96	62.16	65.31	54.90	60.11
T_6	83.39	79.79	81.59	63.68	55.82	59.75	60.72	50.69	55.71
T_7	85.44	80.35	82.90	68.46	58.82	63.64	67.20	56.73	61.96
T_8	83.99	80.53	82.26	65.71	58.08	61.89	64.69	55.07	59.88
T_9	83.54	79.69	81.61	64.96	56.04	60.50	63.75	53.90	58.83
T_{10}	83.61	80.46	82.03	64.79	57.99	61.39	63.41	55.63	59.52
T_{11}	84.37	80.13	82.25	67.87	59.17	63.52	66.42	55.52	60.97
T_{12}	85.13	81.37	83.25	68.58	61.01	64.80	67.08	58.56	62.82
T_{13}	86.25	82.06	84.15	69.90	61.03	65.46	68.96	59.02	63.99
T_{14}	85.15	81.07	83.11	68.04	59.44	63.74	66.58	57.20	61.89
T_{15}	85.45	81.76	83.61	68.26	59.90	64.08	67.25	57.69	62.47
T_{16}	82.56	76.86	79.71	58.28	46.70	52.49	56.54	41.94	49.24
SEm(±)	0.453	0.534	0.632	2.051	1.738	1.648	1.893	1.328	1.262
$CD_{(0.05)}$	1.309	1.541	1.825	5.923	5.020	4.760	5.466	3.836	3.644

Table 4.2.8 Effect of foliar micronutrients on fruit retention percentage at 240DAFS, Pre harvest retention and total fruit retention percentage

	Fruit retention% at 240DAFS			Fruit retention% at pre harvest			Total Fruit retention%		
Treatment	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
T_1	59.67	49.40	54.54	57.12	45.49	51.31	57.12	45.49	51.31
T_2	60.51	48.52	54.51	58.85	42.77	50.81	58.85	42.77	50.81
T_3	57.68	45.54	51.61	56.60	42.57	49.59	56.60	42.57	49.59
T_4	56.25	44.19	50.22	54.62	41.29	47.96	54.62	41.29	47.96
T_5	61.43	49.03	55.23	60.26	46.48	53.37	60.26	46.48	53.37
T_6	57.41	45.91	51.66	56.14	43.51	49.82	56.14	43.51	49.82
T_7	64.78	53.79	59.29	63.03	50.09	56.56	63.03	50.09	56.56
T_8	60.66	50.06	55.36	59.54	46.76	53.15	59.54	46.76	53.15
T_9	60.27	49.87	55.07	59.14	46.14	52.64	59.14	46.14	52.64
T_{10}	60.02	51.60	55.81	58.95	49.27	54.11	58.95	49.27	54.11
T_{11}	64.75	53.46	59.10	63.43	50.63	57.03	63.43	50.63	57.03
T_{12}	64.45	54.91	59.68	63.85	52.29	58.07	63.85	52.29	58.07
T_{13}	65.75	54.96	60.36	65.40	54.28	59.84	65.40	54.28	59.84
T_{14}	63.21	53.08	58.15	61.93	50.77	56.35	61.93	50.77	56.35
T_{15}	64.71	54.55	59.63	63.98	51.80	57.89	63.98	51.80	57.89
T_{16}	51.71	35.96	43.84	50.32	33.36	41.84	50.32	33.36	41.84
SEm(±)	2.619	1.372	1.882	2.725	1.753	2.036	2.725	1.753	2.036
$CD_{(0.05)}$	7.563	3.963	5.435	7.870	5.063	5.880	7.870	5.063	5.880

Table 4.2.9 Effect of foliar micronutrients spray on fruit diameter, fruit length and fruit volume

	Fruit length (cm)			Fruit diameter (cm)			Fruit volume (cc)		
Treatment	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
T_1	5.73	5.71	5.72	6.65	4.88	5.76	110.83	90.01	100.42
T_2	5.95	5.89	5.92	6.80	5.84	6.32	142.08	106.67	124.38
T_3	5.76	5.72	5.74	6.42	5.48	5.95	125.83	85.02	105.43
T_4	5.84	5.78	5.81	6.38	5.56	5.97	132.92	77.50	105.21
T_5	5.76	5.72	5.74	6.47	5.29	5.88	112.08	88.33	100.21
T_6	5.82	5.76	5.79	6.27	5.65	5.96	133.33	66.68	100.01
T_7	5.87	5.81	5.84	6.65	5.50	6.07	130.42	102.51	116.46
T_8	5.89	5.85	5.87	6.71	5.73	6.22	139.17	105.04	122.10
T_9	6.00	5.96	5.98	6.87	6.22	6.54	150.00	108.33	129.17
T_{10}	5.91	5.89	5.90	6.55	5.87	6.21	142.50	90.03	116.27
T_{11}	5.97	5.91	5.94	6.88	6.02	6.45	147.92	110.04	128.98
T_{12}	6.05	5.87	5.96	6.98	5.98	6.48	143.33	128.33	135.83
T_{13}	6.09	5.89	5.99	7.00	6.41	6.71	152.50	124.12	138.31
T_{14}	5.78	5.74	5.76	6.59	5.42	6.01	113.75	90.02	101.89
T_{15}	6.03	5.99	6.01	6.92	7.03	6.98	159.58	97.12	128.35
T_{16}	5.71	5.67	5.69	5.90	4.50	5.20	94.67	92.12	93.39
SEm(±)	0.073	0.052	0.047	0.109	0.300	0.292	1.722	1.499	1.187
$CD_{(0.05)}$	0.210	0.150	0.137	0.315	0.868	0.843	4.972	4.330	3.429

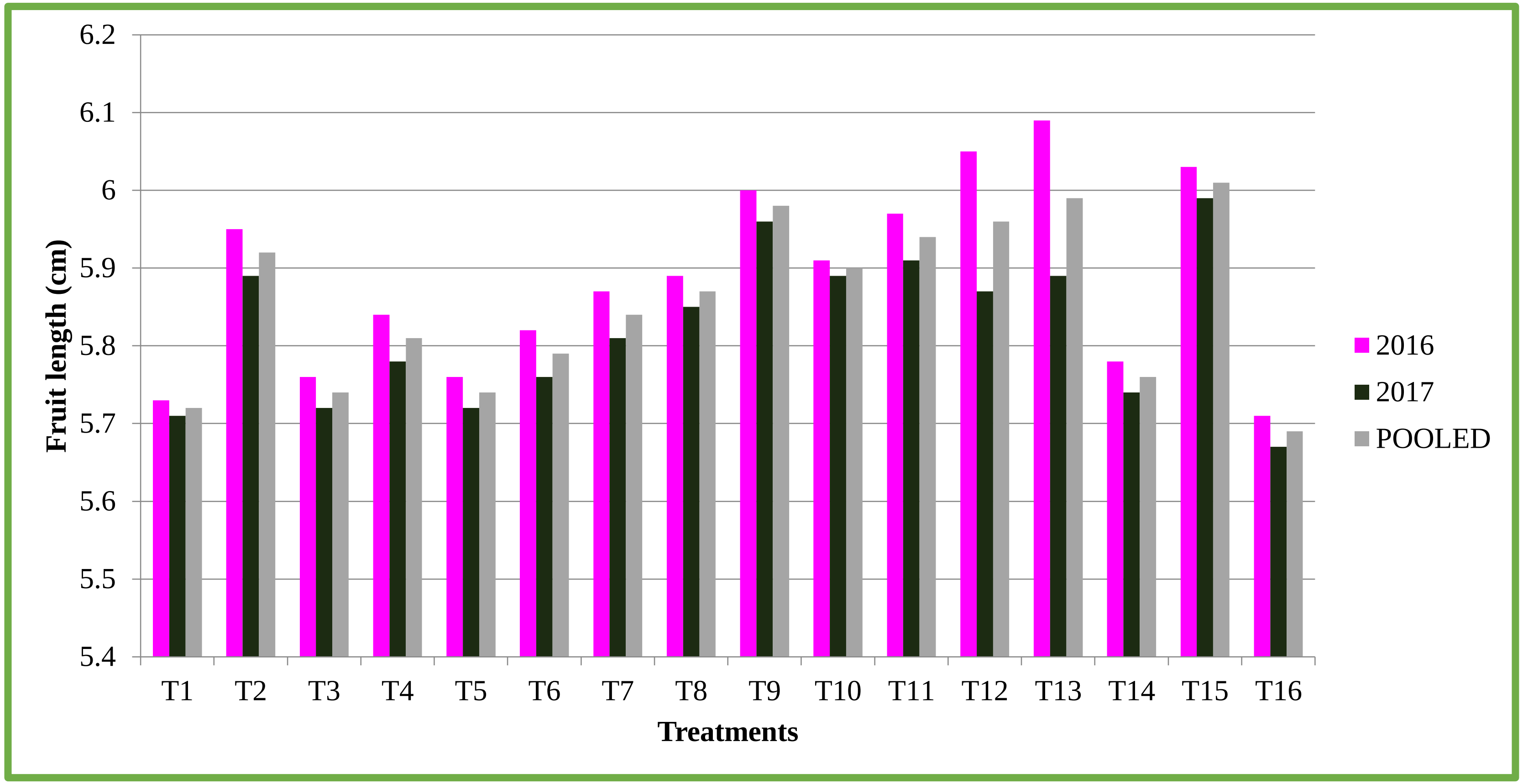


Fig. 4.2.3 Effect of foliar micronutrients spray on fruit length

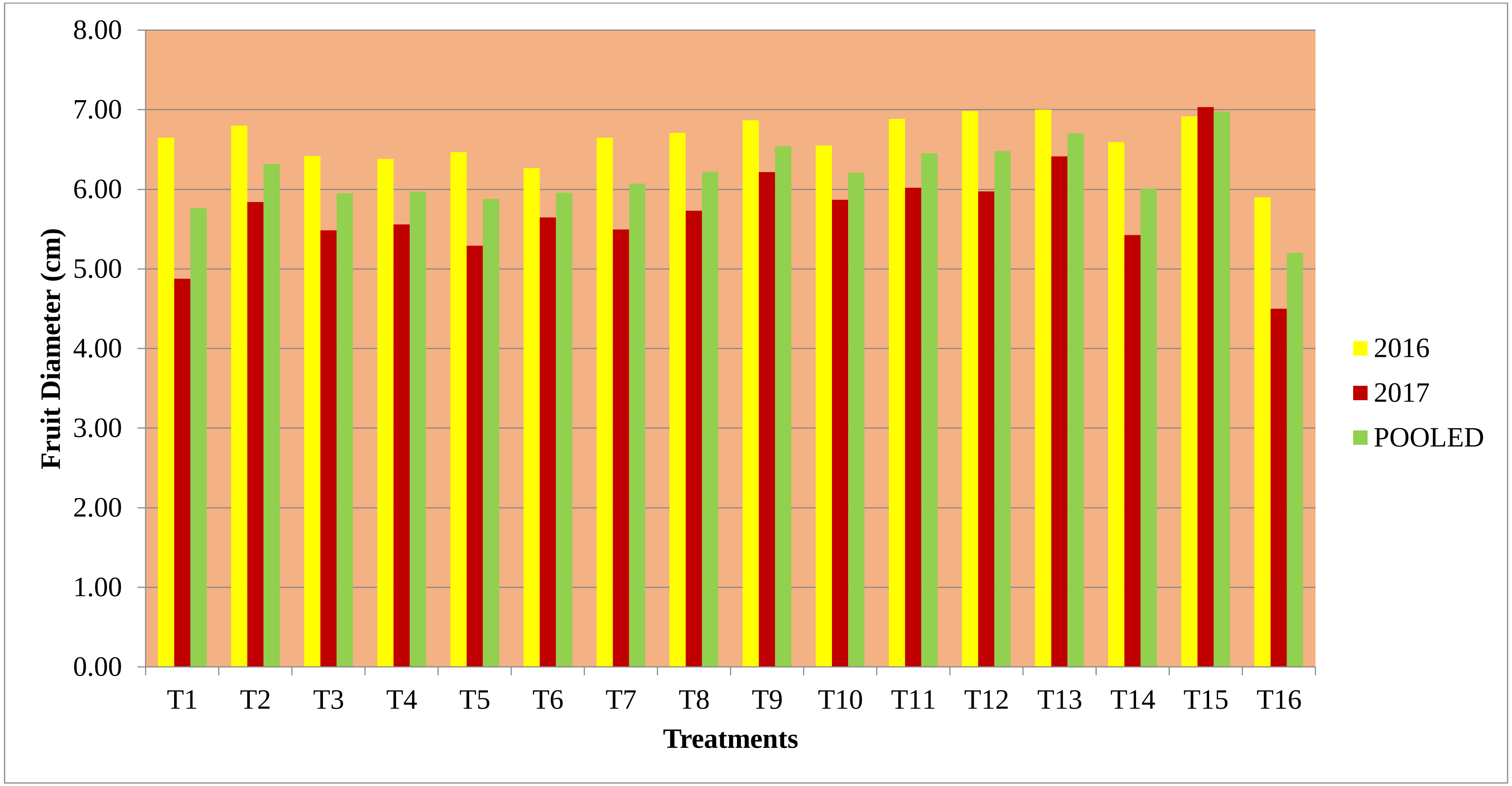


Fig.4.2.4 Effect of foliar micronutrients spray on fruit diameter

Table 4.2.10 Effect of foliar micronutrients spray on juice content, weight and specific gravity of fruit

Treatment	Juice content (ml)			Fruit weight (g)			Specific gravity		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	60.59	55.7	58.12	137.73	79.22	108.47	1.24	1.04	1.14
T_2	55.25	40.0	47.63	101.18	95.14	98.16	0.71	0.87	0.79
T_3	62.75	40.0	51.38	128.86	93.50	111.18	1.02	1.03	1.03
T_4	56.08	47.5	51.79	98.74	97.50	98.12	0.74	1.65	1.20
T_5	64.42	50.0	57.21	132.43	85.50	108.97	1.18	1.27	1.23
T_6	53.17	45.0	49.08	106.51	102.13	104.32	0.80	1.40	1.10
T_7	68.58	52.5	60.54	138.64	94.67	116.66	1.06	1.57	1.32
T_8	69.83	52.5	61.17	139.01	106.00	122.50	1.00	1.04	1.02
T_9	73.58	50.0	61.79	143.55	123.33	133.44	0.96	1.14	1.05
T_{10}	56.50	52.5	54.50	134.00	111.00	122.50	0.94	1.39	1.17
T_{11}	75.25	52.5	63.88	149.47	117.00	133.24	1.01	1.44	1.23
T_{12}	59.78	62.5	61.14	153.25	116.67	134.96	1.07	1.25	1.16
T_{13}	64.81	64.2	64.48	142.23	124.17	133.06	1.03	0.62	0.82
T_{14}	62.75	52.5	57.63	134.19	91.67	112.93	1.18	0.86	1.02
T_{15}	63.16	63.1	63.14	149.95	145.67	147.81	0.94	0.79	0.87
T_{16}	42.23	38.0	40.12	97.52	93.12	95.32	1.03	0.84	0.93
SEm(±)	2.106	1.388	1.746	1.340	2.176	3.601	0.023	0.046	0.026
$CD_{(0.05)}$	6.081	4.007	5.042	3.870	6.284	10.400	0.066	0.132	0.074

Table 4.2.11 Effect of foliar micronutrients spray on peel weight, peel thickness and seed weight of fruit

Treatment	Peel Weight (g)			Peel Thickness (cm)			Seed Weight(g)		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	38.31	26.50	32.40	0.28	0.22	0.25	2.75	3.01	2.88
T_2	39.78	33.50	36.64	0.29	0.26	0.27	2.60	3.00	2.80
T_3	35.41	35.50	35.46	0.26	0.28	0.27	2.08	2.54	2.31
T_4	34.70	28.00	31.35	0.26	0.23	0.24	3.21	3.33	3.27
T_5	35.91	29.50	32.71	0.26	0.23	0.24	3.02	2.91	2.97
T_6	35.19	31.50	33.34	0.26	0.24	0.25	2.53	1.87	2.20
T_7	41.90	31.50	36.70	0.30	0.24	0.27	1.85	2.25	2.05
T_8	39.42	29.50	34.46	0.28	0.23	0.26	2.12	1.42	1.77
T_9	34.52	25.50	30.01	0.25	0.22	0.24	1.47	1.92	1.70
T_{10}	38.81	32.00	35.41	0.28	0.26	0.27	1.99	1.83	1.91
T_{11}	33.25	25.00	29.12	0.25	0.22	0.23	2.27	1.09	1.68
T_{12}	32.42	21.50	26.96	0.25	0.21	0.23	2.01	1.14	1.58
T_{13}	31.92	21.00	26.46	0.24	0.18	0.21	1.17	1.89	1.53
T_{14}	37.29	26.50	31.89	0.28	0.22	0.25	2.70	2.50	2.60
T_{15}	29.89	24.00	26.94	0.23	0.22	0.23	1.12	1.09	1.11
T_{16}	47.14	37.67	42.40	0.32	0.32	0.32	3.17	3.50	3.34
SEm(±)	2.329	1.170	1.675	0.015	0.011	0.015	0.278	0.309	0.341
$CD_{(0.05)}$	6.726	3.378	4.838	0.045	0.033	0.043	0.803	0.892	0.984

fruit TSS content at T_{15} (Foliar application of Zn + Mn + Cu + B) was maximum (10.83^o Brix) followed by T_{13} (Foliar application of Zn + Cu + B)(10.56^o Brix) compared with control (9.33^o Brix).

4.2.4.2. Acidity (%)

It is observed from the data presented in Table 4.2.12 and Figure 4.2.6 that significant variation in fruit acidity was recorded among the treatments and that ranged between 0.49% to 0.68% in 2016 and 0.39% to 0.84% in 2017. Lowest fruit acidity was observed in T_{13} (Foliar application of Zn + Cu + B) (0.49%) which was followed by T_{15} (Foliar application of Zn + Mn + Cu + B) (0.53%) compared with control (0.68%) in the first year (2016) study. In the second year (2017) study, it was found that acidity content of fruits was lowest in T_{15} (Foliar application of Zn + Mn + Cu + B) (0.39%) which was followed by T_{13} (Foliar application of Zn + Cu + B)(0.41%) compared with control (0.84%).

The pooled data of two consecutive years has shown that T_{13} (Foliar application of Zn + Cu + B) recorded lowest fruit acidity (0.45%) followed by T_{15} (Foliar application of Zn + Mn + Cu + B)(0.46%) compared with control(0.76%).

4.2.4.3. TSS/Acid Ratio

The TSS/Acid ratio varied significantly among the treatments and which ranged from 13.67 to 21.71 during 2016 whereas, it varied from 11.08 to 27.57 during 2017. Maximum TSS/Acid ratio of fruits was found in T_{13} (Foliar application of Zn + Cu + B) (21.71) followed by T_{15} (Foliar application of Zn + Mn + Cu + B) (20.46) compared with control (13.67) during the first year (2016) experiment. It was again observed in 2017 that T_{15} (Foliar application of Zn + Mn + Cu + B) recorded highest TSS/Acid ratio (27.57) which was followed by T_{12} (Foliar application of Zn + Mn + B) (25.71) compared with control (11.08). However, the pooled analysis indicated that T_{15} (Foliar application of Zn + Mn + Cu + B) was highest in fruit TSS/Acid ratio (23.46) followed by T_{13} (Foliar application of Zn + Cu + B) (23.43) over control (12.24) as shown in Table 4.2.13.

4.2.4.4. Total Sugar (%)

It is evident from Table 4.2.13 and Figure 4.2.7 that significant variation is observed among the treatments with regard to total sugar content of fruit and found that it ranged from 8.39 % to 9.31 % in the first year (2016) study while it ranged from 8.36% to 9.04% in the second year (2017). Highest total sugar content of fruit (9.31%) is observed in T_{13} (Foliar application of Zn + Cu + B) followed by T_{15} (Foliar application of Zn + Mn + Cu + B) (9.29%) compared with control (8.39%) during 2016. Whereas, in the year 2017, fruits at T_{13} (Foliar application of Zn+Cu+B) recorded highest total sugar (9.04%) which was followed by T_{12} (Foliar application of Zn + Mn + B) (9.01%) compared with control (8.36%). However, the pooled analysis has shown that fruits at T_{13} (Foliar application of Zn + Cu + B) recorded highest total sugar (9.18%) followed by T_{12} (Foliar application of Zn + Mn + B)(9.14%) compared with control (8.38%).

4.2.4.5. Reducing Sugar (%)

It is clear from Table 4.2.13 that reducing sugar content of fruit varied significantly among the treatments during the experimental period. It ranged

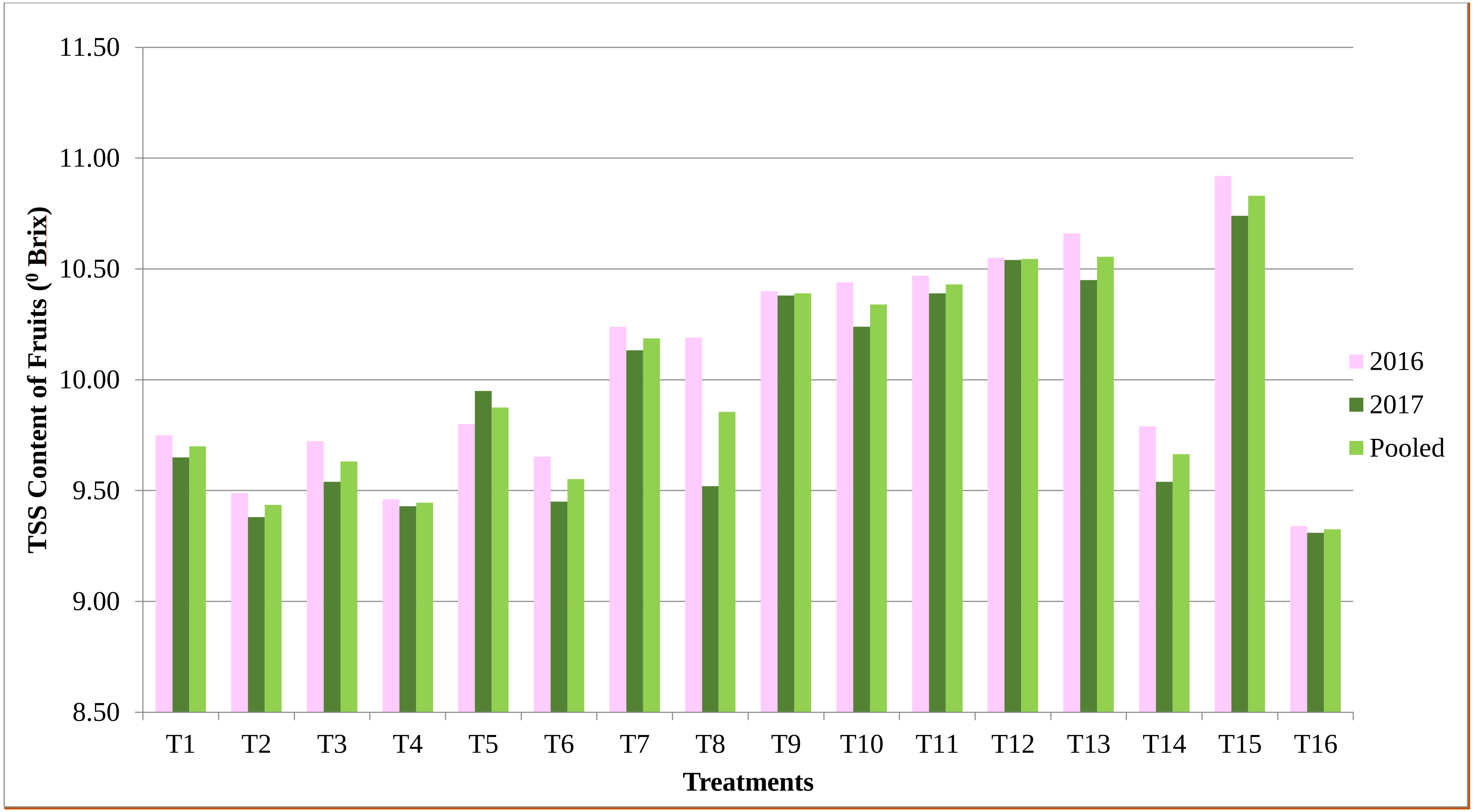


Fig.4.2.5 Effect of foliar micronutrients spray on TSS

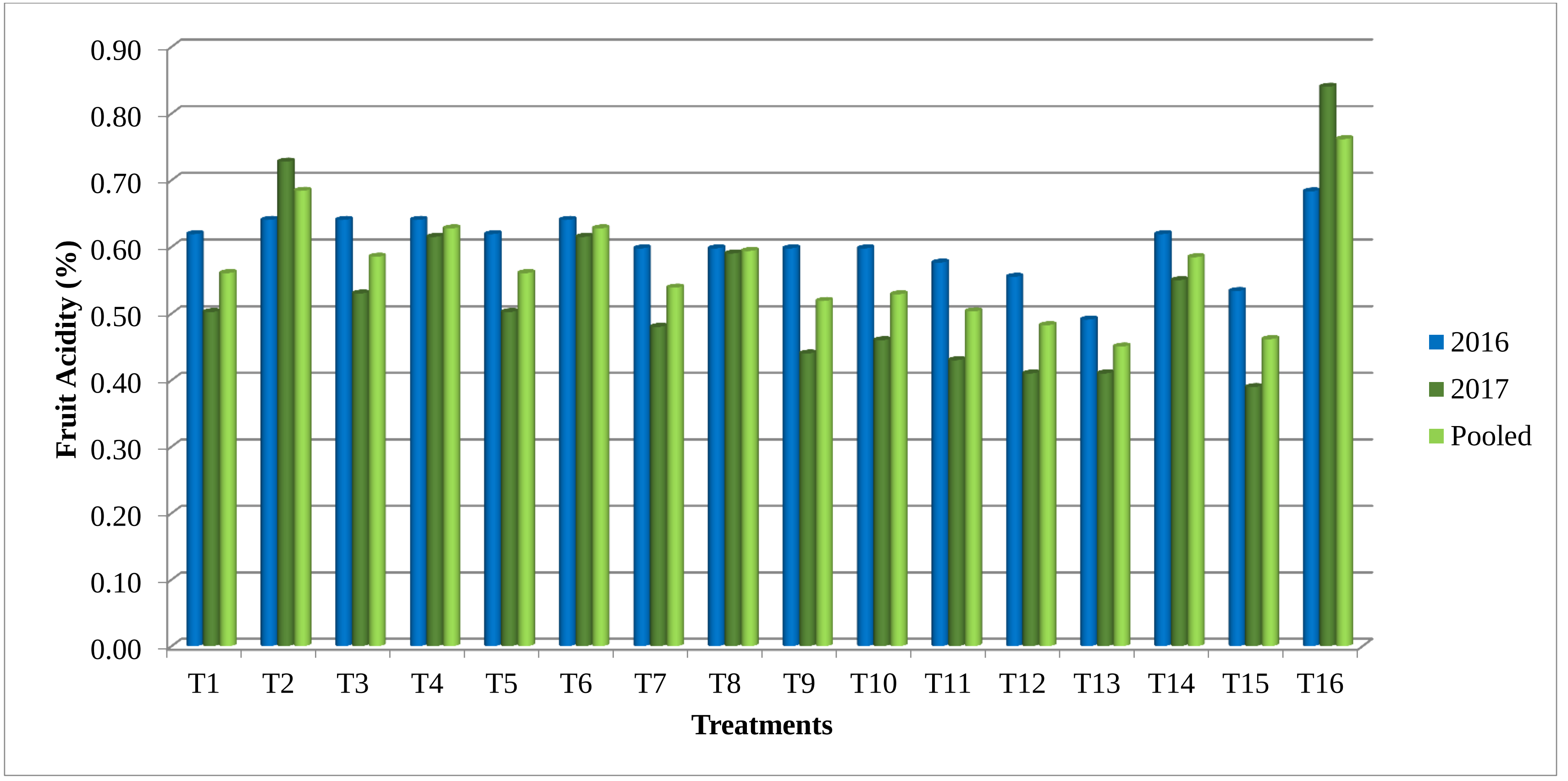


Fig. 4.2.6 Effect of foliar micronutrients spray on fruit acidity

Table 4.2.12 Effect of foliar micronutrients spray on number of seeds, TSS and acidity acidity of fruit

Treatment	Number of Seeds			TSS(° Brix)			Acidity (%)		
	2016	2017	2016	2016	2017	Pooled	2016	2017	Pooled
T_1	17.87	17.93	17.90	9.75	9.65	9.70	0.62	0.50	0.56
T_2	17.59	17.63	17.61	9.49	9.38	9.44	0.64	0.73	0.68
T_3	17.62	17.49	17.56	9.72	9.54	9.63	0.64	0.53	0.59
T_4	17.69	17.81	17.75	9.46	9.43	9.45	0.64	0.61	0.63
T_5	17.84	17.59	17.72	9.80	9.95	9.88	0.62	0.50	0.56
T_6	17.51	17.31	17.41	9.65	9.45	9.55	0.64	0.61	0.63
T_7	16.87	17.42	17.15	10.24	10.13	10.19	0.60	0.48	0.54
T_8	16.94	16.91	16.93	10.19	9.52	9.86	0.60	0.59	0.59
T_9	15.98	17.39	16.69	10.40	10.38	10.39	0.60	0.44	0.52
T_{10}	17.41	16.85	17.13	10.44	10.24	10.34	0.60	0.46	0.53
T_{11}	14.56	17.35	15.96	10.47	10.39	10.43	0.58	0.43	0.50
T_{12}	17.33	15.92	16.63	10.55	10.54	10.55	0.56	0.41	0.48
T_{13}	12.14	11.01	11.58	10.66	10.45	10.56	0.49	0.41	0.45
T_{14}	17.37	17.54	17.46	9.79	9.54	9.67	0.62	0.55	0.58
T_{15}	17.46	14.32	15.89	10.92	10.74	10.83	0.53	0.39	0.46
T_{16}	17.98	17.84	17.91	9.34	9.31	9.33	0.68	0.84	0.76
SEm(±)	0.667	0.463	0.533	0.307	0.190	0.149	0.024	0.069	0.035
$CD_{(0.05)}$	1.926	1.339	1.540	0.886	0.549	0.430	0.068	0.199	0.102

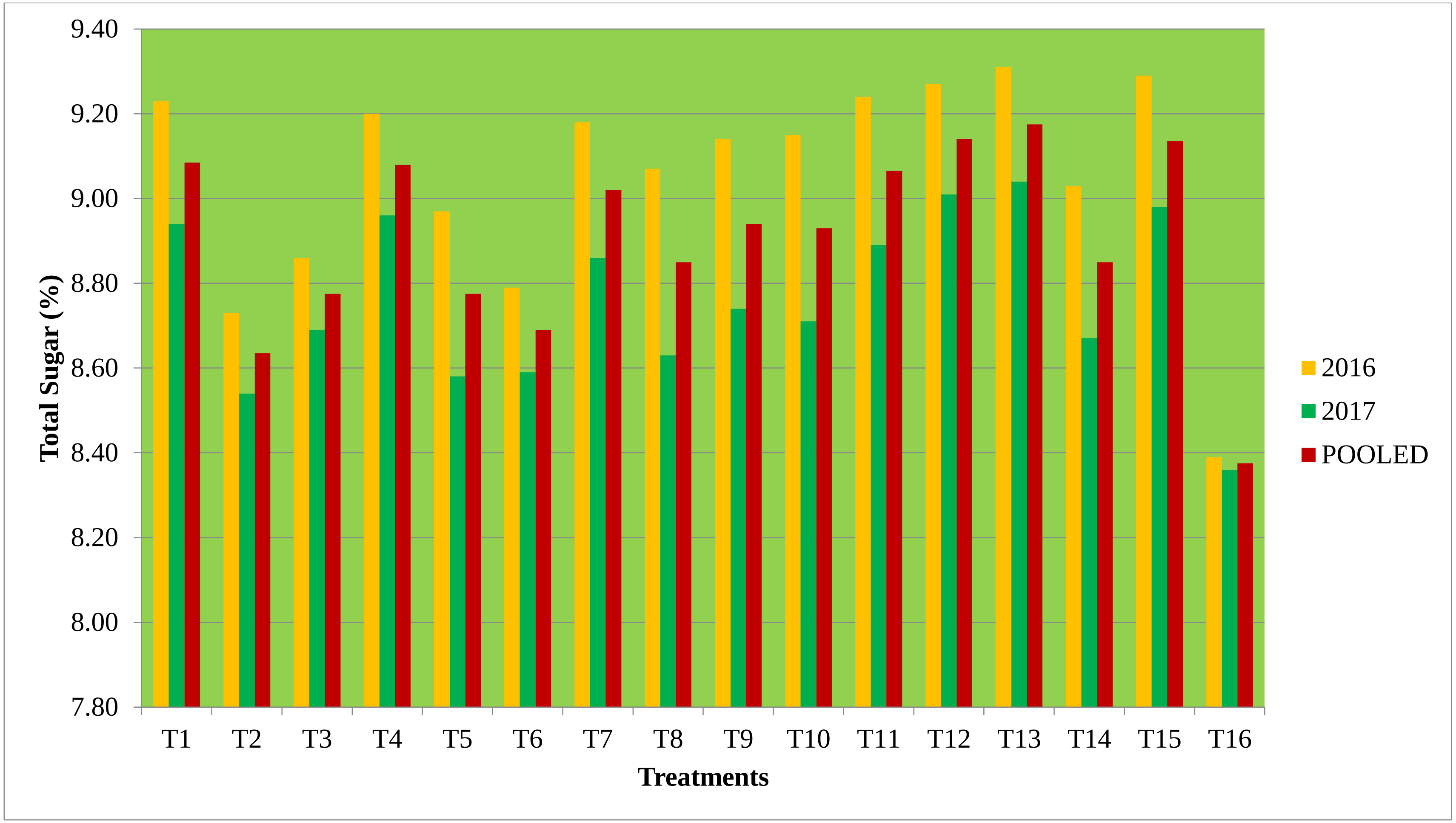


Fig.4.2.7 Effect of foliar micronutrients spray on total sugar

Table 4.2.13 Effect of foliar micronutrients spray on TSS/Acid, Ascorbic acid, Total Sugar and Reducing Sugar content of fruit

Treatment	TSS/Acid			Ascorbic acid (mg/100g of fruit pulp)			Total Sugar (%)			Reducing Sugar (%)		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	15.75	19.21	17.30	44.86	44.54	44.70	9.23	8.94	9.09	6.83	6.72	6.78
T_2	14.82	12.89	13.79	43.67	40.69	42.18	8.73	8.54	8.64	6.29	5.91	6.10
T_3	15.18	18.00	16.46	44.86	44.54	44.70	8.86	8.69	8.78	6.36	6.59	6.47
T_4	14.77	15.33	15.05	43.67	41.69	42.68	9.20	8.96	9.08	6.82	6.84	6.83
T_5	15.83	19.81	17.61	46.05	44.54	45.29	8.97	8.58	8.78	6.39	6.38	6.38
T_6	15.07	15.37	15.22	44.86	41.69	43.27	8.79	8.59	8.69	6.33	6.47	6.40
T_7	17.13	21.11	18.90	46.64	44.54	45.59	9.18	8.86	9.02	6.80	6.68	6.74
T_8	17.05	16.14	16.60	46.64	41.69	44.17	9.07	8.63	8.85	6.56	6.50	6.53
T_9	17.40	23.59	20.02	46.64	48.38	47.51	9.14	8.74	8.94	6.79	6.60	6.70
T_{10}	17.47	22.26	19.55	47.83	44.54	46.19	9.15	8.71	8.93	6.80	6.59	6.69
T_{11}	18.17	24.16	20.73	49.02	52.23	50.63	9.24	8.89	9.07	7.06	6.72	6.89
T_{12}	19.01	25.71	21.85	51.40	52.23	51.82	9.27	9.01	9.14	7.06	6.95	7.01
T_{13}	21.71	25.49	23.43	51.40	48.38	49.89	9.31	9.04	9.18	7.18	7.03	7.11
T_{14}	15.81	17.35	16.53	46.05	44.54	45.29	9.03	8.67	8.85	6.49	6.50	6.49
T_{15}	20.46	27.57	23.46	49.62	52.23	50.92	9.29	8.98	9.14	7.10	6.90	7.00
T_{16}	13.67	11.08	12.24	42.77	39.57	41.17	8.39	8.36	8.38	6.18	6.15	6.17
SEm(±)	0.767	1.142	1.157	0.871	1.410	1.239	0.177	0.078	0.118	0.168	0.167	0.154
$CD_{(0.05)}$	2.215	3.299	3.341	2.516	4.072	3.579	0.511	0.225	0.340	0.486	0.484	0.444

from 6.18% to 7.18% in 2016 while it varied from 5.91% to 7.03% in 2017.

In the year 2016; T_{13} recorded maximum reducing sugar content of fruit (7.18%) followed by T_{15} (Foliar application of Zn + Mn + Cu + B) (7.10%) compared with control (6.18%). But, in the year 2017, T_{13} (Foliar application of Zn + Cu + B) was found highest in fruit reducing sugar percentage (7.03%) followed by T_{12} (Foliar application of Zn + Mn + B) (6.95%). The pooled data resulted that fruits at T_{13} (Foliar application of Zn + Cu + B) recorded highest reducing sugar percentage (7.11%) followed by T_{12} (Foliar application of Zn + Mn + B)(7.01%) compared with control (6.17%).

4.2.4.6. Ascorbic acid (mg/100g)

The data presented in Table 4.2.13 revealed that ascorbic acid content of fruit varied significantly among the treatments compared with control and ranged from 42.77mg/100g of pulp to 51.40mg/100g of pulp during 2016. In the second year (2017) study, it varied from 39.57 to 52.23mg/100g of pulp. Highest ascorbic acid content was found with T_{12} (Foliar application of Zn + Mn + B) and T_{13} (Foliar application of Zn + Cu + B)(51.40mg/100g of pulp) followed by T_{15}(Foliar application of Zn + Mn + Cu + B)(49.62mg/100g of pulp) compared with control (42.77mg/100g of pulp) in the first year study. Whereas, in the second year (2017) observation, T_{11}, T_{12} and T_{15} were found high (52.23mg/100g of pulp) followed by T_9 (Foliar application of Mn + B) and T_{13} (Foliar application of Zn + Cu + B) (48.38mg/100g of pulp) over control (39.57mg/100g of pulp).However, the pooled analysis revealed that T_{12} (Foliar application of Zn + Mn + B) as the best in fruit ascorbic acid content (51.82mg/100g of pulp), followed by T_{15} (Foliar application of

Zn + Mn + Cu + B) (50.92mg/100g of pulp) compared with control (41.17mg/100g of pulp).

4.2.5. Soil nutrient analysis

4.2.5.1. Total Nitrogen (kg/ha)

Total nitrogen content in the experimented soil are depicted in Table 4.2.14. It varied significantly among the treatments and ranged between 673.80 to 727.02kg/ha in 2016 and 671.36 to 724.36kg/ha in 2017. Highest total Nitrogen content of soil was observed in T_{13} (Foliar application of Zn + Cu + B) (727.02kg/ha) followed by T_{15} (Foliar application of Zn + Mn + Cu + B) (725.22kg/ha) compared with control (673.80kg/ha) in 2016. Similarly, treatment T_{13} (Foliar application of Zn + Cu + B) also recorded highest in total N content of soil (724.36kg/ha) followed by T_{15} (Foliar application of Zn + Mn + Cu + B)(723.16kg/ha) while the least was recorded in control (671.36kg/ha) in 2017.

Similarly, the pooled analysis again resulted that highest total soil Nitrogen content in case of T_{13} (Foliar application of Zn + Cu + B) (725.69kg/ha) which was followed by T_{15}(Foliar application of Zn + Mn + Cu + B) (724.19kg/ha) while control plot recorded the least total nitrogen content of soil (672.58kg/ha).

4.2.5.2. Available Phosphorus (kg/ha)

It was found that soil Phosphorus content varied significantly among the treatments over control as depicted in table 4.2.14. Available phosphorus content of soil was varied from 62.87 to 73.77kg/ha during 2016 and 60.87 to 71.26kg/ha in 2017. T_{15}(Foliar application of Zn + Mn + Cu + B)was found highest in soil available

P (73.77kg/ha) while control recorded minimum (62.87kg/ha) in the first year (2016) study, whereas, T_{13}(Foliar application of Zn + Cu + B) recorded highest available soil Phosphorus (71.26kg/ha) followed by T_{12}(Foliar application of Zn + Mn + B)(71.23 kg/ha) while control plant recorded the lowest available soil Phosphorus (60.87 kg/ha) during 2017.

Like, 2017 observation, pooled analysis also recorded highest available P content (72.43kg/ha) with T_{15} (Foliar application of Zn + Mn + Cu + B), and was followed by T_{12} (Foliar application of Zn + Mn + B) (71.98kg/ha), however, it was least in control (61.87kg/ha).

4.2.5.3. Available Potassium (kg/ha)

The data presented in Table 4.2.14 revealed that there was significant variation in available potassium content of soil among treatments. It was varied from 380.00kg/ha to 424.69 kg/ha in 2016 and 376.98kg/ha to 418.04kg/ha in 2017. In the year 2016, highest available soil potassium content was observed with T_{13} (Foliar application of Zn + Cu + B)(424.69kg/ha) followed by T_{15}(Foliar application of Zn + Mn + Cu + B)(419.90) whereas, in the second year (2017), T_{15} recorded maximum amount of soil potassium (418.04kg/ha) which was followed by T_{13}(Foliar application of Zn + Cu + B)(418.01kg/ha) and control recorded minimum (380.00 and 376.98 kg/ha) in both the years. Pooled data revealed that soil potassium content in T_{13} (Foliar application of Zn + Cu + B) was significantly higher (421.35kg/ha) than all the treatments followed by T_{15} (Foliar application of Zn + Mn + Cu + B) (418.97kg/ha), while control plot recorded the least available soil potassium (378.49kg/ha).

4.2.5.4. Soil Manganese (mg/kg)

It is clearly observed from the Table 4.2.15 that soil manganese content varied significantly among the treatments and ranged from 14.74 mg/kg to 16.49mg/kg during 2016 and 14.72mg/kg to 16.41mg/kg during 2017. T_4 {Foliar application of Boron (B)} recorded highest level of soil Manganese (16.49 and16.41 mg/kg) followed by T_{16} (16.20 and 16.16mg/kg) during the first (2016) and second (2017) year study. The pooled data of two consecutive years also has showed that T_4 (Foliar application of Boron (B) recorded the highest level of soil Mn (16.45mg/kg) followed by T_{16} (16.18mg/kg) compared with other treatments.

4.2.5.5. Soil Copper (mg/kg)

The soil copper content among treatments varied significantly and ranged from 1.55 to 1.63mg/kg in the year 2016 and 1.55 to 1.61mg/kg in the year 2017. During the first year (2016) of experiment, T_{11} (Foliar application of Zn + Mn + Cu) and T_{12} (Foliar application of Zn + Mn + B) recorded highest soil copper (1.63mg/kg) among all treatments followed by T_{15} (Foliar application of Zn + Mn + Cu + B)(1.62mg/kg). Similarly, T_{12} (Foliar application of Zn + Mn + B) (1.61mg/kg) recorded highest amount of soil copper (1.61 mg/kg) followed by T_{15} (Foliar application of Zn + Mn + Cu + B)(1.60mg/kg) during second year (2017) of study. The pooled data also observed that T_{12} (Foliar application of Zn + Mn + B) was found highest in soil copper (1.62mg/kg) followed by T_{15} (Foliar application of Zn + Mn + Cu + B) (1.61mg/kg) compared with control (1.56mg/kg) as shown in Table 4.2.15.

Table 4.2.14 Effect foliar micronutrients spray on availability of soil major nutrients

Treatment	Total Nitrogen(kg/ha)			Available Phosphorus (kg/ha)			Available Potassium(kg/ha)		
	2016	2017	2016	2016	2017	Pooled	2016	2017	Pooled
T_1	690.10	685.12	687.61	63.89	61.39	62.64	388.12	385.46	386.79
T_2	678.85	674.23	676.54	62.00	61.78	61.89	384.04	381.26	382.65
T_3	684.11	680.13	682.12	62.04	61.86	61.95	386.59	384.69	385.64
T_4	672.14	668.94	670.54	61.55	61.49	61.52	380.46	378.16	379.31
T_5	688.28	684.36	686.32	63.44	63.12	63.28	389.85	387.65	388.75
T_6	674.46	671.32	672.89	61.75	61.59	61.67	380.88	378.46	379.67
T_7	709.32	706.98	708.15	70.39	70.03	70.21	406.75	404.63	405.69
T_8	694.41	690.25	692.33	66.62	64.16	65.39	396.96	395.46	396.21
T_9	695.92	693.12	694.52	67.68	65.98	66.83	403.26	401.36	402.31
T_{10}	703.81	698.65	701.23	69.91	69.45	69.68	398.77	397.65	398.21
T_{11}	699.42	697.26	698.34	68.42	68.12	68.27	412.28	410.36	411.32
T_{12}	712.36	710.32	711.34	72.73	71.23	71.98	417.10	415.64	416.37
T_{13}	727.02	724.36	725.69	71.44	71.26	71.35	424.69	418.01	421.35
T_{14}	691.10	688.36	689.73	66.39	63.45	64.92	391.08	389.46	390.27
T_{15}	725.22	723.16	724.19	73.77	71.09	72.43	419.90	418.04	418.97
T_{16}	673.80	671.36	672.58	62.87	60.87	61.87	380.00	376.98	378.49
SEm(±)	4.392	5.921	3.685	1.429	1.189	0.960	3.875	2.234	2.504
$CD_{(0.05)}$	12.685	17.100	10.644	4.128	3.434	2.772	11.192	6.452	7.231

Table 4.2.15 Effect of foliar micronutrients spray on availability of soil micronutrients

Treatment	Fe (mg/kg)			Cu(mg/kg)			Zn(mg/kg)			Mn(mg/kg)			B(mg/kg)		
	2016	2017	Pooled	2016	2016	2017	Pooled	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	92.48	91.68	92.08	1.60	1.56	1.58	2.81	2.71	2.76	15.22	15.14	15.18	1.39	1.37	1.38
T_2	92.75	90.89	91.82	1.59	1.55	1.57	2.73	2.65	2.69	15.82	15.74	15.78	1.30	1.26	1.28
T_3	93.54	90.36	91.95	1.59	1.57	1.58	2.74	2.64	2.69	15.42	15.36	15.39	1.33	1.31	1.32
T_4	92.83	91.05	91.94	1.55	1.53	1.54	2.69	2.67	2.68	16.49	16.41	16.45	1.25	1.23	1.24
T_5	92.65	91.65	92.15	1.60	1.58	1.59	2.73	2.69	2.71	15.10	14.98	15.04	1.36	1.34	1.35
T_6	92.22	90.68	91.45	1.57	1.55	1.56	2.69	2.67	2.68	15.95	15.91	15.93	1.29	1.27	1.28
T_7	95.20	92.36	93.78	1.61	1.57	1.59	2.89	2.87	2.88	14.85	14.79	14.82	1.63	1.61	1.62
T_8	94.21	91.35	92.78	1.59	1.57	1.58	2.83	2.79	2.81	14.99	14.91	14.95	1.47	1.45	1.46
T_9	94.90	92.38	93.64	1.60	1.58	1.59	2.85	2.81	2.83	14.97	14.89	14.93	1.53	1.51	1.52
T_{10}	95.03	92.45	93.74	1.61	1.59	1.6	2.86	2.84	2.85	14.93	14.89	14.91	1.60	1.56	1.58
T_{11}	93.60	91.68	92.64	1.63	1.57	1.6	2.88	2.86	2.87	14.87	14.83	14.85	1.55	1.53	1.54
T_{12}	95.10	93.06	94.08	1.63	1.61	1.62	2.97	2.95	2.96	14.80	14.76	14.78	1.67	1.63	1.65
T_{13}	96.47	93.45	94.96	1.60	1.58	1.59	2.99	2.97	2.98	14.83	14.75	14.79	1.69	1.65	1.67
T_{14}	93.20	91.34	92.27	1.58	1.56	1.57	2.80	2.76	2.78	14.98	14.96	14.97	1.43	1.41	1.42
T_{15}	96.12	95.14	95.63	1.62	1.60	1.61	2.93	2.89	2.91	14.74	14.72	14.73	1.66	1.64	1.65
T_{16}	93.03	90.13	91.58	1.57	1.55	1.56	2.69	2.65	2.67	16.20	16.16	16.18	1.28	1.24	1.26
SEm(±)	0.780	0.542	0.463	0.013	0.013	0.011	0.037	0.045	0.047	0.278	0.332	0.256	0.088	0.089	0.088
$CD_{(0.05)}$	2.253	1.565	1.338	0.037	0.038	0.031	0.108	0.129	0.137	0.802	0.960	0.740	0.254	0.257	0.255

4.2.5.6. Soil Zinc (mg/kg)

The Zinc content of soil varied significantly in all the treatments compared with control (Table 4.2.15). It varied from 2.69 to 2.99 mg/kg during 2016 and from 2.64 to 2.97 mg/kg during 2017.The highest level of soil Zinc was obtained in T_{13}(Foliar application of Zn + Cu + B) during 2016 (2.99mg/kg) and 2017 (2.97mg/kg) and was followed by T_{12}(Foliar application of Zn + Mn + B)(2.97mg/kg in 2016, 2.95 mg/kg in 2017).The pooled analysis also indicated that soil Zinc content was highest (2.98 mg/kg) in T_{13}(Foliar application of Zn + Cu + B) which was again followed with T_{12}(Foliar application of Zn + Mn + B)(2.96mg/kg) while T_{16} (control) recorded the least soil Zinc content (2.67mg/kg).

4.2.5.7. Soil Iron (mg/kg)

It is evident from Table 4.2.15 that soil Iron (Fe) content varied significantly over control and ranged from 92.22 to 96.47mg/kg during 2016 and from 90.13 to 95.14 mg/kg in 2017. Highest soil Iron content was observed in T_{13} (Foliar application of Zn + Cu + B) in the first year (2016) study (96.47 mg/kg) which was followed by T_{15} (Foliar application of Zn + Mn + Cu + B) (96.12 mg/kg). Whereas, T_{15} (Foliar application of Zn + Mn + Cu + B) recorded highest soil Iron content (95.14mg/kg) which was followed by T_{13} (Foliar application of Zn + Cu + B) (93.45mg/kg) in the second year (2017) study.

The pooled data indicated that T_{15} (Foliar application of Zn + Mn + Cu + B) with highest soil Iron content (95.63mg/kg) which was followed by T_{13} (Foliar application of Zn + Cu + B) (94.96 mg/kg) compared with control (91.58 mg/kg).

4.2.5.8. Soil Boron (mg/kg)

It is evident from Table 4.2.15 that soil Boron content varied significantly over control and ranged from 1.28 to 1.69mg/kg during 2016 and from 1.24 to 1.65 mg/kg in 2017. Highest Boron content of soil was observed in T_{13} (Foliar application of Zn + Cu + B) in the first year (2016) study (1.69 mg/kg) which was followed by T_{12} (Foliar application of Zn + Mn + B) (1.67mg/kg). Similarly, T_{13} (Foliar application of Zn + Cu + B) recorded highest soil Boron (1.65 mg/kg) in the second year (2017) study which was followed by T_{15} (Foliar application of Zn + Mn + Cu + B) (1.64mg/kg).

Like 2016, the pooled data indicated that T_{13} (Foliar application of Zn + Cu + B) got the highest amount of soil boron (1.67 mg/kg) which was followed by T_{12} (Foliar application of Zn + Mn + B) (1.65mg/kg) compared with other treatments.

4.2.6. Leaf nutrient analysis

4.2.6.1. Total Nitrogen (%)

Nitrogen content of leaf showed significant variation among all treatments compared with control (Table. 4.2.16). It varied from 1.80% to 2.20 % during 2016 and 1.75 % to 2.18 % in 2017. T_{15} (Foliar application of Zn + Mn + Cu + B) was found highest in leaf Nitrogen content (2.20 and 2.18%) followed with T_{13} (Foliar application of Zn + Cu + B) (2.17 and 2.15%) during 2016 and 2017compared with other treatments.

The pooled data showed that leaf Nitrogen content was highest in T_{15} (Foliar application of Zn + Mn + Cu + B) (2.19%) followed with T_{13} (Foliar application of Zn + Cu + B)(2.16%)while T_{16} recorded minimum (1.78%).

4.2.6.2. Available Phosphorus (%)

The available phosphorus content of leaf varied significantly among the treatments and ranged from 0.11% to 0.22% in 2016 and 0.11% to 0.18% in 2017. Plants at T_{12} (Foliar application of Zn + Mn + B) was recorded highest with leaf Phosphorus percentage (0.22%) followed by T_7 (Foliar application of Zn + B) (0.18%) in 2016. T_7 (Foliar application of Zn + B) recorded maximum available leaf P (0.18%) in 2017, which was found at par with T_{12} (Foliar application of Zn + Mn + B) (0.18%).

Pooled analysis showed that plants at T_{12} (Foliar application of Zn + Mn + B) was highest in leaf Phosphorus content (0.20%) followed by T_7 (Foliar application of Zn + B) (0.18%) compared with other treatments, as shown in Table 4.2.16.

4.2.6.3. Available Potassium (%)

It is evident from the Table 4.2.16 that leaf potassium (K) varied significantly among treatments and ranged between 1.18 % to 1.55 % in 2016 and 1.15 % to 1.52% in 2017. Plants at T_{13} (Foliar application of Zn + Cu + B) was found highest in leaf Potassium content (1.55 and 1.52%) in both the years of study while it was followed by T_{15} (Foliar application of Zn + Mn + Cu + B) (1.53%) in the first year (2016) study, and T_{12} (Foliar application of Zn + Mn + B) (1.49%) in the second year (2017) of study. Plant at Control was recorded the least amount of leaf K (1.18 and 1.14%) in both the years.

Similarly, the pooled analysis resulted that highest leaf K in T_{13} (Foliar application of Zn + Cu + B)(1.53%) followed by T_{15}(Foliar application of Zn + Mn + Cu + B)(1.51%) while lowest was observed in control (1.16%).

4.2.6.4. Leaf Manganese (ppm)

It is evident from Table 4.2.17 that leaf manganese (Mn) content varied significantly among the treatments and ranged from 66.62ppm to 94.50ppm during 2016 and from 64.36ppm to 90.39ppm in 2017. Highest leaf manganese content was observed in T_2 (Foliar application of Manganese (Mn) (94.50ppm) in the year 2016 which was followed by T_9 (Foliar application of Mn + B) (90.53 ppm) compared with control (66.62ppm). Whereas, in the year 2017, T_9 (Foliar application of Mn + B) recorded highest amount of leaf Mn (90.39ppm) which was followed by T_2 (90.18ppm) whereas, T_{16} (control) recorded the lowest amount of leaf Mn (66.62 and 64.36ppm) for both the years. The pooled data also indicated that T_2 {Foliar application of Manganese (Mn)} with highest content of leaf manganese (92.34ppm) which was followed by T_9 (90.46ppm) compared with control (65.49ppm).

4.2.6.5. Leaf Copper (ppm)

The data presented in Table 4.2.17 manifested that leaf copper content varied significantly among the treatments and ranged between 14.14ppm to 27.93ppm in 2016 and 12.98ppm to 25.74ppm in 2017. T_3 {Foliar application of Copper (Cu)} was found highest in leaf copper content (27.93ppm) which was followed by T_{10} (Foliar application of Cu +B)(26.08ppm) while control was the least in leaf copper content(14.14ppm) during 2016. Whereas, in the year 2017, T_{13} (Foliar application of Zn + Cu + B) recorded highest amount of leaf Copper (25.74ppm) followed by T_3 {Foliar application of Copper (Cu)} (25.69ppm) whereas, T_{16} (control) recorded the lowest amount (12.98ppm).

However, the pooled data showed that highest amount of leaf Copper in T_3 {Foliar application of Copper (Cu)} (26.81ppm) followed by T_{13} (Foliar application of Zn + Cu + B) (25.78ppm) while lowest was observed in control (13.56ppm).

4.2.6.6. Leaf Zinc (ppm)

Table 4.2.17 revealed that all treatments varied significantly over control with zinc content of leaf. It ranged from 10.55ppm to 41.94ppm in 2016 and 10.49ppm to 40.98ppm in 2017. T_1 {Foliar application of Zinc (Zn)} recorded highest amount of leaf Zinc content in both the year (41.94ppm and 40.98ppm, respectively) followed by T_{13} (Foliar application of Zn + Cu + B) (28.60ppm and 28.57 ppm).

Similarly, the pooled analysis resulted that highest amount of leaf Zinc was recorded in T_1 {Foliar application of Zinc (Zn)} (41.46ppm) followed by T_{13} (Foliar application of Zn + Cu + B) (28.59ppm) while lowest was observed in control (10.52ppm).

4.2.6.7. Leaf Iron (ppm)

Table 4.2.17 revealed that all treatments varied significantly over control with leaf Iron (Fe) content. It ranged from 149.25ppm to 213.11ppm in 2016 and 147.69 to 207.01ppm in 2017. T_{10} (Foliar application of Cu +B) recorded highest amount of leaf Fe in 2016 (213.11ppm) followed by T_{13} (Foliar application of Zn + Cu + B) (208.97ppm) compared with control (149.25ppm). T_{15} (Foliar application of Zn + Mn + Cu + B) recorded maximum leaf Fe content (207.01ppm) in 2017 followed by T_{10} (Foliar application of Cu +B) (206.41ppm) compared with control (147.69 ppm).

Similarly, the pooled analysis resulted that highest leaf Fe was recorded in T_{10} (Foliar application of Cu +B) (209.76ppm) followed by T_{15} (Foliar application of Zn + Mn + Cu + B) (207.34ppm) while lowest was observed in control (148.47ppm).

4.2.6.8. Leaf Boron (ppm)

Table 4.2.17 revealed that all treatments varied significantly over control with leaf Boron (B) content. It ranged from 25.97ppm to 57.70ppm in 2016 and 10.49 to 56.71ppm in 2017. Plants at T_4 [Foliar application of Boron (B)} recorded highest amount of leaf Boron in 2016 and 2017 (57.70 and 56.71ppm) followed by T_{13} (Foliar application of Zn + Cu + B) (43.12ppm) in 2016 and T_{15} (40.28ppm) in 2017 compared with other treatments.

Plants at T_4 {Foliar application of Boron (B)} recorded highest amount of leaf Boron (57.21ppm) in the pooled data followed by T_{13} (Foliar application of Zn + Cu + B) (41.61ppm).

Table 4.2.16 Effect of foliar micronutrients spray on major nutrients content of leaf

	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
Treatment	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	1.93	1.89	1.91	0.14	0.14	0.14	1.33	1.31	1.32
T_2	1.86	1.84	1.85	0.14	0.14	0.14	1.33	1.30	1.31
T_3	1.91	1.83	1.87	0.15	0.15	0.15	1.31	1.29	1.30
T_4	1.83	1.75	1.79	0.14	0.14	0.14	1.28	1.26	1.27
T_5	1.97	1.93	1.95	0.15	0.15	0.15	1.33	1.32	1.33
T_6	1.83	1.81	1.82	0.13	0.13	0.13	1.26	1.26	1.26
T_7	2.13	2.11	2.12	0.18	0.18	0.18	1.45	1.42	1.43
T_8	2.00	1.96	1.98	0.17	0.17	0.16	1.38	1.33	1.35
T_9	2.08	1.94	2.01	0.17	0.17	0.17	1.40	1.39	1.40
T_{10}	2.05	2.03	2.04	0.17	0.17	0.17	1.44	1.41	1.42
T_{11}	2.10	2.06	2.08	0.17	0.17	0.17	1.41	1.39	1.40
T_{12}	2.16	2.12	2.14	0.22	0.18	0.20	1.51	1.50	1.50
T_{13}	2.17	2.15	2.16	0.12	0.12	0.12	1.55	1.52	1.53
T_{14}	1.97	1.95	1.96	0.15	0.15	0.15	1.38	1.37	1.37
T_{15}	2.20	2.18	2.19	0.11	0.11	0.11	1.53	1.50	1.51
T_{16}	1.80	1.76	1.78	0.15	0.15	0.15	1.18	1.15	1.16
SEm(±)	0.091	0.065	0.062	0.017	0.011	0.011	0.039	0.043	0.053
$CD_{(0.05)}$	0.264	0.188	0.180	0.050	0.033	0.031	0.112	0.125	0.154

Table 4.2.17 Effect of foliar micronutrients on micro nutrients content of leaf

Treatment	Zinc (ppm)			Boron (ppm)			Copper (ppm)			Manganese (ppm)			Iron (ppm)		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	41.94	40.98	41.46	27.95	25.49	26.72	17.95	15.89	16.92	68.30	66.12	67.21	157.03	155.43	156.23
T_2	11.62	11.59	11.61	25.97	23.47	24.72	15.14	13.28	14.21	94.50	90.18	92.34	150.52	148.12	149.32
T_3	12.77	12.75	12.76	26.21	24.09	25.15	27.93	25.69	26.81	69.76	66.14	67.95	153.66	151.32	152.49
T_4	12.78	12.76	12.77	57.70	56.71	57.21	18.11	15.45	16.78	69.81	67.13	68.47	155.85	153.65	154.75
T_5	18.73	18.69	18.71	27.62	26.78	27.20	15.93	13.81	14.87	84.44	81.02	82.73	175.40	173.24	174.32
T_6	19.25	19.23	19.24	28.43	26.98	27.71	20.92	18.46	19.69	69.92	68.14	69.03	200.07	197.45	198.76
T_7	20.61	20.57	20.59	38.53	36.49	37.51	19.01	17.95	18.48	70.92	68.12	69.52	188.12	185.46	186.79
T_8	14.97	14.94	14.96	31.84	29.87	30.86	19.63	18.65	19.14	84.81	82.15	83.48	173.13	170.23	171.68
T_9	14.54	14.48	14.51	37.67	35.59	36.63	17.06	14.84	15.95	90.53	90.39	90.46	159.23	157.69	158.46
T_{10}	15.39	15.36	15.37	33.10	31.09	32.10	26.08	22.16	24.12	73.93	71.23	72.58	213.11	206.41	209.76
T_{11}	20.10	20.08	20.09	28.68	27.65	28.17	25.56	23.16	24.36	86.30	84.56	85.43	193.36	191.32	192.34
T_{12}	21.51	21.48	21.50	39.79	37.45	38.62	16.53	14.85	15.69	87.74	87.54	87.64	204.96	204.14	204.55
T_{13}	28.60	28.57	28.59	43.12	40.09	41.61	25.82	25.74	25.78	71.60	69.12	70.36	208.97	204.01	206.49
T_{14}	12.78	12.76	12.77	31.57	30.45	31.01	23.37	20.45	21.91	76.14	73.04	74.59	164.39	161.47	162.93
T_{15}	22.76	22.74	22.75	42.01	40.28	41.15	24.00	21.46	22.73	90.09	87.49	88.79	207.67	207.01	207.34
T_{16}	10.55	10.49	10.52	40.91	10.49	25.70	14.14	12.98	13.56	66.62	64.36	65.49	149.25	147.69	148.47
SEm(±)	3.081	2.166	2.663	2.286	3.669	2.865	1.398	2.423	1.930	2.602	4.073	3.810	3.656	4.406	4.809
$CD_{(0.05)}$	8.897	6.255	7.692	6.603	10.596	8.275	4.039	6.998	5.573	7.514	11.763	11.003	10.558	12.726	13.890

Table 4.2.18 Effect of foliar micronutrients on leaf carbohydrate and leaf C: N Ratio

Treatment	Carbohydrate (%)			Carbohydrate: Nitrogen Ratio		
	2016	2017	Pooled	2016	2017	Pooled
T_1	5.39	5.19	5.29	2.79	2.75	2.77
T_2	5.07	5.01	5.04	2.73	2.72	2.72
T_3	5.16	5.12	5.14	2.70	2.80	2.75
T_4	4.86	4.82	4.84	2.66	2.75	2.70
T_5	5.44	5.40	5.42	2.76	2.80	2.78
T_6	4.93	4.91	4.92	2.69	2.71	2.70
T_7	6.10	6.08	6.09	2.86	2.88	2.87
T_8	5.57	5.53	5.55	2.79	2.82	2.80
T_9	5.66	5.62	5.64	2.72	2.90	2.81
T_{10}	5.80	5.76	5.78	2.83	2.84	2.83
T_{11}	6.43	5.59	6.01	3.06	2.71	2.89
T_{12}	6.23	6.19	6.21	2.88	2.92	2.90
T_{13}	6.43	6.41	6.42	2.97	2.98	2.97
T_{14}	5.58	5.54	5.56	2.83	2.84	2.84
T_{15}	6.39	6.37	6.38	2.90	2.92	2.91
T_{16}	4.75	4.71	4.73	2.64	2.68	2.66
SEm(±)	0.336	0.266	0.279	0.046	0.047	0.033
$CD_{(0.05)}$	0.969	0.769	0.807	0.133	0.137	0.096

4.2.6.9. Leaf Carbohydrate

It was evident from table 4.2.18 that leaf carbohydrate varied significantly among the treatments and which ranged from 4.75% to 6.43%during 2016 and 4.71 % to 6.41 % during 2017. During the first and second year study, plants at T_{13} (Foliar application of Zn + Cu + B) recorded the highest amount of leaf carbohydrate (6.43 and 6.41%) which was followed by T_{15} (Foliar application of Zn + Mn + Cu + B) (6.39 and 6.37%) compared with control (4.75 and 4.71%).

The pooled data revealed that plants at T_{13} (Foliar application of Zn + Cu + B) recorded the highest leaf carbohydrate content (6.42%) which was followed withT_{15} (Foliar application of Zn + Mn + Cu + B) (6.38%) over control (4.73%).

4.2.6.10. Leaf Carbohydrate: Nitrogen Ratio

Table 4.2.18 indicated that leaf Carbohydrate: Nitrogen (C:N) ratio and varied significantly and ranged from 2.64 to 3.06 during 2016 and 2.68 to 2.98 during 2017. The maximum leaf C:N ratio was obtained in T_{11}(Foliar application of Zn + Mn + Cu)(3.06) followed by T_{13}(Foliar application of Zn + Cu + B)(2.97) during 2016 whereas, T_{13}(Foliar application of Zn + Cu + B) recorded the maximum leaf C:N ratio (2.98) which was followed by T_{12}(Foliar application of Zn + Mn + B)(2.92) during 2017. However, the pooled data indicated that T_{13} (Foliar application of Zn + Cu + B) had highest leaf C:N ratio (2.97) which was followed by T_{15}(Foliar application of Zn + Mn + Cu + B)(2.91) compared with control (2.66).

4.2.7. Cost benefit analysis

Perusal of the data presented in Table 4.2.19 revealed that highest Gross Expenditure was obtained with T_{15} (Foliar application of Zn + Mn + Cu + B) (Rs 4,16,584.01) followed by T_{11}(Foliar application of Zn + Mn + Cu)(Rs 4,07,427.60) while lowest gross expenditure was observed with T_{16} (Rs2,57,426.86). Regarding gross income, the highest gross income was observed in T_{13}(Foliar application of Zn + Cu + B)(Rs16,91,200.00) followed by T_{15}(Foliar application of Zn + Mn + Cu + B)(Rs16,80,800.00) while the lowest gross income was observed in control (Rs7,90,400.00). The highest net income was obtained with T_{13}(Foliar application of Zn + Cu + B)(Rs13,40,685.82) followed by T_{15}(Foliar application of Zn + Mn + Cu + B)(Rs12,64,215.99) while T_{16}(Control) recorded lowest net income (Rs5,32,973.14). Comparing all the treatments highest Benefit to Cost ratio was obtained in T_{13} (Foliar application of Zn + Cu + B) (3.82) which was followed by T_7 (Foliar application of Zn + B)(3.52) while control plant recorded Benefit: Cost ratio (2.07).

Table 4.2.19 Effect of foliar micronutrients on Cost: Benefit Ratio

Treatment	Gross expenditure (Rs)	Gross income (Rs)	Net income (Rs)	B:C ratio
T_1	289,294.78	1,078,400.00	789,105.22	2.73
T_2	323,496.70	975,200.00	651,703.30	2.01
T_3	309,489.84	1,019,200.00	709,710.16	2.29
T_4	266,583.28	899,200.00	632,616.72	2.37
T_5	355,364.62	1,132,000.00	776,635.38	2.19
T_6	341,357.76	942,400.00	601,042.24	1.76
T_7	298,451.20	1,348,800.00	1,050,348.80	3.52
T_8	375,559.67	1,186,400.00	810,840.33	2.16
T_9	332,653.12	1,211,200.00	878,546.88	2.64
T_{10}	318,646.25	1,260,800.00	942,153.75	2.96
T_{11}	407,427.60	1,391,200.00	983,772.40	2.41
T_{12}	364,521.04	1,497,600.00	1,133,078.96	3.11
T_{13}	350,514.18	1,691,200.00	1,340,685.82	3.82
T_{14}	384,716.09	1,300,800.00	916,083.91	2.38
T_{15}	416,584.01	1,680,800.00	1,264,215.99	3.03
T_{16}	257,426.86	790,400.00	532,973.14	2.07

* Calculated based on one hectare land.

4.3. Discussion

Khasi Mandarin production is declining at Mizoram even the area under cultivation has increased to 137%. Apart from the disease or pests problems, the major short coming in NEH citrus industry is improper management of soil fertility and plant nutrition (Srivastava, 2001, 2012). Proper management of nutrition and soil fertility is considered as pivotal in successful and remunerative cultivation of citrus fruit which unless otherwise develop an unhealthy orchard that becomes susceptible to diseases and pests infestations. Therefore, systematic management of nutrition in Khasi Mandarin is of immense importance for its successful cultivation with high productivity. The result of the investigation described earlier have been discussed here along with previous research findings.

4.3.1. Experiment No.1: Integrated Nutrient Management of Khasi Mandarin

The integrated application of nutrients in the form of organic manures, bio fertilizers and chemical fertilizers had a great influence on plant growth and development. Maximum plant height was observed with T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) in both 2016 and pooled analysis, whereas, during 2017 it was observed with T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) followed by T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB). However, calculating the promotion percentage of growth over initial, it was found that T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) recorded maximum promotion percentage followed by T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) during 2017 and pooled analysis, whereas T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) was observed highest in 2016. Stem girth was also observed maximum with T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) during the experimental years and pooled analysis. But, in calculation of stem girth promotion percentage T_{12} (FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) was observed the best treatment during the experimental years and pooled analysis. Looking to the plant canopy spread, T_{11}(FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF) recorded maximum plant canopy spread North- South (N-S) during 2016 and pooled analysis, while T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) recorded maximum during 2017. T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) further recorded highest promotion percentage of plant canopy spread N-S during 2017 and pooled data, while T_{11}(FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF) recorded highest promotion percentage during 2016. Similarly, regarding the plant canopy spread East – West (E-W), maximum spread was observed in T_{11} (FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF) during 2016 and in pooled data. Whereas, T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) was found maximum in 2017. However, calculating the promotion percentage of canopy spread (E-W), maximum promotion percentage was observed in T_{11} (FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF) during 2016 whereas, T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) recorded maximum in 2017 and pooled analysis. Increase in plant height, stem girth and plant canopy spread were due to improved soil physical properties observed with organic manures in combination with chemical fertilizers by helping the plant root development and enhancing nutrients uptake thereby leading to faster cell division and cell elongation. These observations were in conformity with the findings of Villasurda (1990) and Yadav *et al*. (2012). Srivastava *et al.* (2002) also opined that better plant growth and nutrient uptake caused by using organic manures like FYM, Plant litter, vermicompost, and bio-fertilizers. Yadav and Vijayakumari (2003) pointed out that the improvement in growth of plants might be due to higher retention capacity of organic manures and nutrients supply which was obtained by application of vermicompost. The improvement in plant growth and development could be due to an excellent content of organic manure with N-P-K content. Neem cake has been known to enrich the soil and protect the plant due to its natural pesticidal properties. Mehesswarappa *et al*. (2003) indicated that integrated nutrient management practices resulted in improvement of tree growth and yield. This may be due to higher holding capacity of water and improved nutrient status of soil due to adoption of integrated nutrient management. Increased in the rate of photosynthesis and accumulation of carbohydrate as a result of multiferous role of FYM and green manuring allow most favorable conditions of soil with increased availability of plant nutrients responsible for better plant growth (Sharma and Bhutani, 2000; Dutta *et al*., 2009) .Improvement in soil health was due to addition of organic matter through organic manures and application of bio-inoculants phosphorus solubilizing bacteria (PSB) and potash mobilizers (KM) in the soil supplemented with organic manures which increase the availability of both P and K over control (Sundara *etal*., 2002; Richards and Bates, 1989; Zende *et al*., 2011). Borah *et al.* (2001) also reported in case of Khasi Mandarin that appreciable tree vigor was obtained from balance nutrition of the plants through combinations of organic (neem cake) and inorganic fertilizers. Tiwari *et al.* (1997) also observed in sweet orange that yield potentiality of inorganic fertilizers with organic manure like neem cake was better than fertilizers or manures alone in respect of agronomic growth parameters *viz.* height, canopy diameter, total canopy volume. Tarai and Ghosh (2006) in Sweet Orange cv. Mosambi found that height, basal leaf and plant spread varied significantly with NPK and neem cake combined application. Goramnagar *et al.* (2000) reported in case of Nagpur oranges that combined application of FYM and inorganic fertilizer produced tall bushy plants with increased leaf area, canopy spread and good scionic relationship. Further, it was opined that among organic manures, application of neem cake was efficient.

Significant variation was also observed in fruit growth and development with application of integrated nutrients. T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) had longest maturity days from fruit set and maximum yield which was followed by T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) in both the experimental years and pooled analysis. Plant at T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) also observed highest fruit set percentage, lowest fruit drop percentage, with maximum fruit retention percentage. However, maximum number of fruits was found in T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB), which was *at par* with T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) in 2016.Whereas, T_6(VC to supply 50% K + 50% RDF+AZ+PSB+ KSB) recorded maximum number of fruits per plant which was *at par* with T_3(Vermi compost (VC) to supply 50% K+ 50% RDF) in 2017. However, in pooled analysis, the data showed that T_3(Vermi compost (VC) to supply 50% K+ 50% RDF) recorded maximum number of fruits per plant, however that was *at par* with treatments T_6(VC to supply 50% K + 50% RDF+AZ+PSB+ KSB).The effectiveness of inorganic fertilizers was greatly enhanced when it was applied along with vermicompost, greenmanuring and FYM. This might have resulted due to better retention of urea in root zone (Mistsui *et al*., 1960; Chin and Kroonje, 1963) and better availability of phosphate and potash to the plants by organic matter (Raychoudhuri, 1976) .Our findings are in conformity with Kumar *et al*. (2013) who reported that highest fruit set percentage, maximum fruit retention percentage and minimum fruit drop percentage was obtained with combined application of recommended dose of fertilizer, along with vermi compost and neem cake in Lemon. Baviskar *et al*. (2011) found out that the plants which received NPK + vermicompost + *Azotobacter*+ PSB recorded maximum yield of fruits. Organic matter in combination with NPK in Khasi mandarin and sweet orange showed highest fruit yield (Ghosh and Besra,1997). Neem cake with NPK gave highest fruit yield in Sweet Orange (Gamal and Ragab, 2003). Beneficial effect of neem cake and inorganic fertilizers in improving the yield was also noted by Borah *et al.* (2001) in Khasi Mandarin and Ingle *et al.* (2001) in Acid Lime. Tarai and Ghosh (2016) also reported in Sweet Orange cv. Mosambi that maximum fruit yield was resulted with application of NPK in combination with neem cake.

In the present study with Khasi Mandarin, maximum fruit length was observed with T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) during 2016 and pooled analysis. Whereas, T_{12} (FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) during 2017. T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) also recorded maximum fruit diameter during

2016, while T_{12} (FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) recorded maximum in the year 2017 and pooled analysis. Significantly heaviest fruit weight was observed in T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) in 2016, 2017 and pooled analysis. Regarding fruit volume, T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) was found highest (196.67cc), followed by T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)(158.33cc) in 2017 and the pooled data, whereas, T_{11}(FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF) recorded maximum in 2016. In case of specific gravity of fruit,T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) was highest during the first year (2016) study, whereas, T_1(Recommended dose of fertilizer (RDF) as 100% inorganic) recorded highest during second year (2017) study and pooled analysis. Number of seed per fruit was lowest with T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) followed by T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) in both the years and in pooled data. Minimum seed weight was obtained with T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) during both the year of study and pooled analysis. But, minimum peel weight was indicated in T_{11}(FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF) followed by T_4(Neem Cake (NC) to supply 50% K+ 50% RDF) in the second year (2017) study and pooled analysis whereas, T_4(Neem Cake (NC) to supply 50% K+ 50% RDF) recorded minimum peel weight of fruit in the first year (2016) study. The observation indicated that minimum peel thickness was observed in T_4(Neem Cake (NC) to supply 50% K+ 50% RDF) in 2016 and pooled analysis, while in the year 2017, T_{11}(FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF) was recorded with minimum peel thickness of fruit. In regards to juice content of fruit, T_4(Neem Cake (NC) to supply 50% K+ 50% RDF),T_{10}(VC to supply 25% K + NC to supply 25% K+ 50% RDF+AZ+PSB+ KSB) and T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) were found to be the best performing treatments during 2016, 2017 and pooled analysis, respectively. Ranjan and Gosh (2006) reported improved fertilizer use efficiency with the application of organic source of nutrients due to induction of growth hormones, which stimulated cell division, cell elongation, increase in fruit weight and fruit number, better root development and better translocation of water uptake and deposition of nutrients which thereby improve the quality of fruits. Prasad and Singhania (1989) reported increased leaf nutrient status, fruit size and weight of Khasi Mandarin with application of organic manures with NPK. Hiwarale *et al.*(2004) observed that acid lime in terms of fruit weight, fruit volume, juice percentage and fruit number per tree were significantly improved in which received neem cake + 100% recommended doses of NPK . Significantly higher yield with better quality fruits were obtained with trees which received NPK+ FYM + Neem Cake (Musmade *et al.*, 2009). Shukla *et al*. (2009) revealed that trees which received 50 percent doses of recommended NPK + FYM (50kg) + 250 g *Azotobacter* (T7) significantly increased the fruit weight. Further, our findings in the present experiment are in support with Kumar *et al.*(2011& 2013) who reported that maximum fruit weight (g), fruit diameter (cm), fruit yield (kg/plant), juice content in Lemon cv. Pant lemon -1 was found under the treatment with NPK + VC+ NC. Nurbhanej *et al*. (2016) observed that with the application of RDF + Vermicompost + AAU PGPR increased fruit volume, fruit weight and fruit diameter. Prasad and Singhania (1989) reported increased in fruit size and weight of Khasi Mandarin with application of organic manures with NPK.

The integrated nutrient management of Khasi Mandarin under the present study had significant variation on fruit biochemical properties .T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) was found highest in fruit TSS,TSS: acidity and minimum in acidity during 2016, 2017 and pooled analysis. However, highest total sugar was observed in T_4 (Neem Cake (NC) to supply 50% K+ 50% RDF) during 2016 and pooled analysis. Whereas, in the year 2017, T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) recorded highest total sugar which was statistically *at par* with T_4 (Neem Cake (NC) to supply 50% K+ 50% RDF). T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) recorded maximum reducing sugar content of fruit in 2016. But, in the year 2017, T_{12} (FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) was found highest in reducing sugar content of fruit followed by T_4(Neem Cake (NC) to supply 50% K+ 50% RDF). Similarly in the pooled data it was found that T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) was recorded highest with reducing sugar content of fruit. Highest ascorbic acid content was found with T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) followed by T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) in the first year (2016) study and pooled analysis. Whereas, in the second year (2017) observation, fruits at T_{12}(FYM to supply 25% K+ VC to supply

25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB)was found highest in ascorbic acid content followed by T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB).Our findings are in support with Tarai and Ghosh (2006) who reported that in Sweet orange cv. Mosambi superior quality fruits (TSS, Total sugar and Ascorbic acid) were observed with those trees that received N: P: K + Neem cake. Combined application of organic manure along with inorganic N, P, and K fertilizers gave quality response on various citrus cultivars (Rokba *et al*., 1995; Borah *et al*., 2001).Organic matter in combination with NPK in Khasi mandarin and Sweet Orange showed improved quality of fruit (Ghosh and Besra,1997). Improved quality of different citrus fruits were obtained by judicious use of organic and inorganic fertilizers by several workers. (Ghose,1990; Kumar *et al*.,1993; Ram *et al*., 1997 and Shukla *et al.,*2000). Musmade *et al.* (2009) reported in acid lime that quality of fruits was significantly improved with the combined application of neem cake, FYM and inorganic fertilizers. Shukla *et al*.(2009) suggested that trees which received recommended NPK + FYM+ *Azotobacter* significantly increased in fruit ascorbic acid , TSS , total sugars , reducing sugar . Kumar *et al.* (2012) reported that fruit quality of lemon cv. Pant lemon like juice percentage, and ascorbic acid content were increased with the treatment of NPK + Vermicompost + Neem cake. Tarai and Ghosh (2016) reported in Sweet Orange cv. Mosambi that improvement in total soluble solids, total sugar, TSS: Acid ratio and vitamin C content of fruits were found in plants which received N: P: K+ neemcake.

In the present study, highest soil Total Nitrogen was observed in T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) in 2016, 2017 and pooled analysis. T_{12}(FYM to supply 25% K+

VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) again recorded highest available Soil Phosphorus content in 2017 and pooled analysis while T_1(Recommended dose of fertilizer (RDF) as 100% inorganic) was found highest in 2016. However,T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+KSB) was found highest in available Soil Potassium, Manganese, Copper, Zinc content, during both the experimental years and in pooled analysis. However, highest Iron content of soil was observed in T_4 (Neem Cake (NC) to supply 50% K+ 50% RDF) in both the years and pooled analysis. Significant variation was observed with leaf major and micronutrients in the current study. T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) was found highest in leaf Nitrogen content in 2016 and pooled analysis while T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) recorded highest in 2017. T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) again recorded highest in Phosphorus content of leaf in 2016 and pooled, while T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) recorded maximum leaf P in 2017. T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) was found highest in leaf Potassium content during the first year (2016) study while, it was found highest in T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) during 2017 and pooled data. T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) recorded highest leaf Manganese content in 2017 and pooled data, while highest leaf manganese content was observed in T_{11} in 2016. However, T_4 (Neem Cake (NC) to supply 50% K+ 50% RDF) was found highest in leaf copper content during both the years and pooled analysis. T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) recorded highest leaf Zinc and Iron content in both the experimental years (2016 & 2017) and in pooled data.T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) recorded the highest carbohydrate content of leaf in both the years of study and pooled data. Plants at T_4 (Neem Cake (NC) to supply 50% K+ 50% RDF) were observed highest in leaf carbohydrate to leaf nitrogen (C:N ratio) in 2016 and pooled data while T_9(FYM to supply 25% K + NC to supply 25% K+ 50% RDF+AZ+PSB+ KSB) recorded the maximum C:N ratio in 2017. Trivedi *et al*. (2012) reported that highest potassium uptake, maximum available P_2O_5 and K_2O were noted under biocompost treatment and maximum nitrogen uptake was resulted with incorporation of vermicompost and FYM resulted in the maximum phosphorus uptake and organic carbon content in the soil. However, addition of biofertilizers recorded higher available P_2O_5 content in the soil. Mir *et al*. (2014) reported that significant increased of soil pH, soil N, soil P, soil K, water holding capacity, porosity, particle density, bulk density , organic carbon , iron, manganese (Mn), zinc (Zn) and copper (Cu) were obtained with combined application of vermicompost, bio-fertilizers, FYM, green manure and recommended dose of NPK. The application of organic manure with NPK were the most suitable nutrient application which increased significantly the concentration of soil organic carbon (SOC) and major soil nutrients nitrogen, phosphorus and potassium (Zhao *et al.*, 2014). Shukla *et al*. (2009) opined that trees which received NPK + FYM+ *Azotobacter* significantly increased in leaf nitrogen, phosphorus, potassium contents. Patel *et al.* (2009) observed that the microbial and inorganic fertilizers in combination with micronutrients influenced on leaf nutrient status of sweet orange cv. Mosambi. and resultant changes in rhizosphere soil microbial biomass. Prasad and Singhania (1989) reported about increased leaf nutrient status of Khasi Mandarin with application of organic manures + NPK. Chalwade *et al*. (2005) reported that in case of Kagzi lime (*Citrus aurantiifolia*) integrated nutrient management had significantly improved the physicochemical properties of the soil.

In the present study of integrated nutrient management of Khasi Mandarin, maximum *Azotobacter* count was observed in T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) in the first year (2016) study, while T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) recorded maximum *Azotobacter* count in soil during second year (2017) study and pooled data. Soil at T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) was observed highest in Phosphorus Solubilizing Bacteria (PSB) for both the experimental years and pooled analysis. The highest Potassium solubilizing bacterial count of soil was observed in T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) in 2016 and pooled data while T_9(FYM to supply 25% K + NC to supply 25% K+ 50% RDF+AZ+PSB+ KSB) recorded highest in soil Potassium solubilizing bacterial count in 2017. Mukhopadhyay and Sen (1997) reported that biofertilizers increased the plant spread as inoculation of biofertilizers increased cell metabolism due to increased enzyme activity, chlorophyll content and photosynthetic processes. Our findings are in agreement with Mitra *et al.* (2012) who reported that neem cake when applied along with *Azotobacter* substantially increased soil microbial population which improved soil health and thereby the growth and productivity of the tree. Marathe *et al*. (2012) also reported that Sweet orange orchards applied with FYM, Vermi-compost, wheat straw on nitrogen equivalent basis and green manuring with sun hemp as singly or in combination with inorganic or biofertilizers like

Azotobacter and PSB effectively increased the microbial population in the soil. Patel *et al.* (2009) observed that the microbial and inorganic fertilizers in combination with micronutrients influenced resultant changes in rhizosphere soil microbial biomass in Sweet orange cv. Mosambi.

In the present study, the highest net income was obtained with T_{12}(FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB) followed by T_7(NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB). However, highest benefit to cost ratio was obtained in T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)(3.95) which was followed by T_4(Neem Cake (NC) to supply 50% K+ 50% RDF). Tiwari *et al*. (1997) found that combined application of NPK and neem cake gave the most effective benefit to cost ratio (1:2.14) in Sweet Orange. Ingle *et al.* (2001) reported that application of organic source of nutrient through neem cake + NPK significantly maximized monitory returns per rupee investment than other treatment combinations in Acid Lime. Musmade *et al.* (2009) reported significantly high monetary returns than other treatment combinations with trees receiving NPK+ FYM and Neem cake in Acid Lime. Shukla *et al*. (2009) found that trees which received NPK + FYM+ *Azotobacter* significantly increased in B: C ratio. Mitra *et al.* (2012) reported that neem cake when applied along with *Azotobacter* reported maximum benefit / cost ratio.

4.3.2. Experiment No.2: Foliar application of micro nutrients on growth, development and fruit quality of Khasi Mandarin

Soil application of inorganic fertilizer has failed to sustain the high yield expectancy on a long term basis due to depletion of soil carbon stock and consequently emerged multiple nutrient deficiencies (Khehra, 2014). Foliar application of micronutrients a method for quick element supply which allows consumption of nutrients by the plant much faster than uptake from the soil through roots is an innovative approach for improving citrus yield. The result of the present investigation which was written earlier have been discussed here with previous research findings of others.

In the present study, plant height varied significantly among the treatments with application of foliar micro nutrients. Maximum plant height and percent promotion of growth (height) over initial was observed in T_{13}(Foliar application of Zn + Cu + B) in both the study year (2016 & 2017) and pooled analysis. Maximum stem girth was also observed in T_{13}(Foliar application of Zn + Cu + B) in both the year and pooled analysis, however, in case of percent promotion of growth over initial stem girth, maximum was observed with T_{13}(Foliar application of Zn + Cu + B)in 2017 and pooled data whereas, T_{12}(Foliar application of Zn + Mn + B) showed maximum promotion percentage of stem girth in the first year study (2016). T_{13}(Foliar application of Zn + Cu + B) recorded maximum plant canopy spread (N-S) in 2016, 2017 and pooled analysis followed by T_{12} (Foliar application of Zn + Mn + B). Regarding promotion percentage of plant canopy spread (N-S), T_9(Foliar application of Mn + B) recorded highest promotion percentage in 2016 while in 2017 and in case of pooled data, T_{12}(Foliar application of Zn + Mn + B) recorded highest percentage. Maximum canopy spread (E-W) was observed in T_{13}(Foliar application of Zn + Cu + B) followed by T_{12}(Foliar application of Zn + Mn + B) in 2016 and 2017 and in pooled data. Maximum promotion percentage of canopy spread (E-W) was found in T_7(Foliar application of Zn + B) followed by T_{13} in 2016, whereas; T_{10}(Foliar application of Cu +B) recorded maximum in 2017. However, the pooled data showed T_{13}(Foliar application of Zn + Cu + B) as maximum in percentage promotion of canopy spread (E-W). This finding is in close conformity with Ram and Bose (2000) in Mandarin Orange. The improvement in plant growth and development could be due to the involvement of micronutrients in the synthesis of many compounds which are essential for plant growth and development and also act as an activator for many enzymes. The micronutrients are required in small amounts, however play a great role in plant metabolism (Katyal, 2004; Kazi *et al.*, 2012). Increase in plant height and leaf growth might be due to the active involvement of Zn in the synthesis of tryptophan which is a precursor of indole acetic acid synthesis, thereby increase tissue growth and development (Swietlik, 1999). Calvert (1970) reported that significant growth, yield and quality of citrus fruit were found by other researchers with definite role of N, P, Mg, Zn, and B in India. Marschner (2003) stated that because of foliar fertilization, the plant pump out more sugars and other exudates from its roots into the rhizosphere thereby improving the plant growth and development. Srivastava and Singh (2006a,b) reported that canopy growth was observed to be best with plants which received NPK with micronutrients ($ZnSO_4$+$MnSO_4$ along with borax /tree). Mattos *et al*. (2010) indicated that better plant growth was attained with supply of N + Cu in 'Pera' sweet orange.

In the present experiment, treatments varied significantly with days from fruit set to maturity. Longest maturity days was observed in T_{12} (Foliar application of Zn + Mn + B) which was followed by T_{13} (Foliar application of Zn + Cu + B) in both the study year (2016 & 2017) and in pooled data. T_{13}(Foliar application of Zn + Cu + B) indicated highest fruit set percentage in both 2016 and pooled analysis and while T_{15}(Foliar application of Zn + Mn + Cu + B) showed highest fruit set percentage in

2017. On the other hand, plants at T_{13} (Foliar application of Zn + Cu + B) showed minimum fruit drop percentage and maximum fruit retention percentage and maximum number of fruits per plant followed by T_{12} (Foliar application of Zn + Mn + B). Consequently, T_{13} (Foliar application of Zn + Cu + B) showed highest yield in 2016 and pooled data and while T_{15} (Foliar application of Zn + Mn + Cu + B) showed highest yield in 2017. Srivastava *et al*. (1981) reported that from the long term (16 years) micro-nutrient trial with Mandarin Orange cv. Coorg, plants sprayed with Cu, Mn, and Zn gave significantly higher fruit yield than the untreated controlled plant. Quaggio (2011) reported that Zinc (Zn), manganese (Mn) and boron (B) are important micronutrient for citrus production. Alla *et al.*(1985) reported that the yield of sweet orange trees was increased with application of copper, manganese and iron. Garcia *et al*. (1984) reported that as leaf Zn and Mn content increased, fruit let drop decreased. It is also found in Sweet lime that reduced leaf chlorosis and significantly increased yield with application of iron, zinc and manganese sulfates in soil and as a foliar spray. Ghosh and Besra (2000) reported that application of micronutrient along with NPK observed highest number of fruits in Sweet Orange. Perveen and Rehman (2000) also concluded that increased citrus fruit yield was observed with foliar spray of Zn, Mn and B and it was also noted that B alone spray could not give satisfactory yield unless it was combined with Zn and Mn. Elham *et al*. (2006) observed that Valencia oranges fertilized with NPK accompanied with Zn, Fe and Mn spray gave the best results with regard to fruit set and yield. Abd-Allah (2006) reported increased fruit set, yield and number of fruits per plant with application of Potassium di-hydrogen phosphate, calcium chelate and boric acid on Washington Navel Orange. Rahman and Haq (2006) reported on Sweet Orange (cultivar “Red Blood”) that fruit yield increased with foliar sprays of Zn, Mn and B. Tariq *et al*. (2007) reported that in Sweet Orange Nitrogen along with Zn and Mn resulted in maximum fruit yield. Combined foliar sprays of MSA, Zn and K reduced the citrus fruit drop. Ashraf *et al*. (2013) reported that Citrus, especially in Kinnow, fruit dropping was reduced by the foliar spray of Zn, K or Zn+K but the most promising results were recorded with foliar spray containing both Zn and K. The increase in number of fruit and yield might be due to reduction in fruit drop. Nijjar (1985) reported that Zn is required for prevention of abscission layer formation which thereby decrease the preharvest fruit drop. Karim *et al*.(2017) reported deficiency of boron (B) in citrus has serious consequences for tree health and crop production. Foliar application of B appeared to increase fruit set percentage in Sweet orange cv. Hamlin trees. Previous studies indicate that boron influenced in vivo and in vitro pollen germination in many crops. A plausible explanation for increased fruit yield may be that the applied boron was transported to the flowers where it exerted its influence on increased fruit set through an effect on pollen viability and/or pollen tube growth. Kazi *et al*. (2012) reported in Sweet Orange that NPK bulk recommended dose + multi micronutrient showed significantly superior values of number of fruits per tree. Deficiency of micronutrients (Zn, Cu, Fe and Mn) in the soils of citrus orchards also affects the fruit dropping (Ibrahim *et al*., 2007; Ashraf *et al*., 2012). Severe deficiency of Zn was noted long ago in the citrus orchards of Punjab and Pakistan which become hindrance in successful cultivation (Rehman *et al.*, 1999). However, foliar application of Zn control the premature fruit drop in citrus (Rodríguez et al., 2005; Ashraf *et al*., 2012).

In the experiment -2, T_{15} (Foliar application of Zn + Mn + Cu + B) recorded maximum fruit length and fruit diameter in 2017 and pooled analysis while T_{13} (Foliar application of Zn + Cu + B) recorded maximum length of fruit in 2016. Again plants at T_{15} (Foliar application of Zn + Mn + Cu + B) had heaviest fruit weight in 2017 and pooled analysis while T_{12} (Foliar application of Zn + Mn + B) recorded maximum fruit weight in 2016. Maximum fruit volume was obtained in T_{13} (Foliar application of Zn + Cu + B) in 2017 and in case of pooled data whereas, T_{15} (Foliar application of Zn + Mn + Cu + B) scored maximum in 2016. Lowest number of seed was observed in T_{13} (Foliar application of Zn + Cu + B) followed by T_{15} (Foliar application of Zn + Mn + Cu + B) in case of pooled data. On the other hand, T_{15} (Foliar application of Zn + Mn + Cu + B) recorded minimum seed weight followed by T_{13} (Foliar application of Zn + Cu + B) in pooled data of both the years (2016 & 2017).T_{13} (Foliar application of Zn + Cu + B) recorded minimum peel weight in 2017 and in pooled data while observed second lowest with peel weight in 2016 by coming after T_{15} (Foliar application of Zn + Mn + Cu + B). Minimum peel thickness was also obtained with T_{13} (Foliar application of Zn + Cu + B) in 2017 and pooled data while it was *at par* with T_{15} (Foliar application of Zn + Mn + Cu + B) in 2016. Similarly, T_{13} (Foliar application of Zn + Cu + B) recorded maximum juice content in 2017 and pooled data while T_{11} (Foliar application of Zn + Mn + Cu) recorded highest juice content of fruit in 2016.The increase in fruit weight with the spray of $ZnSO_4$ and Boric acid might be due to their involvement in hormonal metabolism, increase in cell division, and cell wall expansion. Boron stimulate rapid metabolization of water and sugar in the fruit thereby increasing accumulation of dry matter within the fruit (Bhatt *et al*., 2012). Tariq *et al*. (2007) reported maximum fruit size with application of Zn + B in Sweet Orange. Mohamed *et al.* (1995) reported that combine or alone application of copper, manganese and iron sulfates as foliar spray, enhanced performance and improved quality of orange juice. Devi *et al.* (1997) found that the plants supplied with soil application of $ZnSO_4$ and $FeSO_4$ and combined foliar spray of the micronutrient increased the juice content of Sweet Orange fruits. Rehman (1992) also reported increase in Vitamin C content of citrus fruit due to foliar application of these micronutrients. Percentage of juice in Sweet Orange was increased significantly by boron alone. Abd-Allah (2006) reported increased fruit weight per tree significantly by different nutrient treatments specially when sprayed with Potassium di-hydrogen phosphate, calcium chelate and boric acid on Washington Navel Orange tree either as a single or in combination. Hafez and El-Metwally (2007) reported that application of Zn and K alone or in combination obtained significant difference on chemical and physical characteristics of fruit in Washington Navel orange. Tariq *et al*. (2007) reported in Sweet Orange that B alone obtained the minimum percentage of peel and minimum percentage of rag with Zn + Mn, maximum fruit size with Zn + B and maximum fruit volume with Zn + Mn. Kazi *et al*. (2012) reported in Sweet Orange that NPK bulk recommended dose + multi micronutrient significantly improved weight of fruit per tree. Ullah *et al*. (2012) reported that ‘Kinnow’ Mandarin was significantly affected by foliar application of B with a significant increase in fruit weight. Chaudhari *et al*. (2016) reported in Sweet Orange that application of balanced dose of NPK along with multi micronutrient increased weight of fruit, juice content and fruit girth. Singh *et al.* (2018) found that Sweet Orange trees that received combined treatment of Zn+ B +

Cu observed highest juice percentage, minimum number of seeds with minimum peel thickness of fruit.

Significant variation was observed in both the experimental years and pooled analysis in Experiment – 2 in case of fruit Total Soluble solids (TSS) content where T_{15}(Foliar application of Zn + Mn + Cu + B) was found highest among all treatments. Lowest acidity was obtained with T_{13} (Foliar application of Zn + Cu + B) in the first year study and pooled data while T_{15} (Foliar application of Zn + Mn + Cu + B) was found lowest fruit acidity in the second year (2017) study. The pooled analysis and second year study indicated that T_{15} (Foliar application of Zn + Mn + Cu + B) was highest in TSS/Acid ratio while it followed T_{13} (Foliar application of Zn + Cu + B) which had highest TSS: acid ratio of fruit in the first year (2016) study. Significant variation was also observed among the treatments with regards to total sugar content of fruit. Highest total sugar and reducing sugar content of fruit were recorded in T_{13} (Foliar application of Zn + Cu + B) during both the experimental years and pooled data analysis. Highest ascorbic acid content of fruit was found with $T_{1\,2}$(Foliar application of Zn + Mn + B). However, T_{15} (Foliar application of Zn + Mn + Cu + B) was also found high in fruit ascorbic acid content. The findings are in line with Singh *et al*. (2018) in Sweet Orange cv. Mosambi who reported that improved TSS, ascorbic acid, reducing sugar, total sugar and minimum acidity were observed with treatment which contained Zinc+ Boron+ Copper. Previous studies revealed that efficient translocation of photosynthates to the fruit was regulated by copper, boron and zinc (Ullah *et al*., 2012). They also reported that acidity percentage of Mandarin fruit might have been reduced due to higher synthesis of nucleic acid. Cu (copper) increase photosynthetic activity and when combined with Zn and B it increased the sugar compounds and cause more accumulation of total soluble solids in fruit juice. Similar kind of observation was reported by Babu and Yadav (2005) in Khasi Mandarin. Singh and Singh (1981) reported in 'Dancy tangerine' (*Citrus reticulata* Blanco) that the combined spray of zinc sulphate + copper sulphate improved fruit quality like more pulp, juice, T.S.S, sugars and ascorbic acid content, reduced peel, rag, total acidity and starch. Mann *et al*. (1985) found that micronutrients (Zn, Cu, Fe and Mn) spray on the leaves of sweet orange improved quality parameters such as juice percentage, reducing sugar and vitamin C content of fruit. Rehman (1992) also reported increase in reducing sugar by Mn alone and vitamin C contents by Zn alone, Zn+ Mn or Zn+ B through foliar application, suggesting that each nutrient had different role on the quality of sweet oranges. Mohamed *et al.* (1995) reported that combine or alone application of copper, manganese and iron sulfates as foliar spray, enhanced performance and improved quality of orange juice. Abo-El Komsan *et al*. (2003) reported the best result in fruit quality of Balady Orange trees with NPK + Mg + S +Zn+ Fe+Mn + citric acid. Kulkarni (2004) recorded that foliar application of $ZnSO_4$ +$FeSO_4$ + Borax gave the highest sugar content in juice of Sweet Orange fruits. Tariq *et al*. (2007) reported in Sweet Orange that vitamin C contents was improved by Zn + B through foliar spray and suggested that Zn+Mn or Zn+B may be applied as foliar spray in combination with urea and surfactant for getting the improved quality of citrus fruit. Ashraf *et al*. (2012) reported that the application of Zn, K and SA or Zn+K+SA was effective in improving the quality parameters of citrus fruit. Kazi *et al*. (2012) reported in Sweet Orange that NPK bulk recommended dose + multi micronutrient through soil showed significantly maximum reducing and non reducing sugar with minimum fruit acidity.

They opined that higher level of sugar due to micronutrient application including boron might be possible. Increase in ascorbic acid content was observed which is synthesized from sugar (Mengel and Kirkby, 1987). Ullah *et al*. (2012) reported that soluble solid concentration (SSC): titratable acidity (TA) ratio, ascorbic acid, total sugars in 'Kinnow' Mandarin was significantly affected by foliar application of boron. Chaudhari *et al*. (2016) reported in Sweet Orange that application of balanced dose of NPK along with multi micronutrient increased ascorbic acid content, reducing and non reducing sugar, whereas fruit acidity is low.

Highest Total Nitrogen content of soil was observed in T_{13} (Foliar application of Zn + Cu + B) followed by T_{15}(Foliar application of Zn + Mn + Cu + B) compared with control in both the years and pooled analysis. It was found that soil Phosphorus content was found significantly different over control in all the treatments.T_{15}(Foliar application of Zn + Mn + Cu + B) was found highest in the first year (2016) study and pooled data while T_{13}(Foliar application of Zn + Cu + B) recorded highest available Phosphorus in soil in the second year (2017) study. On the other hand,T_{13}(Foliar application of Zn + Cu + B) was found highest in the first year (2016) study and pooled data while T_{15}(Foliar application of Zn + Mn + Cu + B) was found highest in the second year (2017) study in respect to Potassium content of soil. Significant variation was also observed with micronutrients content in soil under the present experiment. Highest soil Iron content was observed in T_{13} (Foliar application of Zn + Cu + B) in the first year study, whereas, T_{15} (Foliar application of Zn + Mn + Cu + B) recorded highest amount of soil Fe which was followed by T_{13} (Foliar application of Zn + Cu + B) in the second year (2017) study and in pooled data. T_{12} (Foliar application of Zn + Mn + B) recorded highest Copper content of soil among all treatments followed by T_{15} (Foliar application of Zn + Mn + Cu + B) during the experimental period. T_{13} (Foliar application of Zn + Cu + B) recorded highest Zinc content of soil among all treatments followed by T_{12} (Foliar application of Zn + Mn + B) during the study period and in pooled data. T_4{Foliar application of Boron (B)} recorded highest level of soil Manganese during the first and second year study along with pooled data. T_{13}(Foliar application of Zn + Cu + B) recorded highest soil Boron content in both the year of study and in pooled data followed by T_{12}(Foliar application of Zn + Mn + B) in the first year and in pooled data while T_{15}(Foliar application of Zn + Mn + Cu + B) recorded second highest in soil boron during the second year study. Leaf Nitrogen content showed significant variation among all treatments compared with control. T_{15} (Foliar application of Zn + Mn + Cu + B) was found highest in leaf Nitrogen content followed with T_{13}(Foliar application of Zn + Cu + B) during 2016 and 2017 and pooled analysis.T_{12}(Foliar application of Zn + Mn + B) was recorded with highest leaf Phosphorus percentage in 2016 and pooled data while T_7(Foliar application of Zn + B) recorded maximum leaf Phosphorus content in 2017 followed by T_{12}(Foliar application of Zn + Mn + B). T_{13}(Foliar application of Zn + Cu + B) was found highest in leaf Potassium content during the experimental years and pooled analysis which was followed by T_{15}(Foliar application of Zn + Mn + Cu + B) in the first year (2016) study and pooled data while T_{12}(Foliar application of Zn + Mn + B) in 2017. Highest leaf manganese content was observed in T_2 (Foliar application of Manganese (Mn) in the year 2016 and pooled data while in the year 2017, plants at T_9 (Foliar application of Mn + B) recorded highest leaf manganese content which was followed by T_2 compared with T_{16} (control). T_3 [Foliar application of Copper (Cu)] was found highest in leaf copper content in 2016 and pooled data, whereas; in the year 2017, T_{13} (Foliar application of Zn + Cu + B) recorded highest copper content of leaf followed by T_3 {Foliar application of Copper (Cu)} in comparison with T_{16} (control). T_1 {Foliar application of Zinc (Zn)} recorded highest amount of leaf Zinc content in both seasons of the year and pooled data followed by T_{13} (Foliar application of Zn + Cu + B). T_{10} (Foliar application of Cu +B) recorded highest amount of leaf Iron content in 2016 and pooled data whereas, T_{15}(Foliar application of Zn + Mn + Cu + B) recorded maximum leaf Iron in 2017 followed by T_{10}(Foliar application of Cu +B) compared with control. T_4{Foliar application of Boron (B)}recorded highest amount of leaf boron in both the years along with pooled data followed by T_{13}(Foliar application of Zn + Cu + B). During the first year (2016), second year (2017) and pooled data, T_{13}(Foliar application of Zn + Cu + B) recorded the highest value of leaf carbohydrate which was followed by T_{15}(Foliar application of Zn + Mn + Cu + B). C:N ratio of leaf was recorded highest in T_{13} (Foliar application of Zn + Cu + B) during 2017 and pooled data while it was found maximum in T_{11}(Foliar application of Zn + Mn + Cu) followed by T_{13}(Foliar application of Zn + Cu + B) during 2016.Mann *et al*. (1985) found that micronutrients (Zn, Cu ,Fe and Mn) spray on the leaves of sweet oranges increased the concentration of the respective nutrient in the leaves. Razeto *et al*. (1988) reported that single application of Mn increased Mn concentration in orange leaves greater than when applied in combination with Zn. Abd-Allah (2006) reported increased N, P and K content in the leaves compared with the untreated trees with application of Potassium di-hydrogen phosphate, calcium chelate and boric acid at full bloom stage of Washington Navel Orange tree either as a single or in combination. Rahman and Haq (2006) reported on sweet orange (cultivar "Red

Blood") that with the foliar spray of the respective micronutrients, leaf concentrations of Zn and Mn were also increased. Eman *et al*. (2007) revealed that most treatments especially those included zinc improved leaf N, K and Zn contents on Washington Navel Orange. Hafez and El-Metwally (2007) reported that application of Zn and K alone or in combination obtained significant difference leaf mineral content (N, P, K and Zn) in Washington Navel orange. Tariq *et al*. (2007) reported that foliar spray of Zn, Mn and B along with urea significantly increased the concentration of Zn and Mn in citrus leaves. Ullah *et al*. (2012) reported that significant difference was observed in Kinnow Mandarin leaf nitrogen (N), phosphorus (P), potassium (K),boron (B), and zinc (Zn) content when different concentrations of boric acid was sprayed at fruit set stage.

Highest gross expenditure was obtained with T_{15} (Foliar application of Zn + Mn + Cu + B) whereas, the highest gross and net income were observed in T_{13} (Foliar application of Zn + Cu + B) followed by T_{15} (Foliar application of Zn + Mn + Cu + B) while the lowest gross income was observed in control. Comparing all the treatments highest Benefit to Cost ratio was obtained again in T_{13}(Foliar application of Zn + Cu + B) due to better influence of micronutrients on yield and fruit quality of Khasi Mandarin fruits thereby fetching more prices and more income in spite of their high expenditure caused due to the high cost of micro nutrients. Our findings are in accordance with Kumar *et al*.(2017) who reported that in Nagpur Mandarin maximum gross returns, highest net profit were obtained with the application of calcium nitrate + boric acid + Zinc sulphate treatment.

Chapter - 5

SUMMARY AND CONCLUSION

The investigation entitled Nutrient Management in Khasi mandarin (*Citrus reticulata* Blanco) under Subtropical Agro-Climatic Condition in Mizoram was carried out during 2016 and 2017 at Thiak village of Aizawl district, Mizoram.

The findings of the investigation may be summarized as below:

Experiment 1: Integrated Nutrient Management of Khasi Mandarin

- Integrated Nutrient Management improved the plant growth and development. The highest plant height (5.59 m) was observed with the application of NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB (T_7), while the highest promotion percentage of plant height (10.45%) over initial was observed with the application of FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF+AZ+PSB+ KSB (T_{12}) whereas, the lowest (5.02 m) (5.64%) was recorded in control (T_{13}).
- The maximum plant girth (53.41 cm) was observed with the application of NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB (T_7), while the highest promotion percentage of girth (13.86%) over initial was observed with the application of FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF+AZ+PSB+

KSB (T_{12}) whereas, the lowest plant girth and percentage promotion over initial [(35.67cm) (7.30%)] was recorded in control (T_{13}).

- The highest fruit set per cent (64.26 %) was resulted with the application of FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF+AZ+PSB+ KSB (T_{12}) which was followed by the application of NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB (T_7) (63.07%) while control (T_{13}) recorded the lowest fruit set per cent (50.00%).

- Integrated Nutrient Management decreased the total fruit drop per cent significantly. The lowest fruit drop per cent was recorded with the application of FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF+AZ+PSB+ KSB (T_{12}) whereas, the highest fruit drop per cent (58.44%)was recorded in control (T_{13}).

- The maximum yield (39.97 t/ha), fruit weight (158.25g), juice content (65.63ml) and TSS (11.23 °Brix) content of fruit was observed with the application of FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF+AZ+PSB+ KSB (T_{12}) whereas control (T_{13}) recorded the lowest yield (5.17 t /ha), fruit weight (89.51g), fruit juice content (35.79ml) and fruit TSS (8.53 °Brix).

- Application of nutrients in integrated manner, enhanced soil nutrients availability. Highest soil Nitrogen (1180.49kg/ha), Phosphorus (69.53kg/ha) was observed with the application of FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF+AZ+PSB+ KSB (T_{12}) whereas; the application of NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB (T_7) resulted highest soil Potassium content

(600.03kg/ha) while control (T_{13}) recorded the least soil Nitrogen (256.72kg/ha), Phosphorus (18.84kg/ha), Potassium (104.57kg/ha), respectively.

- Soil micronutrients like Mn, Cu, Zn were found highest(24.36mg/kg), (1.92mg/kg) and (4.78mg/kg), respectively, with the plants which received NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB (T_7) whereas, highest soil Fe (116.34mg/kg) was recorded in plants which received Neem Cake (NC) to supply 50% K+ 50% RDF (T_4) while lowest amount of soil Mn(16.74mg/kg), Cu(1.56mg/kg), Zn(2.67mg/kg) and Fe(89.64mg/kg) were recorded in control plants.

- The highest count of *Azotobacter* (64.56 X 10^6 CFU/g) was observed in case of application of FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF+AZ+PSB+ KSB (T_{12}) whereas, highest count of PSB (72.12X 10^6 CFU/g) and KSB (106.82X 10^6 CFU/g)were observed in the plants which received NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB (T_7) while the lowest count were observed in control [*Azotobacter*(6.57 X 10^6 CFU/g), PSB (11.25 X 10^6 CFU/g) and KSB (12.67 X 10^6 CFU/g), respectively].

- The highest leaf total Nitrogen (2.63%), Phosphorus (0.16%) and Potassium (1.64%) were recorded with application of FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF+AZ+PSB+ KSB (T_{12}). However, the minimum content were recorded in control plants [leaf N (1.60%), P(0.07%) and K(0.61%), respectively].

- Leaf micronutrients (Fe, Zn) were found highest [(227.55ppm), (29.32ppm)] with the application of NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB

(T_7) while leaf Mn was observed highest (81.27ppm) with application of FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF+AZ+PSB+ KSB (T_{12}), however, highest leaf Cu (20.53ppm) was recorded in case of the plants treated with Neem Cake (NC) to supply 50% K+ 50% RDF (T_4) while lowest content were recorded in control [Fe (110.95ppm), Mn(64.78ppm), Cu (12.23ppm) and Zn (13.87ppm)].

- Regarding the C:N ratio, highest (3.36) was observed with plants which received Neem Cake (NC) to supply 50% K+ 50% RDF (T_4) while control recorded the least (2.63).

- The gross income (Rs. 31,97,600.00) and net income (Rs. 23,70,402.09) per hectare of cultivation were found highest from plants treated with application of FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF+AZ+PSB+ KSB (T_{12}), whereas, application of NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB (T_7) recorded the highest benefit: cost ratio (3.95). While, the lowest benefit : cost ratio (1.59) and lowest net income (Rs2,53,949.08) were recorded in control (T_{13}).

Conclusion

Based on the summary the following conclusions have been drawn from the present investigation:

- NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB (T_7) and FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB (T_{12}) were found to be the two best performing treatments among all in terms of plant growth characters, soil health improvement and leaf nutrient status, high net income and high Benefit: Cost ratio.

- Among all the treatments, FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB (T_{12}) was the best treatment in respect of yield and quality parameters of Khasi Mandarin.

- In respect of C:N ratio, application of Neem Cake (NC) to supply 50% K+ 50% RDF (T_4) recorded the best treatment. However, the two best performing treatments *viz,* FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB (T_{12}) and NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB (T_7) also recorded reasonably high C: N ratio.

Experiment 2: Foliar application of micro nutrients on growth, development and fruit quality of Khasi Mandarin

- Application of foliar micronutrients improved the plant growth and development. The highest plant height (5.56 m) and the highest promotion percentage of height (9.14%) over initial was observed with the application of Zn + Cu + B (T_{13}) whereas, the lowest height (5.29 m) and percentage promotion (5.91%) was recorded in control (T_{16}).

- The maximum plant girth (52.44 cm) and the highest promotion percentage of plant girth (13.77%) over initial was again observed with the application of Zn + Cu + B (T_{13}) whereas, the lowest plant girth (36.89 cm) and per cent promotion (8.79%) was recorded in control (T_{16}).

- The highest fruit set per cent (59.90 %) was resulted with the application of Zn + Cu + B (T_{13}) whereas, the lowest (52.97%) was recorded in control (T_{16}).

- The highest number of fruits per plant (143.02 nos.) was recorded with application of Zn + Cu + B (T_{13}) whereas, the lowest number of fruits per plant (93.30) was recorded in control (T_{16}).

- Application of Zn + Cu + B (T_{13}) recorded highest yield (21.14 t/ha) whereas, the lowest yield (9.88 t/ha) was recorded in control (T_{16}).

- Regarding the fruit quality parameters, highest TSS content (10.83°Brix), fruit length(6.01cm), diameter(6.98cm) and fruit weight (147.81g) were recorded with plants which received application of Zn + Mn + Cu + B (T_{15}) while, fruit juice content (64.48ml), total sugar (9.18%) and reducing sugar (7.11%) were found highest with application of Zn + Cu + B (T_{13}) whereas, the lowest content of TSS (9.33 °Brix), fruit length (5.69cm), fruit diameter (5.20cm), fruit weight (95.32g), juice content (40.12ml), total sugar (8.38%) and reducing sugar (6.17%) were recorded in control (T_{16}).

- With respect to soil nutrient status, maximum Nitrogen (725.69kg/ha) and Potassium (421.35kg/ha) were observed with plants which received combined application of Zn + Cu + B (T_{13}) while maximum Phosphorus (72.43 kg/ha) was recorded with application of Zn + Mn + Cu + B (T_{15}).

- Soil micronutrients like Zn and B were recorded highest (2.98kg/ha)(1.67kg/ha) with application of Zn + Cu + B (T_{13}), soil Fe (95.63kg/ha) with application of Zn + Mn + Cu + B (T_{15}) , Soil Cu (1.62kg/ha) with foliar application of Zn + Mn + B (T_{12}) and Mn (16.45kg/ha) with foliar application of Boron (B) (T_4) .

- With regards to leaf macro nutrient status, highest leaf total Nitrogen (2.19%) was observed with application of Zn + Mn + Cu + B (T_{15}) , leaf Phosphorus content (0.198%) with foliar application of Zn + Mn + B (T_{12}), leaf Potassium content (1.53%) with application of Zn + Cu + B (T_{13})

- Leaf micronutrient Content of Zinc was recorded highest (41.46ppm) with plants which received foliar application of Zinc (Zn) (T_1, highest leaf Boron (57.21ppm) with foliar application of Boron (B) (T_4) , maximum leaf Copper (26.81ppm) with foliar application of Copper (Cu) (T_3) and leaf Manganese (92.34ppm) with foliar application of Manganese (Mn)(T_2) and leaf Iron content (209.76ppm) with foliar application of Cu +B (T_{10}) . However, the treatment (T_{13}) with Zn + CU+B also showed reasonably high percentage of leaf micro nutrients (28.59ppm,41.61ppm, 25.78ppm,70.36ppm, and 206.94ppm of Zn, B, Cu, Mn and Fe, respectively) against control [Zn (10.52), B(25.70),Cu (13.56),Mn (65.49) and Fe (148.47) ppm] .

➢ With regards to leaf C: N ratio, it was observed highest (2.97) with plants which received application of Zn + Cu + B (T_{13}) while control recorded lowest value (2.66).

➢ The gross income (Rs16,91,200.00), net income (Rs. 13,40,685.82) and benefit: cost ratio (3.82) per hectare of cultivation was found highest with application of Zn + Cu + B (T_{13}) while control recorded the lowest net income (Rs 5,32,973.19) and benefit : cost ratio (2.07).

Conclusion

Based on the summary of results, the experiment may be concluded with the following points:

➢ Among all treatments, application of Zn + Cu + B (T_{13}) was the best treatment in respect of vegetative growth parameters, yield, C: N ratio, income and benefit :Cost ratio.

- In terms of fruit quality parameters, treatment with application of Zn + Cu + B (T_{13}) and application of Zn + Mn + Cu + B (T_{15}) were found to be the two best performing treatments among all the other treatments.

- Regarding the leaf nutrient status particularly leaf macro nutrients content differed significantly among different treatments as leaf Total N was found highest with application of Zn + Mn + Cu + B (T_{15}), leaf P content with application of Zn + Mn + B (T_{12}), leaf K content with application of Zn + Cu + B (T_{13}). Though leaf Zn content with application of Zinc (Zn)(T_1), leaf B with foliar application of Boron (B) (T_4), leaf Cu with foliar application of Copper (Cu) (T_3), leaf Mn content with foliar application of Manganese (Mn) (T_2) and leaf Fe with foliar application of Cu +B (T_{10}) scored highest but combination application also caused high content of these micro elements in T_{13}& T_{15} against control.

Therefore, from the present study on 'Nutrient Management in Khasi Mandarin (*Citrus reticulata* Blanco.) under subtropical Agro – Climatic Condition in Mizoram' it may be concluded that NC to supply 50%K + 50% RDF +AZ +PSB +KSB (T7) and FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB (T_{12}) as the two best method of Integrated Nutrient Management (INM) and Zn + Cu + B (T13) as the best foliar micronutrient combination to obtain high yield of quality Khasi Mandarin fruits with economic return.

Plate 1: General View of Experimental Orchard

Plate 2: Khasi Mandarin Plants at Experiment 1

Plate 3: Khasi Mandarin Plants at Experiment 2

Plate 4: Plants under different treatments in Experiment 1(T_1 – T_6)

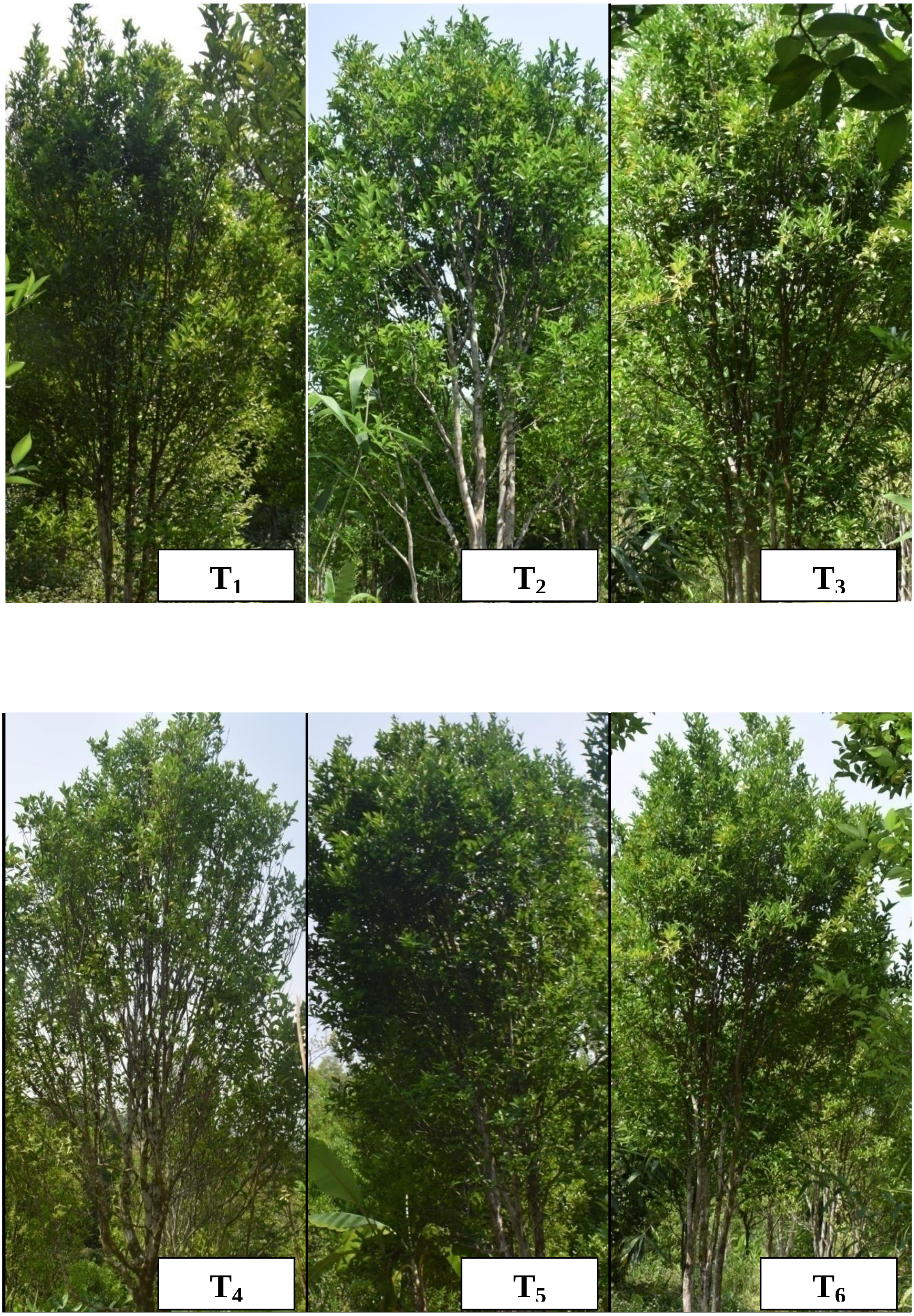


Plate 5: Plants under different treatments in Experiment 1($T_7 – T_{13}$)

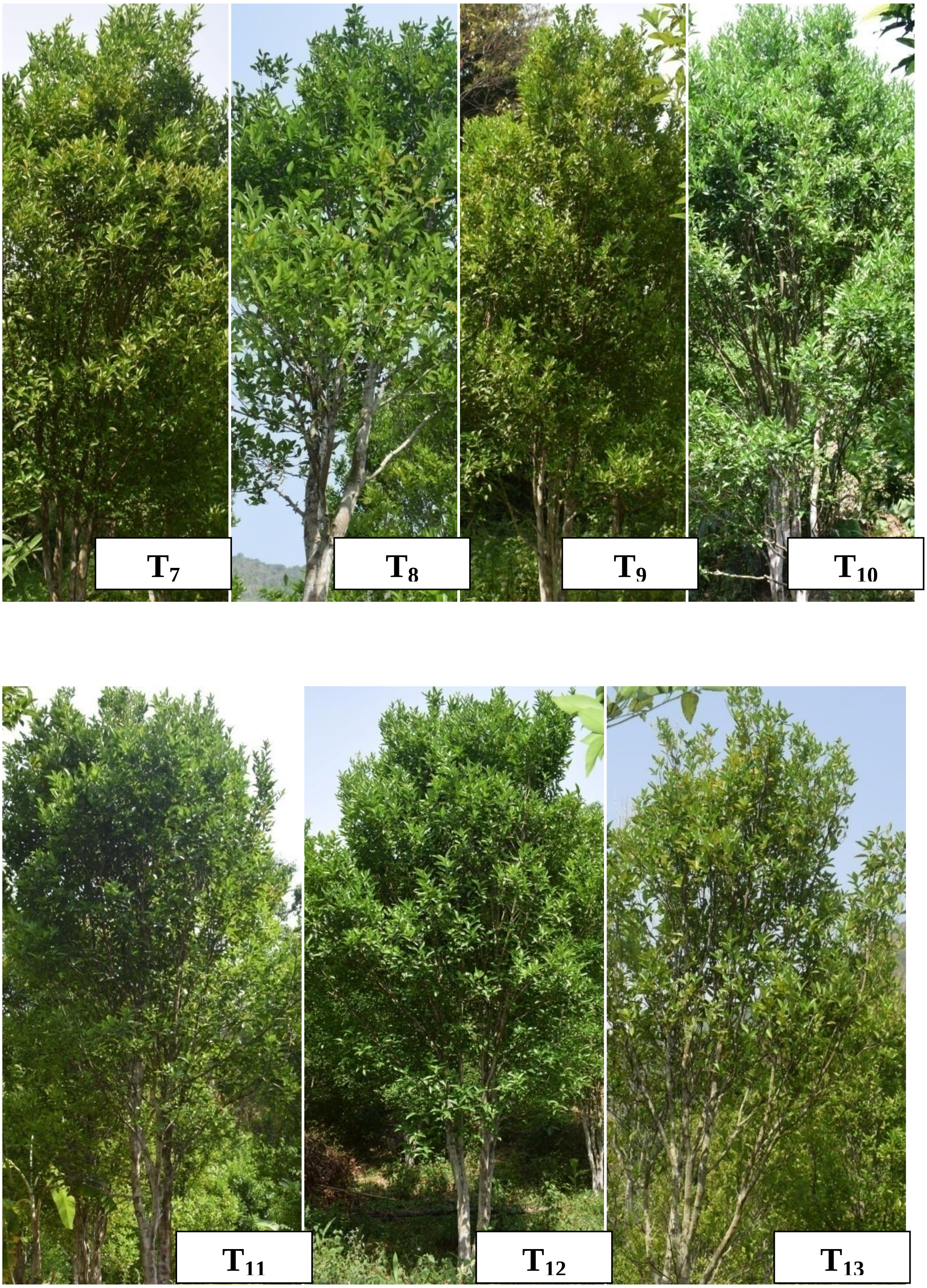


Plate 6: Plants under different treatments in Experiment 2(T_1 – T_8)

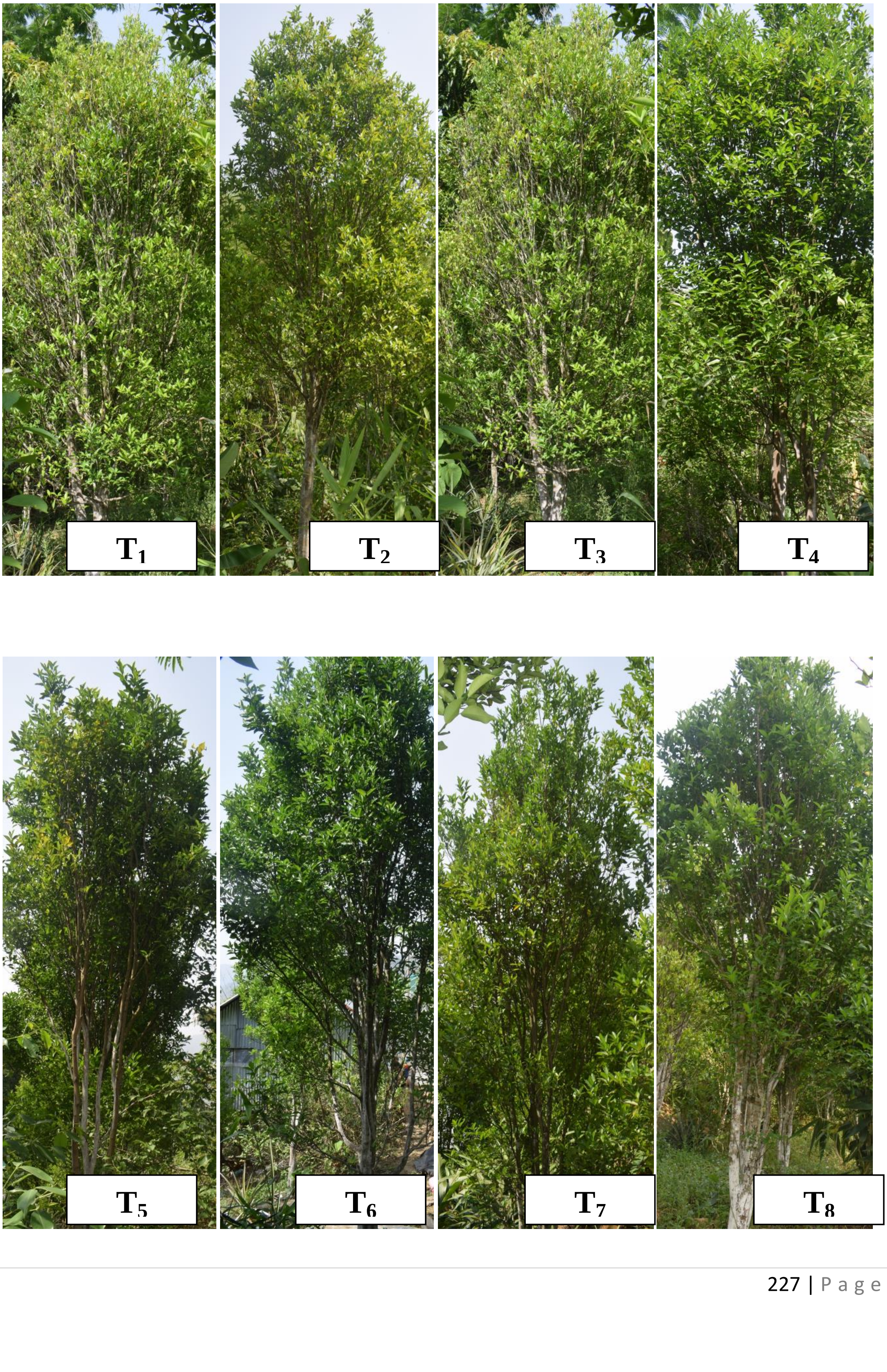


Plate 7: Plants under different treatments in Experiment 2(T_9 – T_{16})

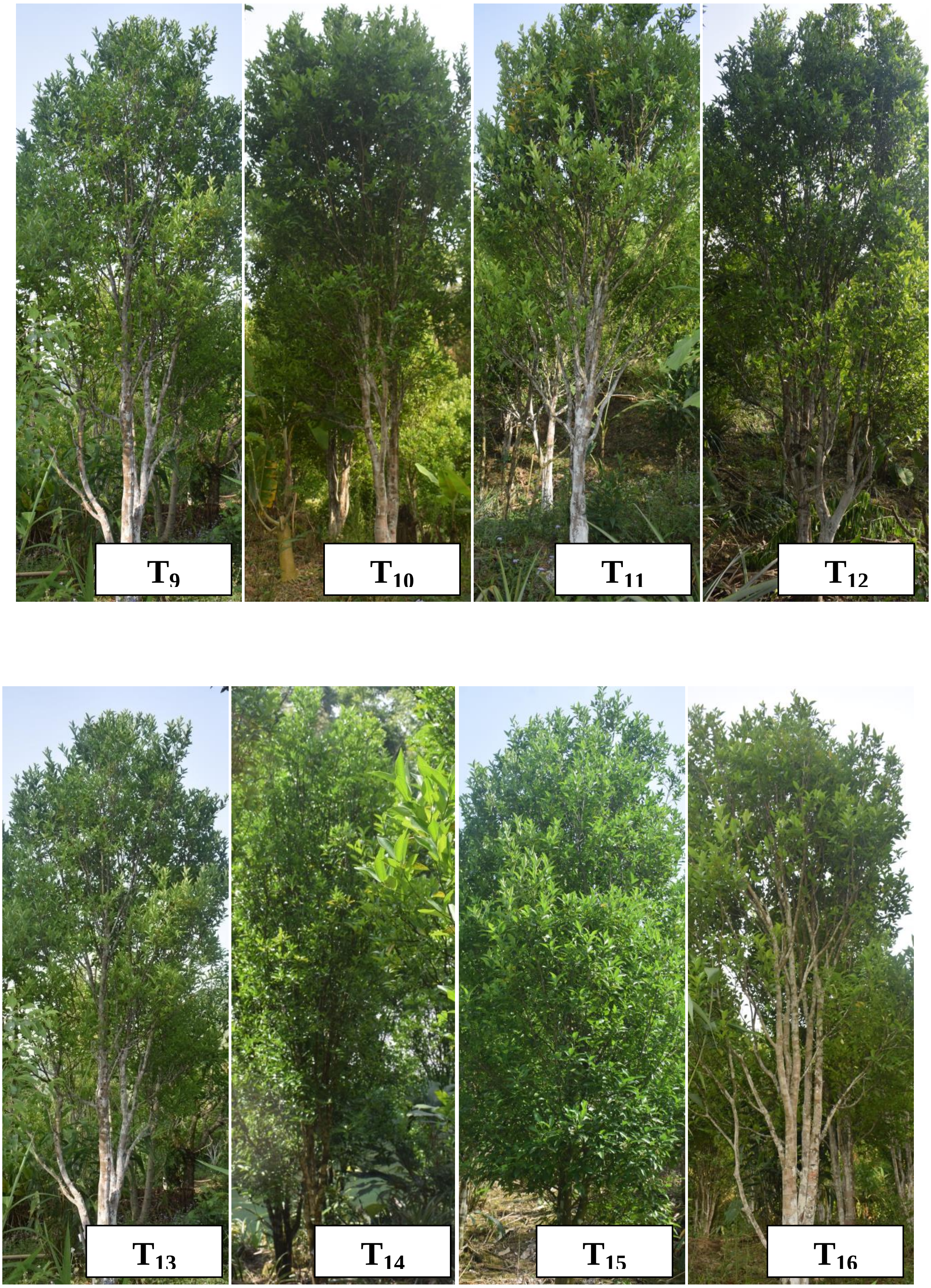


Plate 8: Khasi Mandarin Plants at Fruiting


Experiment 1


Experiment 2

Plate 9: Khasi Mandarin Plants at fruit ripening

Plate 10 : Khasi Mandarin Fruits at harvesting

Plate 11: Fruits under different treatments in Experiment 1(T_1-T_6)

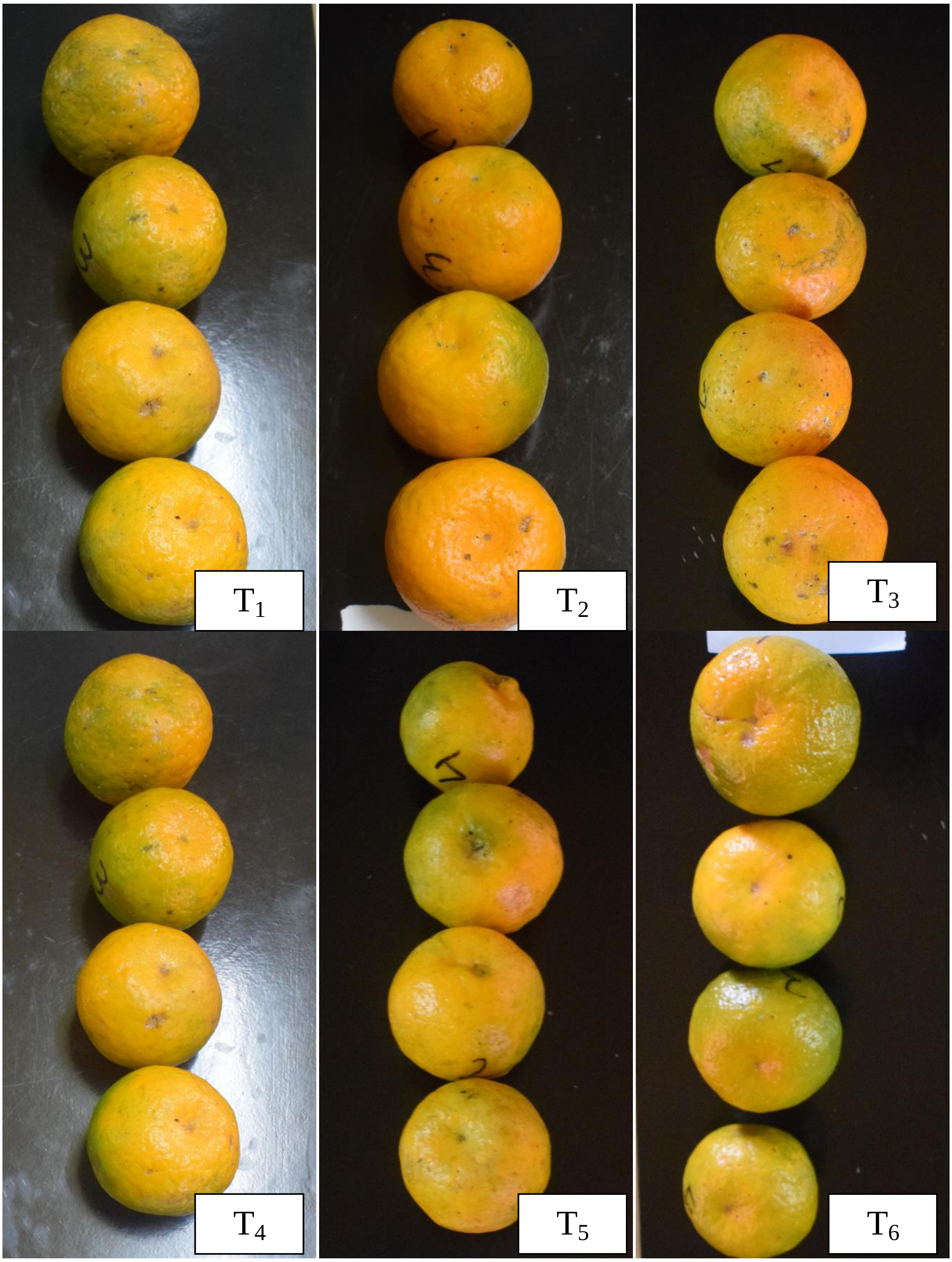


Plate 12: Fruits under different treatments in Experiment 1(T_7-T_{13})

Plate 13: Fruits under different treatments in Experiment 2(T_1-T_8)

Plate 14: Fruits under different treatments in Experiment 2(T_9-T_{16})

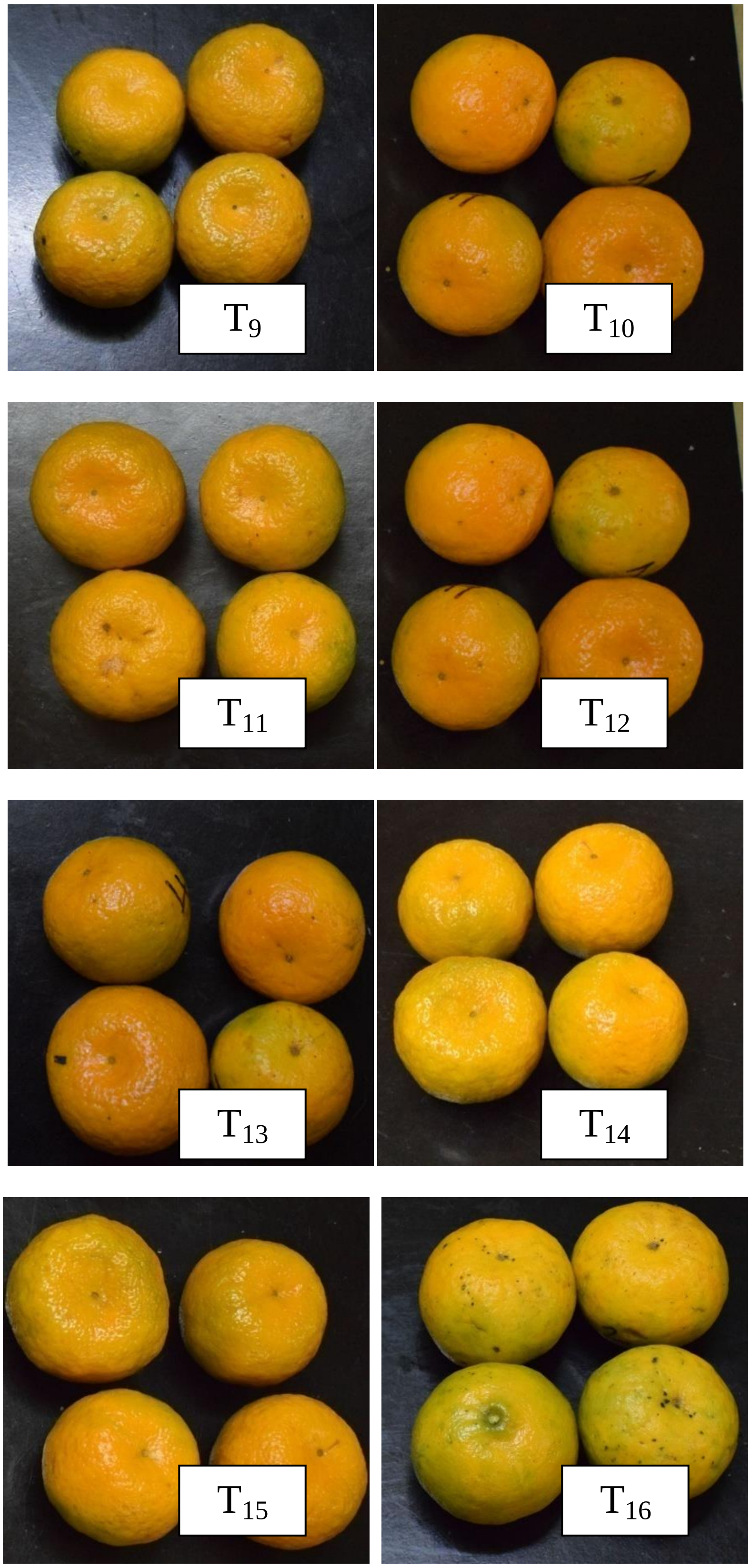


Plate 15: Different activities during the research period

Plate 16: Different activities during the research period(laboratory activities)

BRIEF BIO-DATA OF JENNY ZOREMTLUANGI

Name	Jenny Zoremtluangi
Date of Birth	01.02.1982
Gender	Female
Marital status	Married
Fathers name	Mr. R. Sangmawia (L)
Mothers name	Mrs. Tlangliani
Permanent Address	Chanmari, Aizawl, Mizoram Near B.H.H.O Fitness Centre House No. D-53

Academic Qualification:

- Qualified NET in 2009
- M.Sc. (Hort) in Floriculture and Landscaping, Bidhan Chandra Krishi Viswavidyalaya University, (Class topper) *
- B.Sc (Horticulture), College of Horticulture and Forestry, Pasighat, Arunachal Pradesh. (Gold medallist)*

Seminar/Symposium /Training attended

i. Attended training programme on Production Technology of Citrus for NEH Region during 14- 16th March, 2012 at Directorate of Horticulture organised by National Research Centre for Citrus.

ii. Partcicipated "International Conference on Sustainable Agriculture for Food and Livelihood Security" during 27-29th Nov, 2012 at PAU, Ludhiana.

iii. Participated in Training on Modern Scientific Method of Rubber Cultivation and Processing at Nucleus Rubber Estate and Training Centre, Agartala during 6th - 10th March 2006.

iv. Participated in Orientation Programme on Viticulture at NRC for Grapes, Pune during 28-30th October, 2013.

v. Participated training on "Production, processing and value addition in seed spices" during 13th-14thDec, 2012 organised by NRC on seed spices, Rajasthan.

vi. Participated training on Advances in Vegetable Production Technology at College of Horticulture and Forestry, Pasighat, CAU on 3rd to 10th November, 2009.

vii. Participated training on HDP and canopy management of important fruit crops from 17th Feb to 18th Feb, 2011 organised by CIH, Medziphema.

viii. Participated training on Post harvest management of horticultural crops during 10th to 12th Dec, 2012 organised by CIH, Medziphema.

DETAILS OF ECONOMICS OF CULTIVATION PER HECTARE (In Rs.) OF EXPERIMENT 1

Cultivar: Khasi Mandarin Plant Population: 1111 Spacing: 3 X 3 m, wages: Rs 250 per manday.													
Preparatory Cost	**T_1**	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**	**T_7**	**T_8**	**T_9**	**T_{10}**	**T_{11}**	**T_{12}**	**T_{13}**
Land Preparation & ploughing	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00
Pit Digging	22220.00	22220.00	22220.00	22220.00	22220.00	22220.00	22220.00	22220.00	22220.00	22220.00	22220.00	22220.00	22220.00
Cost of Planting Material @ Rs.40/-	44440.00	44440.00	44440.00	44440.00	44440.00	44440.00	44440.00	44440.00	44440.00	44440.00	44440.00	44440.00	44440.00
Planting (30 Mandays @Rs.250)	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00
Infrastructure													
Store House	30000.00	30000.00	30000.00	30000.00	30000.00	30000.00	30000.00	30000.00	30000.00	30000.00	30000.00	30000.00	30000.00
Euipments & implements	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00
Manuring and fertilization													
Urea @ Rs.15/Kg	21731.16	10832.25	10832.25	10832.25	10832.25	10832.25	10832.25	10832.25	10832.25	10832.25	5332.80	5332.80	0.00
Single Super Phosphate @ Rs.16/Kg	33330.00	16656.11	16656.11	16656.11	16656.11	16656.11	16656.11	16656.11	16656.11	16656.11	8319.17	8319.17	0.00
Muriate of Potash @Rs.30/Kg	32996.70	16331.70	16331.70	16331.70	16331.70	16331.70	16331.70	16331.70	16331.70	16331.70	7999.20	7999.20	0.00
Farm Yard Manure @ Rs.4/Kg	0.00	266640.00	0.00	0.00	266640.00	0.00	0.00	133320.00	133320.00	0.00	133320.00	133320.00	0.00
Vermi Compost@ Rs.12/Kg	0.00	0.00	571276.20	0.00	0.00	571276.20	0.00	285571.44	0.00	285571.44	285571.44	285571.44	0.00
Neem Cake@Rs.20/Kg	0.00	0.00	0.00	333300.00	0.00	0.00	333300.00	0.00	166650.00	166650.00	166650.00	166650.00	0.00
Azotobactor @Rs.150/Kg	0.00	0.00	0.00	0.00	16665.00	16665.00	16665.00	16665.00	16665.00	16665.00	0.00	16665.00	0.00
Phosphate Solubilizing Bacteria@Rs.150	0.00	0.00	0.00	0.00	16665.00	16665.00	16665.00	16665.00	16665.00	16665.00	0.00	16665.00	0.00
Potash Mobilizng Bacteria@Rs.150/Kg	0.00	0.00	0.00	0.00	16665.00	16665.00	16665.00	16665.00	16665.00	16665.00	0.00	16665.00	0.00
Application of Manures & Fertilizers (Basal & Top Dressing: 15 mandays @Rs.250)	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	0.00
Irrigation													
Ring Basin Irrigation (25 Mandays @ Rs	6250.00	6250.00	6250.00	6250.00	6250.00	6250.00	6250.00	6250.00	6250.00	6250.00	6250.00	6250.00	6250.00
Interculture Operation													
Weeding (20 Mandays @ Rs.250)	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00
Training and pruning (20 Mandays @ Rs	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00
Plant Protection													
Plant Protection Chemicals	8910.22	8910.22	8910.22	8910.22	8910.22	8910.22	8910.22	8910.22	8910.22	8910.22	8910.22	8910.22	8910.22
Application of Plant Protection Chemicals (10 Mandays @ Rs.250)	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00
Harvesting													
Harevsting (30 Mandays @ Rs.250)	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00
Packaging (10 Mandays @ Rs.250)	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00
Total Expenditure	249878.08	472280.28	776916.48	538940.28	522275.28	826911.48	588935.28	674526.72	555605.28	707856.72	769012.83	819007.83	158070.22
Misc. Exp. (@1% of total expenditure)	2498.78	4722.80	7769.16	5389.40	5222.75	8269.11	5889.35	6745.27	5556.05	7078.57	7690.13	8190.08	1580.70
Gross Expenditure	252376.86	477003.08	784685.65	544329.68	527498.03	835180.60	594824.63	681271.99	561161.33	714935.29	776702.96	827197.91	159650.92
Yield (Tons/ha)	11.56	25.86	25.62	33.56	28.72	27.45	36.82	27.08	31.93	30.23	36.18	39.97	5.17
Return (@ Rs.80/kg of Fruits)	924800.00	2068800.00	2049600.00	2684800.00	2297600.00	2196000.00	2945600.00	2166400.00	2554400.00	2418400.00	2894400.00	3197600.00	413600.00
Gross Income	924800.00	2068800.00	2049600.00	2684800.00	2297600.00	2196000.00	2945600.00	2166400.00	2554400.00	2418400.00	2894400.00	3197600.00	413600.00
Net Income	672423.14	1591796.92	1264914.35	2140470.32	1770101.97	1360819.40	2350775.37	1485128.01	1993238.67	1703464.71	2117697.04	2370402.09	253949.08
Benefit:Cost Ration	2.66	3.34	1.61	3.93	3.36	1.63	3.95	2.18	3.55	2.38	2.73	2.87	1.59

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DETAILS OF ECONOMICS OF CULTIVATION PER HECTARE (In Rs.) OF EXPERIMENT 2

Cultivar: Khasi Mandarin Plant Population : 1111 Spacing 3X 3m, wages : Rs. 250 per man day																
Preparatory Cost	**T_1**	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**	**T_7**	**T_8**	**T_9**	**T_{10}**	**T_{11}**	**T_{12}**	**T_{13}**	**T_{14}**	**T_{15}**	**T_{16}**
Land Preparation & ploughing	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00
Pit Digging	22220.00	22220.00	22220.00	22220.00	22220.00	22220.00	22220.00	22220.00	22220.00	22220.00	22220.00	22220.00	22220.00	22220.00	22220.00	22220.00
Cost of Planting Material @ Rs.40/-	44440.00	44440.00	44440.00	44440.00	44440.00	44440.00	44440.00	44440.00	44440.00	44440.00	44440.00	44440.00	44440.00	44440.00	44440.00	44440.00
Planting (30 Mandays @Rs.250)	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00
Infrastructure																
Store House	30000.00	30000.00	30000.00	30000.00	30000.00	30000.00	30000.00	30000.00	30000.00	30000.00	30000.00	30000.00	30000.00	30000.00	30000.00	30000.00
Euipments & implements	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00
Manuring and Fertilization																
Urea @ Rs.15/Kg	21731.16	21731.16	21731.16	21731.16	21731.16	21731.16	21731.16	21731.16	21731.16	21731.16	21731.16	21731.16	21731.16	21731.16	21731.16	21731.16
Single Super Phosphate @ Rs.16/Kg	33330.00	33330.00	33330.00	33330.00	33330.00	33330.00	33330.00	33330.00	33330.00	33330.00	33330.00	33330.00	33330.00	33330.00	33330.00	33330.00
Muriate of Potash @Rs.30/Kg	32996.70	32996.70	32996.70	32996.70	32996.70	32996.70	32996.70	32996.70	32996.70	32996.70	32996.70	32996.70	32996.70	32996.70	32996.70	32996.70
Zinc Sulphate	31552.40	0.00	0.00	0.00	31552.40	31552.40	31552.40	0.00	0.00	0.00	31552.40	31552.40	31552.40	0.00	31552.40	0.00
Manganese Sulphate	0.00	65415.68	0.00	0.00	65415.68	0.00	0.00	65415.68	65415.68	0.00	65415.68	65415.68	0.00	65415.68	65415.68	0.00
Copper Sulphate	0.00	0.00	51547.50	0.00	0.00	51547.50	0.00	51547.50	0.00	51547.50	51547.50	0.00	51547.50	51547.50	51547.50	0.00
Boric Acid	0.00	0.00	0.00	9065.76	0.00	0.00	9065.76	0.00	9065.76	9065.76	0.00	9065.76	9065.76	9065.76	9065.76	0.00
Application of Manures & Fertilizers (Basal & Top Dressing: 30mandays @Rs.250)	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00
Irrigation																
Ring Basin Irrigation (25 Mandays @ Rs250)	6250.00	6250.00	6250.00	6250.00	6250.00	6250.00	6250.00	6250.00	6250.00	6250.00	6250.00	6250.00	6250.00	6250.00	6250.00	6250.00
Interculture Operation																
Weeding (20 Mandays @ Rs.250)	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00
Training and pruning (20 Mandays @ Rs.250)	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00
Plant Protection																
Plant Protection Chemicals	8910.22	8910.22	8910.22	8910.22	8910.22	8910.22	8910.22	8910.22	8910.22	8910.22	8910.22	8910.22	8910.22	8910.22	8910.22	8910.22
Application of Plant Protection Chemicals (15Mandays @ Rs.250)	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00
Harvesting																
Harevsting (30 Mandays @ Rs.250)	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00
Packaging (10 Mandays @ Rs.250)	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00	3750.00
Total Expenditure	286430.48	320293.76	306425.58	263943.84	351846.16	337977.98	295496.24	371841.26	329359.52	315491.34	403393.66	360911.92	347043.74	380907.02	412459.42	254878.08
Misc. Exp. (@1% of total expenditur	2864.30	3202.94	3064.26	2639.44	3518.46	3379.78	2954.96	3718.41	3293.60	3154.91	4033.94	3609.12	3470.44	3809.07	4124.59	2548.78
Gross Expenditure	289294.78	323496.70	309489.84	266583.28	355364.62	341357.76	298451.20	375559.67	332653.12	318646.25	407427.60	364521.04	350514.18	384716.09	416584.01	257426.86
Yield (Tons/ha)	13.48	12.19	12.74	11.24	14.15	11.78	16.86	14.83	15.14	15.76	17.39	18.72	21.14	16.26	21.01	9.88
Return (@ Rs.80/kg of Fruits)	1078400.00	975200.00	1019200.00	899200.00	1132000.00	942400.00	1348800.00	1186400.00	1211200.00	1260800.00	1391200.00	1497600.00	1691200.00	1300800.00	1680800.00	790400.00
Gross Income	1078400.00	975200.00	1019200.00	899200.00	1132000.00	942400.00	1348800.00	1186400.00	1211200.00	1260800.00	1391200.00	1497600.00	1691200.00	1300800.00	1680800.00	790400.00
Net Income	789105.22	651703.30	709710.16	632616.72	776635.38	601042.24	1050348.80	810840.33	878546.88	942153.75	983772.40	1133078.96	1340685.82	916083.91	1264215.99	532973.14
Benefit:Cost Ration	2.73	2.01	2.29	2.37	2.19	1.76	3.52	2.16	2.64	2.96	2.41	3.11	3.82	2.38	3.03	2.07

Chapter - 2

REVIEW OF LITERATURE

2.1. Role of plant nutrients in plant growth and development

Wadleigh (1957) also reported that protein and chlorophyll synthesis were markedly improved with the application of higher dose of N.

Agarwala and Sharma (1976) observed that the increase in plant growth with the application of nitrogen may be explained from the fact that the nitrogen is the major constituent of many compound of great physiological importance in the metabolism such as amino acids, proteins, nucleic acids, porphyrins, enzymes and co enzymes. They also reported that like nitrogen, phosphorus plays an important role as a structural component of cell. It is a constituent of the sugar phosphates- ADP, ATP etc., nucleic acids, nucleoproteins, purine and pyrimidine nucleotides.

Hirobe (1981) studied the effect of 100, 200, 300 and 400 kg/ha nitrogen fertilizer for 9 years in mandarin trees and reported that the tree trunk diameter with 300 kg/ha N and crown volume with 400 kg/ha N were observed maximum in size.

Sing (1984) observed the effect of different concentrations of nitrogen on quantity and quality of the Mexican lime fruit and stated that the highest water content was observed with the fruit of trees that received highest amount of nitrogen (1200 g per tree)during summer. Whereas, highest vitamin C and total soluble solid were obtained in juice of the plants that received highest nitrogen (1200 g per tree) during fall period.

Alla *et al*. (1985) reported the best effect on citrus root growth in the three year experiment with application of 800 g N per plant and significant growth parameters of citrus species was also observed with N application by Kumar *et al.* (1993).

Application of inorganic fertilizers, manures and biofertilizers increased the soil nitrogen, phosphorus and potassium contents (Dutta *et al*., 2010 and Prasad *et al*., 2010) improve fruit quality (Ram and Prasad, 1988; Natesh *et al*., 1993; Pandey *et al*., 2005 and Srinivas *et al*., 2001) which is rather sensitive to K availability (Alva *et al.*, 2006)and availability of K increased fruit size with thick and harsh peel whereas smaller fruits with thin peel was observed with no K content . Better fruit quality was observed with combined application of organic and inorganic manure by enhancing soil nutrient availability and helps the plants to uptake large amount of solute from rhizosphere (Gawande *et al*., 1998 and Patel and Naik, 2010).

Ram and Rajput (2000) reported positive response in terms of growth, yield and quality to organic manures and inorganic fertilizers (the cheap available nutrient source).

Goramnagar *et al.* (2001) indicated that the application of Phosphorus and Potassium in the form of SSP and murate of potash increased their respective contents in leaf and soil in proportion to rates applied. P through SSP led to higher Ca content in the leaves and soil. Synergistic effects of Mg with N were observed in leaves, but the level of Mg in soil was substantially decreased. N content in soil was increased by all treatments, contents of P, K and Ca were only influenced by application of fertilizer in combination. Compared to the rest of the treatments, treatment with 15kg FYM+180g P_2O_5 was more efficient.

Srivastava *et al.* (2002) reviewed better plant growth and nutrient uptake like P, Ca, Zn, Cu, and Fe as compared to non-mycorrhizal trees by using organic manures like FYM, Plant litter, vermicompost, and bio-fertilizers and also by exploiting the synergism between citrus-vesicular arbuscular mycorrhizal fungus.

Yadav and Vijayakumari (2003) pointed out that the improvement in growth of plants might be due to higher retention capacity of organic manures and nutrients supply which was obtained by application of vermicompost.

Maheswarappa *et al*. (2003) indicated that integrated nutrient management practices coupled with adopting high density cropping system results in improvement of tree growth and yield. This may be due to higher holding capacity of water and improved nutrient status of soil due to adoption of integrated nutrient management.

Alva *et al*. (2006) reported that magnesium, calcium, and ammonium N uptake is prohibited due to high K availability in the soil which thereby deteriorate quality of juice like acidity and TSS (%).

Khan *et al*. (2009) revealed that significant variation was observed with application of organic manures - FYM and press mud, biofertilizer (VAM) and inorganic agricultural grade iron pyrites either alone or in combinations regarding the active iron, sap pH and total chlorophyll content of acid lime.

Mattos *et al*. (2010) observed that phosphorus enhanced plant growth and production of citrus fruits.

Yaseen and Ahmad (2010) studied that application of NPK fertilizers on drip line in combination with foliar spray was found to improve production of quality citrus (kinnow) fruits up to 63%.

Improved soil physical properties were observed with organic manures in combination with chemical fertilizers by helping the plant root development and enhancing nutrients uptake thereby leading to faster cell division and cell elongation and consequently increased the plant height, spread and stem girth (Villasurda ,1990 and Yadav *et al*., 2012).

Gautam *et al.* (2012)reported in sweet orange var. Nucellar (*Citrus sinensis* L.Osbeck) that maximum vegetative growth was found with application of Farm yard manure and green manuring in combination with chemical fertilizers. This might be due to the increased in the rate of photosynthesis and accumulation of carbohydrate as a result of multiferous role of FYM and green manuring to allow most favorable conditions of soil with increased availability of plant nutrients responsible for better plant growth (Sharma and Bhutani, 2000; Dutta *et al*., 2009) .

Increase in tree height, spread, volume, shoot length and number of shoot emergence per branch might be due to the stimulative activity of microflora in the rhizosphere which increased availability of nutrients and improved plant growth in the trees which received chemical fertilizers and biofertilizers in sweet orange (Singh *et al*., 2000; Aseri *et al.*,2008) .

Zambrosi *et al*. (2013) stated that citrus growth was limited with low-phosphorus (P) availability and thereby conducted an experiment with trees on Cleopatra mandarin (CM) and Rangpur lime (RL) by applying different treatments which consists of P rates (20, 40, and 80 mg kg^{-1} of soil).The result indicated improved root and shoot growth, higher leaf P concentration, Phosphorus uptake, and Phosphorus root uptake efficiency (PUE) were obtained with Phosphorus application.

Lal and Dayal (2014) observed in acid lime that the soil texture and porosity was improved by giving goat manure and NPK fertilizers due to their bulkiness properties which improved the plant root development and available nutrients uptake thereby leading faster cell division, cell elongation and consequently increased the height of the tree, plant canopy spread and plant girth.

Ramana *et al*. (2014) observed in sweet orange that highest plant height (3.09 m) canopy volume (20.9 m^3) were resulted with application of 50 % recommended dose of N &K .Whereas, significant variation was observed with the number of fruits per tree (345.69) and fruit yield (61.69 kg/tree) in plants which received N &K at 75% recommended dose through fertigation. The same treatment also recorded the highest C: B ratio of 1:2.29.

2.2. Role of plant nutrients in Fruit growth, development and quality

The effectiveness of inorganic fertilizers was greatly enhanced when it was applied along with vermicompost, green manuring and FYM. This might have resulted due to better retention of urea in root zone (Mitsui *et al.*, 1960; Chin and Kroonje, 1963) and better availability of phosphate and potash to the plants by organic matter (Raychoudhuri, 1976) .

In 'Valencia' oranges, application of NPK increased the fruit size (Hernandez,1981). In ten-year fertilizer experiment with 'Valencia' oranges, Bevington (1984) studied the influence of NPK on quality and yield of 'Valencia' late oranges and found maximum juice and TSS content was observed with low N and high P and K application. Desai *et al.* (1981) obtained best fruit quality in oranges with application of NPK at 500: 170:391 g/tree. In 'Kinnow' mandarin, Mann and Sandhu (1988) reported that increased fruit weight, peel thickness, and acidity were observed with increasing N application, and decreased size of fruit, content of juice , TSS content, TSS/acid ratio and vitamin C content. The phosphorus application increased weight of fruit, content of juice, TSS content and TSS : acid ratio but it decreased fruit size, peel thickness, titratable acidity and content of vitamin C. Nunez and Valdez (1994) reported that K applications increased weight of fruit, fruit size, thickness of peel, juice content and vitamin C content but decreased TSS :acid ratio. The fruit weight of Sweet oranges, and the highest percentage of TSS and total sugars were observed with application of Nin the form of ammonium nitrate, P in the form of triple superphosphate and K in the form of potassium sulphate to 'Valencia' oranges at different combinations. They observed that omitting K advanced fruit ripening and reduced acidity, while treatments had no effect on juice and TSS content.

Koseoglu *et al.* (1995) applied N, P and K to 'Satsuma' mandarin at five different rates. Increasing K rates increased juice, but decreased TSS. Rind thickness was positively correlated with leaf N and K contents, but negatively correlated with leaf P content. The TSS percentage were negatively correlated with leaf N and positively correlated with leaf K.

The fruit juice which were given micronutrient recorded low acidity level because of their utilization in respiration and rapid metabolic transformation of organic acids in to sugars (Brahamachari *et al.*, 1997). Similar result was reported by Patil and Hiwarale (2004) in acid lime.

Huchche *et al*. (1998) reported significant increase in yield of Nagpur Mandarin by applying N in the form of inorganic up to 800gper plant per year compared to single application of FYM in Typic Haplustert soil.

Achilea (1999) stated that crop quality is mainly determined with the availability of potasium to the crop where the most important function of K is activation of enzyme, carbohydrates accumulation and organic acids. Improved fruit size, dry matter, colour, taste and integrity and resistance to biotic and abiotic stresses and B:C ratio were observed with the combined application of potassium and Nitrate in citrus fruits.

Berghman *et al*. (1999) studied the reasons for poor yields from citrus plantations managed organically in Corsica. Leaf mineral composition was compared in clementines grown under inorganic and organic fertilizer application on a brown leached soil developed in old alluvium. Poor nitrogen assimilation by roots also resulted low yields.

Yield of fruit and fruit quality in citrus largely depends on nitrogen (N) and potassium (K) fertilization (Cantarella *et al*., 2003; Alva *et al*., 2006).

Ranjan and Gosh (2006) reported that improved fertilizer use efficiency with the application of organic source of nutrients was due to induction of growth hormones, which stimulated cell division, cell elongation, increase in fruit weight and fruit number, better root development and better translocation of water uptake and deposition of nutrients which thereby improve the quality of fruits.

Schumann *et al*. (2010) stated that deficiencies of major and micronutrients like B, Cu, Mn decreased resistance to pest and diseases attack.

Ashraf *et al*. (2010) stated that application of K was found to increase the fruit yield and quality but K at100 kg K_2O per hectare was more significant in improving the fruit weight and size, and peel thickness than other K rates in all the selected orchards. However, juice volume and percentage significantly increased when K was applied at 75 kg K_2O per hectare at all sites.

Srivastava (2011) stated that Potassium, as a major nutrient is claimed to have catalyzing importance in maximizing the quality yield of citrus.

Increased K supply associated with increased leaf K concentration resulted increased fruit size (Quaggio *et al.*, 2011).

Sujeet *et al*. (2014) indicated that Kinnow fruit yield and quality like maximum yield was observed at 80% of ETc and 700 g K/plant/year (32.67 t/ha), Total Soluble Solids (TSS) was found highest in case of 80% of ETc and 700 g K/plant/.Whereas, the juice content was maximum at 100% ETc and 800 g/plant/year potassium. The treatment (80% ETc and 700 g K/plant/year) was the best as it resulted in high yield and better quality with saving of water. Thus, 80% ETc and 700 g K/plant/year, which could be recommended for fertigation scheduling to increase yield and quality of Kinnow grown in northern India under potassium deficit soils.

2.3. Role of Integrated Nutrient Management on Citrus:

2.3.1. Plant growth and development

It was found that leaf area was increased with application of NPK in combination with farmyard manure (FYM) (Pennisi,1971a & b ; Motskobilli, 1984; Piemanac, 1985; Beridze1990), winter hardiness (Motskobilli, 1986) in 'Satsuma' mandarin, and by substituting up to 50% N with FYM in 'Coorg' mandarin, canopy volume was increased (Mustaffa *et al.*, 1997), and fruit quality (juice, total soluble solids, rag content, etc.) in 'Nagpur'mandarin (Huchche *et al*.,1998).

Chandrababu and Shanmugam (1983) reported an increase in the stem height and trunk diameter of different citrus species with VAM.

Single or combined application of FYM with NPK improved the leaf area (Motskobilli ,1984) and winter hardiness in Satsuma mandarin (Motskobilli ,1986) in comparison to NPK alone.

Increase in canopy volume and girth of Coorg mandarin was reported by substituting 25, 50 and 75% of urea-N with groundnut cake (Mustaffa *et al*., 1997). Tiwari *et al.* (1997) also observed in sweet orange that yield potentiality of inorganic fertilizers with organic manure like neem cake was better than fertilizers or manures alone in respect of agronomic growth parameters *viz.* height, canopy diameter, total canopy volume along with yield.

Goramnagar *et al.* (2000) reported that the growth of Nagpur Oranges was better in the rainy season than in the summer season and was marginal during winter. Application of 15 kg FYM + 360 g N + 180 g P_2O_5 plant^{-1} produced tall bushy plants with increased leaf area, spread and good scionic relationship. Among organic manures, application of neem cake was efficient.

Goramnagar *et al.* (2001) observed that the application of Phosphorus and Potassium in the form of SSP and murate of potash increased their respective contents in leaf and soil in proportion to rates applied. P through SSP led to higher Calcium (Ca) content in the leaves and soil. Synergistic effects of Magnesium (Mg) with N were observed in leaves, but the level of Mg in soil was substantially decreased. N content in soil was increased by all treatments; contents of P, K and Ca were only influenced by application of fertilizer in combination. Compared to the rest of the treatments, treatment with 15kg FYM+180g P_2O_5 was more efficient.

Tarai and Ghosh (2006) reported in case of 6 year old sweet orange cv. Mosambi budded on rough lemon that different growth parameters, i.e. height, basal leaf and plant spread varied and not followed a regular sequence in different treatments which include N200g: P75g: K150g + 2 kg of neem cake per plant which was in combination with N, P, K foliar spray content of 2.30, 0.12 and 1.30%, respectively. Superior quality fruits (TSS, Total sugar and Ascorbic acid) were also observed from the same trees, i.e. those that received N200g: P75g: K150g + 2 kg of neem cake per plant. VAM application gave no significant result either in production or in quality improvement.

Baviskar *et al*. (2011) found out that the plants which received NPK (1125g: 750g: 375g) + vermicompost (15kg) + *Azotobacter* (250g) + PSB(250g)/ tree recorded maximum yield of fruits per tree as well as physico-chemical traits.

Ibe *et al.* (2011)reported that organic and inorganic fertilizers plays an important role in sustaining citrus production and also increased height of the tree and canopy spread through a better fertility management system.

Jain *et al.*(2012) studied that effect of Mycorrhiza and Vermicompost as well as their interaction on plant growth characteristics of Nagpur mandarin (*Citrus reticulate* Blanco) during pre-bearing stage. The results revealed that treatment M3 i.e. mycorrhiza @30 g/plant showed superior results with respect to increase in plant height (42.94 %), root stock girth (37.93%), scion girth (34.73%), canopy volume (41.86%), leaf area (46.73%), relative water content of leaves (69.38 %) and plant spread E-W (30.32%) and N-S (25.91%) over control. An application of 6 kg

Vermicompost per plant showed significantly better result with respect to most of the vegetative growth parameters as compared to their lower doses and control. Amongst various treatment combinations used, treatment M3V3 (mycorrhiza @30 g/plant + Vermicompost 6 kg/plant) showed significantly superior over most of the treatment combinations including control in plant growth and development characters like root stock girth, scion girth, plant height, plant spread (E-W and N-S), canopy volume and relative water content of leaves.

Parveen *et al*. (2012)reported that nutrients *viz*., N, P, K, Fe, Mn, Zn and B plays an important role in citrus decline because of this,they should be included in fertilization programme on a regular basis.

Singh *et al*. (2012) reported that judicious use of organic inputs with inorganic are ecofriendly and maintain the long term ecological balance of soil ecosystem and are the alternative source to meet the nutrient requirement in fruit crops referred to as sustainable agriculture.

Integrating higher dose of nitrogen (300g) in chemical form with *Azotobacter* produced early vegetative growth and improved yield rather than application of inorganic nitrogen alone (Patel *et al.,* 2012).

Patil *et al.* (2017) indicated in sweet orange var. Nucellar that amongst different INM based treatments, the treatment receiving 75% RDF + 25% FYM + Green manuring recorded significantly highest plant height, Girth of stem, plants spread and canopy volume as compare to other treatments. Application of 75% RDF + 25% vermicompost + Green mannuring recorded significantly maximum fruit numbers/ tree. The yield of fruit was recorded better with application of 75% RDF + 25% vermicompost + Green mannuring.

2.3.2. Fruit quality

Beridze (1990) reported in 5 years old ‘Meyer’ Lemon tree, that the yield was highest(6.6t/ha) in the plants which received basal dressing of NPK(150kg :120kg :80 kg) and 25kg peat per hectare as a mulching materialwith 55tonnes/ha FYM.

Prasad and Singhania (1989) reported increased leaf nutrient status, fruit size, weight and yield of Khasi Mandarin was observed with application of organic manures with NPK.

Combined application of organic manure alongwith inorganic N, P, and K fertilizers gave quality response on various citrus cultivars (Rokba *et al.*,1995; Borah *etal.*, 2001).

Highest fruit yield and improved quality (Ghosh and Besra,1997) and concentration of different nutrient in index leaves (Singh *et al.*,1993) were observed with 25kg organic matter in combination with 400g N, 150g P, 300g K in Khasi mandarin and sweet orange grown, respectively on acid red soil under humid tropical climate of north east India and alkaline sandy loam soil of north west India.

Tiwari *et al*. (1997) stated that combined application of NPK (800g: 300g: 600g) and 15 kg neem per plant per year gave the most effective in regards to various growth parameters, yield and cost-benefit ratio (1:2.14) in sweet orange.52 kg FYM, 1.82 kg $(NH_4)_2SO_4$-N per tree in ‘Balady’ mandarin gave highest fruit yield with improved quality (El-Koumey *et al*., 2000) and 15kg neem cake, NPK (800g: 300g:600g) per tree per year in Sweet Orange (Gamal and Ragab,2003).

Ghosh (1990)reported in 'Mosambi' that a significant improvement in fruit production was obtained by applying N at 500 g, phosphorus at 100 g and K at 400 g per year. Sharma and Azad (1991) revealed that the maximum fruit number and weight of fruit were recorded with 100 g N + 50 g P + 0 g K in Mandarin orange.

Sarooshi *et al* .(1991) suggested that orange trees in New South Wales of Australia required 75-150 kg N per hectare and about 90 kg of P per hectare for optimum production.

Koseoglu *et al.* (1995) reported for Seven-year-old 'Satsuma' oranges that highest yield was obtained with 420 g N, 323 g P_20Sand 355 g K_20/tree. Earlier in 1990, the same workers obtained the highest yield in 'Satsuma' oranges with N at 475 g, P_20 Sat 320 g and K_20 at 355g/tree. Dris *et al.* (1997) studied in 'Clementine' mandarins that the maximum yield was observed with application of NPK@ 600: 150:600g/tree.

Intrigliolo and Roccuzzo (1999) studied that sprinkler-irrigated and plants which received 450 g N, 400 g P_2O_5 and 600 g K_2O/plant in each year showed earlier and significant differences in acidity and TSS: Acidity ratio.

Improved vegetative parameters, growth, yield, and quality of different citrus fruits were obtained by judicious use of organic and inorganic fertilizers by several workers (Ghose,1990; Kumar *et al*.,1993; Ram *et al*., 1997 and Shukla *et al.*,2000).

Mohandas (1999) reported that combined application of bio- fertilizers with organic manures and inorganic fertilizers in a balanced proportion increased the yield and quality of crops.

Beneficial effect of neem cake and inorganic fertilizers in improving the yield was also noted by Borah *et al.* (2001) in Khasi Mandarin and Ingle *et al.* (2001) in Acid Lime.

Improved fruit length, leaf content of N,P,K, fruit set, yield, number of fruits per tree, fruit weight, juice percentage, percentage of total soluble solids and ascorbic acid content were observed with trees supplied with organic fertilizers in combination with the mineral N source. FM (filter mud, a by- product of sugar industry) application showed better overall results compared with that of FYM. FM @ 120 with 6.00kgN per tree gave the best yield and fruit quality (Ebraheim and Mohamed, 2000).

Ingle *et al.* (2001) studied the influence of organic source of nutrient through neem cake @ 7.5kg/tree and 15 kg/tree, alone or in combination with 50, 75 and 100% of 600 g N, 300 g P_2O_5 and 300 g K_2O, on quality and yield of acid lime. Half dose of Nitrogen, along with full dose of Potassium, Phosphorus and neem cake, were applied in the second week of June and the remaining half of N was applied one month after fruit set. Results revealed that the yield and quality of acid lime fruits were found to be significantly improved due to application of neem cake, along with chemical fertilizers. Significantly higher yield with better quality fruits were obtained from the trees which received NPK (600g:300g:300g)with 15 kg neem cake per tree per year, with maximum monitory returns per rupee investment than other treatment combinations.

Dubey and Yadav (2003) conducted an experiment regarding the response of Khasi mandarin to organic versus inorganic fertilization. Better mean fruit yield (107 kg/tree), was observed with trees which received 110 kg pig manure. Higher yield (111 kg/tree) was obtained with the application of nitrogen@ 750 gm per tree. The application of 650 gm K_20 had highest mean fruit yield/tree (107 kg). However, combination of 110kg pig manure + 750g N + 650K produced highest fruit yield/tree (163 kg) and lowest fruit drop (19.73 %).

Dudi *et al.* (2003) reported application of FYM on Kinnow Mandarin showed significant growth.

Aariff Khan *et al*. (2004) observed that the yield of fruit of acid lime was significantly and positively influenced by the application of iron pyrites [pyrites] (IP at 100, 200 and 300 g/plant), press mud (PM at 4 and 8 kg/plant), farmyard manure (FYM at 25 and 50 kg/plant) and VAM (150 g/plant), either individually or in combination, in both years. Among the treatments, the integrated use of 200 g IP/plant along with 25 kg FYM + 2 kg PM/plant out yielded the other treatments in both direct and cumulative effects. The total amount of soluble solids was not significantly affected by the direct effect treatments, while the cumulative effect of treatments in the second year was significant. The acidity of the different treatments increased significantly in direct and cumulative effect treatments over the control. FYM at 50 kg/plant, alone, gave the highest cumulative effect (18 and 24 months) for acidity, whereas 25 kg FYM + 2 kg PM + 200 g IP/plant recorded the highest acidity at 12 months of direct effects.

Hiwarale *et al.*(2004) observed that the fruit yield of acid lime in terms of number and fruit weight per tree were significantly improved in trees which received neem cake @7.5 kg + 100% recommended doses of NPK. The average fruit volume and weight , juice percentage, total soluble solids (TSS) also improved by application of neem cake @ 7.5+100% NPK per plant.

Chalwade *et al*. (2005) conducted an experiment on a Vertisol grown with kagzi lime (*Citrus aurantiifolia*) in Parbhani, Maharashtra, India, to observe the influence of integrated nutrient management on various properties of soil. The treatments include: recommended rates of fertilizer (N, P_2O_5 and K_2O at 800, 400 and 400 g/tree, respectively); micronutrients ($FeSO_4$, $ZnSO_4$ and Borax at 75, 50 and 25 g/tree, respectively); enriched coir pith compost (teracare); and farmyard manure. Results indicated that the integrated nutrient management treatments significantly improved the physicochemical properties of the soil.

Abd El Motty *et al.*(2006)reported that the best results with regard to fruit quality ,fruit set and yield were obtained in Valencia oranges fertilized with NPK (1250g:700g :800g) per tree. Varying levels of N, P, K, Zn, Fe and Mn effectively differed fruit set, yield and most physical and chemical properties of Valencia orange fruits.

Tarai and Ghosh (2006) reported that fruit production of Mosambi was highest in the plants which were treated with N200: P75: K150 g + 2 kg of neem cake per plant which was given in combination with foliar spray of N:P:K(2.30:0.12:1.30 %). Superior quality fruits (TSS, Total Sugar and Ascorbic acid) were also obtained from the same plants, i.e. those that received N200: P75: K150g + 2 kg of neem cake per plant. VAM application gave no significant result either in production or in quality improvement. Mahendra and Singh (2009) also reported in Sweet Orange var. Nucellar that application of organic manures, biofertilizers with NPK increased growth, yield and quality.

Khan and Begum (2007a) reported that the tree which was supplied with higher rate of FYM at 50 kg/plant and simultaneously, application of iron pyrites at 200 g along with FYM at 25 kg + press mud at 2 kg per tree were superior treatments and significantly increased the available nutrient status of N, P, K and S in both years over the control in acid lime.

Khan and Begum (2007b) studied the effects of inorganic and organic fertilizers on the performance of 3-years-old acid lime (*C. aurantiifolia*). In first year, FYM at 50 kg per plant resulted in the greatest plant height and plant girth. Plant volume was greatest for 25 kg FYM + 2 kg Press mud + 200 g Iron Pyrites/tree. In second and third year the highest total chlorophyll contents were obtained with 50 kg FYM /tree and 25 kg FYM + 2 kg Press mud + 200 g Iron Pyrites /tree.

Marathe and Bharambe (2007) stated that leaf analysis was more superior over soil analysis where significant nutrient concentration in leaves was observed more with yield and quality parameters than the soil available nutrients.

Medhi *et al*. (2007)reported that the plants supplied with Mustard Oil Cake (MOC) (10kg/plant), bio-fertilizers (*Azotobacter* and PSB)and K_2O (600 g/plant) with no inorganic N observed highest soil pH, available P_2O_5, leaf P and K. Whereas, significant difference was recorded with soil organic carbon(Organic Carbon), available Nitrogen, fruit quality (Juice, Total Soluble Solid, Total sugar, Ascorbic acid) and yield with highest economic return (5.75) with plants that received half of the recommended dose of inorganic N and $P_2O_5$and were supplemented through *Azotobacter* and PSB along with K_2O (600g/plant) and Mustard Oil Cake (7.5 kg/plant).

Musmade *et al.* (2009) reported from three years pooled data revealed that the vegetative growth parameters, yield of fruit and acid lime quality was significantly improved with the combined application of neem cake, FYM and inorganic fertilizers. Significantly higher yield (147.65 kg $plant^{-1}$) with better quality fruits were obtained from the 10 year old trees receiving 600:300:600 g NPK+15 kg each of FYM and neem cake per plant per year with maximum monetary returns i.e. Rs.5.45 per rupee investment than other treatment combinations.

Patel *et al.*(2009) observed that the microbial and inorganic fertilizers in combination with micronutrients (0.4% foliar spray)influenced on growth, yield and leaf nutrient status of sweet orange cv. Mosambi, and resultant changes in rhizosphere soil microbial biomass. The treatment comprised of application of full dose of NPK, AMF (Nutrilink- mixed strains of IARI), *Azospirillum*, and micro-nutrients sprays in different combinations along with a control. Significant influence on plant height, trunk diameter, canopy spread, yield and quality of fruit were observed with different microbial and inorganic fertilizers applications. Application of ¾th N (300 g) + ¾th P (250 g) + ¾th K (300 g) + AMF (Nutrilink- mixed strains of IARI) (5 g) + *Azospirillum* (5 g) + along with spray of 0.4 per cent micronutrients (Cu+Fe+B+Zn) resulted in the maximum plant height, trunk growth, fruit yield , juice content and TSS: acid ratio.

Shukla *et al*. (2009) revealed that trees which received 50 per cent doses of recommended NPK + FYM(50kg) + 250 g *Azotobacter* significantly increased the fruit weight (153.30 g), canopy volume (201.42 m^3), Ascorbic acid (198.30 mg/100 g pulp),TSS (14%), total sugars (8.10%), reducing sugar (4.77%), leaf nitrogen (1.40%), phosphorus (0.46%), potassium (1.17%) contents and fruit yield (28.95 kg per plant). Nitrogen, phosphorus and potassium content of the leaf were positively correlated with fruit yield. Further, regression analysis revealed that fruit weight (r2 = 0.914) dominantly influenced the fruit yield and leaf nitrogen content also influenced (r2 = 0.499) fruit yield significantly. The combined application of 50 per cent dose of recommended NPK + 250 g *Azotobacter* + 50 kg FYM (T7) showed maximum fruit yield per plant (28.95kg) with higher B: C ratio (2.53:1).

Kumar *et al.*(2011, 2013) observed that the maximum number of fruit/tree, fruit weight (g), fruit diameter (cm), fruit yield (kg/plant), juice content (%), ascorbic acid (%), acidity (%) in Lemon cv. Pant lemon -1 was found under the treatment (T_7) 50% NPK (210 g N+140 g P+210 g K)+15 kg VC+5 kg NC.

Kumar *et al.*(2012) studied the effect of Integrated Nutrient Management on yield and quality of lemon cv. Pant lemon and stated that the maximum fruit yield (15.42 kg /plant), juice percentage (29.89), maximum acidity content (5.76%) and ascorbic acid (54.58 mg/100g pulp) with the treatment T7 50% NPK (210g N+140g P+210g K) +15 kg Vermicompost + 5 kg Neem cake in spring flush. Ashkevari *et al.* (2013) reported that application of ammonium sulfate (100, 150 and 200 g per plant), triple super phosphate (0, 25, 50, and 75 g per plant) and potassium sulfate (0, 50, 100, 150 g per plant) significantly affect the quantity and quality of citrus fruit and also indicated the significance of NPK fertilization for citrus production.

75% RDF + Vermicompost 9 kg/tree + AAU PGPR Consortium 3.5 ml/tree reported the minimum acidity (7.32 %) while 100 % RDF reported the maximum acidity.It was reported that acidity decreases with increase in the total soluble solids (Baviskar *et al.*,2011 in Sapota ; Patel *et al.*,2009 in Sweet orange ;Yadav *et al.*,2011in Mango;Yadav *et al.*,2013 in Aonla).

Lal and Dayal (2014) reported that 50% RDF+ 50% Goat manure in Acid lime gave the highest vegetative growth and yield (7.58 kg/tree) of fruits with maximum fruit length (4.43cm), fruit diameter (3.99cm) and fruit weight (35.71g) .Similarly best quality fruits were also produced with maximum TSS (10.42%), fruit juice (43.37%), ascorbic acid (86.33mg/100g juice) content, acidity (6.06%) minimum seed (1.15%) under the same treatment.

Khehra (2014) reported minimum fruit cracking and highest fruit quality with that tree which received FYM (75kg/tree), inorganic nitrogen (350g/tree) along with biofertilization (a*zotobacter* 18g/tree) in Lemon cv. Baramasi.

Khehra and Bal (2014) reported in Lemon that tree height was significantly improved with FYM (150 Kg/tree) + inorganic fertilizer (525g/tree) + *Azotobacter* (18g/tree) where 10.33 per cent and 9.31 per cent increase were recorded as compared to 5.90 per cent increase and 6.40 per cent increase under control during 2007 and 2008 respectively.

Srivastava *et al*. (2014) reported a much higher magnitude of response. The net increase in canopy volume with 100% recommended dose of fertilizers (RDF) was much higher compared with 75% RDF +25% Vm +MC, with significantly better fruit quality parameters. Soil quality parameters like soil microbial biomass (SMB) and soil microbial biomass nutrients (SMBN) were much higher with 75% RDF +25% Vm + MC as compared with exclusive use of IF as100% RDF.

Bhuyan *et al*. (2016) found that plants which received 60% of their required nutrients as per soil test basis from chemical fertilizer and 40% from Cow dung were found best with yield and qualitative parameters along with highest marginal rate of return in Mandarin Orange var. BARI Manderin-1.Use of sole organic matter was cost dominated while integrated use of organic and inorganic nutrients showed the best marginal rate of return. This results are in accordance with Nasreen *et al*. (2013).

Madarakhandi *et al*. (2015) also reported that INM increased yield of Kinnow mandarin.

Khehra *et al*. (2016)studied the influence of tree spacing and nutrition on vegetative performance and yield of 6 years old Kinnow mandarin raised on rough lemon rootstock. Maximum plant height was observed under spacing 6 x 4m (3.24m) and nutrient level 75% inorganic + 25% FYM (3.21m), however, maximum spread (E-W) was noted under (6 x 5m) and 50% inorganic + 50% green manure and spread (N-S)under (6 x 6m), and 100% inorganic only.Maximum number of fruits per plant (161.66) was counted in 100% inorganic only and 6 x 5m (155), whereas maximum average fruit weight was weighed in 50% inorganic + 50% green manure (150.80g) and 6 x 6m (145.19). maximum fruit yield(22.26kg/plant)was observed in 100% inorganic only and (6 x 5m) (22.40kg/plant). Fruit quality in terms of juice and TSS was not affected by any of the spacing and nutrient levels. However, maximum acidity was recorded in 100% inorganic only.

Nurbhanej *et al*. (2016) observed that with the application of 75% RDF + vermicompost 9 kg/tree + AAUPGPR Consortium 3.5 ml/tree, fruit volume (53.87 cc), fruit weight (53.20 g), fruit diameter (4.52 cm) and fruit yield per tree (46.92 kg), total soluble solids (8.85 °Brix.) and ascorbic acid content (29.63 mg/100g juice) were recorded maximum and with minimum acidity (7.32 %).

Tarai and Ghosh (2016) reported in Sweet Orange cv. Mosambi that maximum vegetative growth, total soluble solids, total sugar, TSS: Acid ratio and vitamin C content of fruits were recorded in plants which received N:P:K(200g:75g:150g) + neemcake 2kg/tree/year. Maximum fruit yield 9kg/tree was resulted with application of NPK (200g: 75g:150g) in combination with 2.0kg of neem cake as compared with control (3.0kg/plant).

Kumar *et al.* (2017) observed in Sweet Orange that the highest tree height, annual shoot growth, fruit yield, fruit weight, fruit set, fruit size, fruit volume and fruit quality like Total soluble solids, Reducing Sugar, Total Sugar and Non-Reducing sugar were observed with 60% nitrogen of recommended dose of fertilizer + 40% organic manure (FYM).

2.3.3.Soil fertility status

Azotobacter and *Azospirillium* inoculants on several non-legumes crops experienced 5-15% yield increased and N contribution about 25kg / ha and the used of Phosphobacter in found to increase the efficiency of ground rock phosphate and superphosphate applied in neutral to alkaline soils (Subha Rao *et al*., 1980).

Mukhopadhyay and Sen (1997) reported that the plant spread increased by inoculation of biofertilizers which increased cell metabolism as a result of increased enzyme activity, chlorophyll content and photosynthetic processes.

Singh *et al.* (2000) revealed that Azospirillium and VAM (Vesicular Arbuscular Mycorhizae) are gaining popularity as bio fertilizers for fixation of atmospheric nitrogen, better mobilization of fixed phosphorus and better availability of these compounds to the plants.

Naik and Babu (2007) reported that in terms of crop productivity and maintainance of soil health, application of vermicompost along with mineral fertilizers has given encouraging results.

Dheware and Waghmare (2009) studied an influence of inorganic fertilizers along with 10 g Azospirillum and 10 g PSB by mixing with FYM and stated that the application of biofertilizers increased the no. of fruits per tree and average weight of fruits. Significant influence was also observed on no. of fruits per tree and average weight of fruits.

Mitra *et al.* (2012) studied in high density guava that neem cake when applied along with *Azotobacter* increased yield, fruit size significantly and improve quality of fruit and also showed the maximum cost/benefit ratio. They concluded that soil applied with organic manures along with biofertilizers substantially increased soil microbial population which improved soil health and thereby the growth and productivity of the tree.

Marathe *et al*.(2012) observed eight-year-old sweet orange orchards applied with FYM, vermi-compost, wheat straw on nitrogen equivalent basis and green manuring with sun hemp as singly or in combination with inorganic or biofertilizers like *Azotobacter* and PSB including control plots effectively increased the microbial population in the soil.

Trivedi *et al*. (2012) reported that highest potassium uptake, maximum available P_2O_5 and K_2O were noted under biocompost treatment and maximum nitrogen uptake was resulted with incorporation of vermicompost and FYM resulted in the maximum phosphorus uptake and organic carbon content in the soil. However, addition of biofertilizers recorded higher fruit yield and available P_2O_5 content in the soil.

The application of 80kg FYM in combination with 750g nitrogen per plant led to significant increase in soil nitrogen at different depths (0-15cm, 15-30cm, 30-60cm) over initial level (Garhwal *et al.,* 2014).

Mir *et al*. (2014) reported that significant increased of soil pH, soil N, soil P, soil K, water holding capacity, porosity , particle density, bulk density , organic carbon, iron, manganese (Mn), zinc (Zn) and copper (Cu) were obtained with combined application of vermicompost @20 kg/tree, bio-fertilizers @ 80 g/tree, FYM@ 20 kg/tree, green manure (GM) sunnhemp (*Crotalaria juncea* L.) and recommended dose of NPK.

Singha *et al.* (2014) observed that NPK application had a major role in dehydrogenase activity.

The application of 25-30 t/ha organic manure (swine manure), 160-200 kg/ha N: 100-150 kg/ha P_2O_5 : 120-160 kg/ha K_2O were the most suitable fertilizer application which increased significantly the concentration of soil organic carbon (SOC) and major soil nutrients nitrogen, phosphorus and potassium (Zhao *et al.*, 2014).

2.4. Role of micronutrients

2.4.1. Zinc

Zinc is considered as an important nutrient for growth and development of fruit crops for good quality and high production. It directly play role in the formation of several enzymatic action which govern the metabolic reactions in the plant system. It uses to regulate the oxidation-reduction reaction in the plant which may induce the formation of chlorophyll for photosynthetic activity. It is essential for plants due to its involvement in the synthesis of tryptophan which is a precursor of IAA (indole acetic acid) (Ahmad *et al*., 2012). Zinc may also play a vital role for reproductive activity and it may regulate the absorption and translocation of water in the plant system. The deficiency of zinc caused little leaf and mottle leaves in citrus. It may also retard the vegetative growth and inhibiting the formation of seeds in different vegetable crops. It has been reported that zinc deficiency causes structural deformities in the root tips and affected the water and nutritional uptake and translocations. Zinc involves in various enzymes activity such as, dehydrogenase, aldolases, isomerases, transphosphorylases, RNA and DNA polymerases (Swietlik, 1999).Taiz and Zeiger (1994) reported that many enzymes require zinc ions for their activity, and zinc may be required for chlorophyll biosynthesis in some plants. Zinc is believed to be involved in chlorophyll synthesis through its influence on protein, carbohydrate and energy metabolism (Bergmann, 1992). Shivanandam *et al*. (2007) reported that zinc has been identified as a component of approximately 60 enzymes involved in the growth hormone promoter synthesis (auxin).

2.4.2. Iron

Iron is the major component indispensable for chlorophyll synthesis. In association with different enzymes viz. catalase, peroxidase, cytochrome oxidase are of great significance in cellular metabolism of plants. Although, iron is an immobile element but it helps in absorption of other nutrients. It actively takes part in oxidation-reduction reaction in the plants which helps in respiration and photosynthesis processes. These modes of action may actively associate in plant growth and reproductive activities. A remarkable role of iron is the synthesis of protein which may become a major component of chloroplast formation. In recent years iron deficiency is also becoming a limiting factor in plant growth development. Characteristic chlorosis is developed in the deficiency of iron where intravascular area of young leaves turn light gray to yellow. A large brown necrotic areas develop in the deficiency of iron which may affect the photosynthetic activity. Iron is involved in various physiological processes of plant systems, namely formation of chlorophyll and degradation synthesis of protein which contains chloroplasts and electron carriers in enzyme systems (Somasundaram *et al*., 2011). Ferrous plays a key role in several enzyme – systems, in which haeme or haemin is the prosthetic group (Khurshid *et al*., 2008).

2.4.3. Boron

Boron plays an important role to enhance plant growth and development in fruit crops. It is considered more necessary for fixation of nitrogen in different leguminous vegetable like beans and pea. It is mostly concerned with its uptake by root and its efficient use in plants. It helps to keep calcium soluble and increase the mobility in the plants. It regulate potassium and calcium ratio which may improve the growth of the plants. It has been also considered as essential component for cell division which is very necessary for the growth and development of plant. Boron plays role in cell division, cell elongation, sugar metabolism and accumulation of carbohydrates (Sourour, 2000 and Dutta, 2004). Boron is concerned with precipitating excess cations, buffer action, and maintenance of conducting tissues with regulatory effect on other elements. Boron deficiency symptoms are characterized by cessation of protein synthesis evidenced by the accumulation of carbohydrates nitrogenous and ammonium compounds. Death of the apical meristems of the root and the stem is also caused under the conditions of boron deficiency. The younger leaves tend to roll half circle from the tip to the base and they become thick. Boron influences in vivo and in vitro pollen germination (Pierson *et al*., 1994; Dabas and Jindal, 1981; Misra, 1972). Boron increases fruit set and yield by improving pollen viability and pollen tube growth by translocating into developing flowers. Boron is required more in reproductive growth in many crops than that needed for vegetative growth (Mengel and Kirkby, 1982; Marschner *et al*., 1986; Hanson, 1991).Boron plays an important role in pollination process (Lee and Kim, 1991).

2.4.4. Manganese

As all other micronutrients, manganese plays a role in seedling and leaf growth. Without good leaf productivity, growth slows and yield suffers. Deficiencies are worse on sandy soils and those with a high pH. Intermittent deficiencies are found in poorly consolidated seedbeds or where soils are particularly dry. Manganese is required for chlorophyll formation and oxide-reduction reactions in cells. It is also involved in the metabolism and synthesis of proteins. Manganese is required in the process of photosynthesis (Mengel and Kirkby, 1987). It primarily functions as part of the plant enzyme system, activating several metabolic functions (Somasundaram *et al.*,2011).It is involved in the oxygen – evolving step of photosynthesis and membrane function, as well as serving as an important activator of numerous enzyme in the cell (Wiedenhoeft, 2006).

2.4.5. Copper

It ensures photosynthetic growth and maintains leaf growth as well as good skin quality. Deficiencies are more common on organic or sandy soils and where excessive nitrogen rates have been applied (Shukla, 2016). It is involved in the stimulation of lignification of all plant cell walls, photosynthesis and electron carriers in enzyme systems of plant (Somasundaram *et al*., 2011).It plays an important role in the synthesis and or stability of chlorophyll and other plant pigments.

2.5. Role of micronutrients on Citrus:

Calvert (1970) reported that significant growth, yield and quality of citrus fruit were also found by other researchers with definite role of N, P, Mg, Zn, and B in India.

Singh and Singh (1981) reported in ‘Dancy tangerine’ (*Citrus reticulata* Blanco) that the combined spray of zinc sulphate (0.5%) + copper sulphate (0.5%) reduced the incidence of granulation to 45% from 78% in control. The disorder was reduced with low concentrations of boric acid (25 and 50 mg 1^{-1}) and calcium hydroxide (2%). Fruit quality like more pulp, juice, T.S.S., sugars and ascorbic acid content, reduced peel, rag, total acidity and starch were improved with all these treatments. The application of these nutrients is, therefore, considered to be a successful tool in reducing granulation in this cultivar of mandarin.

Srivastava *et al.* (1981) reported that from the long term (16 years) micro-nutrient trial with Mandarian Orange cv. Coorg, plants sprayed with Cu, Mn, and Zn gave significantly higher fruit yield than the untreated controlled plant.

Leon *et al.* (1983) also found that increased Mn and Znresulted high B concentration in lemon leaves.

Garcia *et al*. (1984) reported that as leaf Zn and Mn content increased,fruit let drop decreased.

Alla *et al.* (1985) reported that the yield of sweet orange trees was increased with application of copper, manganese and iron.

Mann *et al*. (1985) found that micronutrients (Zn,Cu,Fe and Mn) spray on the leaves of sweet oranges increased the concentration of the respective nutrient in the leaves.Other quality parameters such as % juice, reducing sugar and vitamin C were significantly affected by one or more micronutrients.

Chiu and Chang (1985) reported that in Citrus,curing B deficiency was more effective with foliar spray of boric acid than soil application.

Razeto *et al*.(1988) reported that single application of Mn increased Mn concentration in orange leaves greater when applied singly than in combination with Zn.

Rehman (1992) also reported increase in Vitamin C content of citrus fruit due to foliar application of these micronutrients. Juice percentage in sweet oranges was increased significantly by B alone, reducing sugar by Mn alone and vitamin C contents by Zn alone, Zn+ Mn or Zn+ B through foliar application, suggesting that each nutrient had different role on the quality of sweet oranges.

Mohamed *et al.* (1995) reported that combine or alone application of copper, manganese and iron sulfates in concentrations 0.5 to 1 % as foliar spray, enhanced performance and improved quality of orange juice.

Devi *et al.*(1997) found that the plants supplied with soil application of $ZnSO_4$ and $FeSO_4$ @ 50 g/tree each and combined foliar spray of the micronutrient at 0.5% concentration increased the juice content of Sweet Orange fruits. It is also found in Sweet lime that reduced leaf chlorosis and significantly increased yield with application of iron, zinc and manganese sulfates in soil and as a foliar spray of these materials.

Pestana *et al.* (1999) stated that the greatest diameter and fresh weight of fruits were obtained in the treatment with iron chelate (500 mg Fe $litre^{-1}$).

Fawzi and El- Fouly (2000) reported that soil tests and leaf analysis of citrus orchards in Egypt revealed that deficiency of Zn, Mn, Fe or Cu was significantly correlated with low yields.

Ghosh and Besra (2000) reported that application of micronutrient along with NPK observed highest number of fruits in Sweet Orange.

Perveen and Rehman (2000) also concluded that increased citrus fruit yield was observed with foliar spray of Zn, Mn and B and it was also noted that B alone spray could not give satisfactory yield unless it was combined with Zn and Mn.

Abo-El Komsan *et al*. (2003)reported the best result in yield and fruit quality of Balady Orange trees with four times spray of mixture containing NPK + Mg + S @ 5%+Zn, Fe, Mn @ 0.05% + citric acid @1000mg kg^{-1}. Similar observation was reported by Ingle *et al.*(2001) in acid lime.

Application of some nutrients through foliage can be from 10 to 20 times as efficient as soil application. However, this efficiency is not always achieved in actual practice due to weather extremes, application of the wrong spray mix, or of the right mix at wrong time (Perveen and Rehman, 2000; Yaseen *et al*., 2004; Alva *et al*., 2006; Zaman and Schumann, 2006). A properly formulated foliar spray particularly amended with appetizers/bioactive materials/bio-stimulants and surfactants increases uptake of nutrients from the soil (Yaseen *et al*., 2004) because foliar fertilization causes the plant to pump out more sugars and other exudates from its roots into the rhizosphere (Marschner, 2003).

Quaggio et *al.* (2003) reported maximum yield with application of 4 kg boron per ha, in soil.

Kulkarni (2004) recorded that foliar application of $ZnSO_4$ (0.5%) +$FeSO_4$ (0.4%) + Borax (0.2%) gave the highest sugar content in juice of Sweet Orange fruits.

Foliar fertilization increased yield, resistance to disease and insect pests, improved drought tolerance and enhanced fruit quality (Havlin *et al*., 2005; Omaima and El-Metwally, 2007; Tariq *et al*., 2007). It has been used for supplying supplemental doses of minor and major nutrients, plant hormones, stimulants and other beneficial substances.

The best response with reference to various parameters viz., flowering intensity, fruit set, tree volume, fruit yield, soil fertility changes, leaf nutrient composition and fruit quality were obtained with the foliar application of $FeSO_4$ @ 200 g / tree/ year. The treatment involving combined application of $FeSO_4$ (200 g /tree/ year) and FYM (10 kg /tree/ year) responded much better over treatment $FeSO_4$ @ 200 g / tree/ year showing the superiority of combined application of $FeSO_4$ and FYM over $FeSO_4$ alone (Srivastava and Singh, 2004).

Srivastava and Singh (2006b) reported that canopy growth, fruit yield, fruit quality and leaf nutrient concentration were observed to be best with plants which received 1200 N - 600 P_2O_5 - 600 K_2O - micronutrients (300 g each of $ZnSO_4$ and $MnSO_4$ alongwith 100 g borax /tree) on Typic Ustorthent soil type. Whereas, on Typic Haplustert soil type, 600 g N - 400 g P_2O_5 - 300 g K_2O + micronutrients (300 g each of $ZnSO_4$ and $MnSO_4$ alongwith 100 g borax/tree) and 400 g $MgSO_4$ / tree proved most effective.

Elham *et al*. (2006) observed that Valencia oranges grown on Troyer Citrange fertilized with1250gN +700g P_2O_5 +800g K_2O/tree accompanied with Zn, Fe and Mn spray in chelated form at 0.1% gave the best results with regard to fruit set, yield and fruit quality.

Abd-Allah (2006) reported increased N, P and K content in the leaves compared with the untreated trees with application of Potassium di-hydrogen phosphate at 1%, calcium chelate at 0.5% and boric acid 300 ppm at full bloom stage of Washington Navel Orange tree either as a single or in combination. Fruit set, yield as number of fruits and weight (kg) per tree were significantly improved by different nutrient treatments specially when sprayed at various combinations, also fruit quality was improved by spraying different nutrients. However, spraying calcium chelate in combination with boric acid or potassium di-hydrogen phosphate was found as promising treatments under the condition of this investigation.

Rahman and Haq (2006) reported on sweet orange (cultivar “Red Blood”) that fruit yield increased with foliar sprays of Zn at 0.4, Mn at 0.2 and B at 0.04kg/ha dissolved in 400 litres of water. With the foliar spray of the respective micronutrients, leaf concentrations of Zn and Mn were also increased but leaf B was not significantly influenced by B spray. Critical levels of Zn, Mn and B in leaves were found to be 22, 25 and 29 mg kg^{-1}, respectively in Sweet Orange trees. Therefore, it was suggested that trees required foliar application with the relevant micronutrient when its leaf concentration goes down the critical level.

Banuls *et al*. (2003)reported that Fe application @3 g $tree^{-1}$ increase concentration of readings like Cl, N, K, Mg, Fe, and Mn concentration in leaves on Clementine (*Citrus clementina* Ort. ex. Tan) grafted on Troyer citrange (*C. sinensis* × *Poncirus trifoliata*) rootstock . Iron treatment increased yield and some of the fruit quality parameters, like total juice, sugar, and acid contents.

Eman *et al*. (2007) revealed that most treatments especially those included zinc sprays improved leaf N, K and Zn contents on Washington Navel Orange.

Hafez and El-Metwally (2007) reported that application of Zn at 0.4% and K at 1% alone or in combination obtained significant difference on leaf mineral content (N, P, K and Zn), chemical and physical characteristics of fruit and yield (kg)/tree

Tariq *et al*. (2007) reported in Sweet Orange that 1.56 kg N ha^{-1} and 0.4 kg surfactance ha^{-1} in 400 L of water when sprayed along with 0.4 kg Zn ha^{-1} and 0.2 kg Mn ha^{-1} obtained the maximum fruit yield. B alone obtained the minimum percentage of peel% and juice in sweet oranges and minimum percentage rag with Zn + Mn, maximum fruit size with Zn + B and maximum fruit volume with Zn + Mn. Similarly, reducing sugar by Mn alone and vitamin C contents by Zn + B through foliar spray, hence, it was suggested that each micronutrient had different role on the quality of citrus fruit. Foliar spray of Zn, Mn and B along with urea significantly increased the concentration of Zn and Mn in citrus leaves, while the concentration of B was not affected with foliar spray, perhaps due to dilution within the citrus tissues. Therefore, it was suggested that Zn+Mn or Zn+B may be applied as foliar spray in combination with urea and surfactance for getting the maximum yield and improved quality of citrus fruit.

Mattos *et al*. (2010) evaluated the supply of N and Cu status of 'Pera' sweet orange. Better plant growth was attained at 240 mg per litre of N and 5 to 10 mg per litre of Cu, Similarly, bud take was optimum with intermediate Cu supply. Excess of Cu also reduced Mn uptake by plants. Greater Cu concentration was observed in root tissues from the upper part of nursery bags, compared to the lower part which, was in line with the Cu adsorption in the substrate, as indicated by a maximum concentration of 310 mg kg^{-1} of Cu.

Quaggio (2011) reported that Zinc (Zn), manganese (Mn) and boron (B) are important micronutrient for citrus production, which deficiency symptoms are frequent in the citrus groves.

Ashraf *et al*. (2012) reported that the application of Zn, K and SA (salicylic acid) or Zn+K+SA was effective in improving the yield and quality parameters of citrus fruit at all sites. Foliar sprays of 10μM SA + 0.25% each of Zn and K reduced the citrus fruit drop by 30% and also improved the juice quality. Kinnow fruit yield and juice quality can be effectively enhanced with proper nutrient and hormone applications depending on site conditions.

Kazi *et al*. (2012) reported in Sweet Orange that NPK bulk recommended dose + multi micronutrient through soil showed significantly superior values of number of fruits per tree (554 & 553), weight of fruit per tree (132.90 and 143.80kg and productivity per hector (36.18 and 39.83 t/ha), maximum reducing and non reducing sugar, minimum acidity. Higher level of sugar due to micronutrient application including boron might be possible. Ascorbic acid was noted to the tune of 46.10 to 58.01 mg/100 ml juice, cause behind increase in ascorbic acid content which is synthesized from sugar (Mengel and Kirkby, 1987).

Sarrwy *et al.* (2012) reported that the best results with regards to foliar application were obtained by mono potassium phosphate (MKP) at 1.5% concentration with 0.5% chelated Zn with improved leaves nutritional status whereas, both KNO_3 and potassium thiosulfate (KTS) at 1.5% concentrations with 0.5% chelated zinc in Mandarin cv. Balady, enhanced yield and fruit physical and chemical characteristics were obtained.

Ullah *et al*. (2012) reported that significant difference was observed in Kinnow Mandarin leaf nitrogen (N), phosphorus (P), potassium (K),boron (B), and zinc (Zn) along with flush length, spread tree height, tree and tree trunk sprayed with different diameter when concentrations of boric acid viz. (0.1%, 0.2%, 0.3% and 0.4%) at fruit set stage. Results also revealed that leaf length and leaf age showed non-significant results after foliar B application. Yield of the ‘Kinnow’ Mandarin was significantly affected by foliar application of B and a significant increase in fruit weight at harvest was also observed. Soluble solid concentration (SSC): titratable acidity (TA) ratio, ascorbic acid, total sugars, total phenolic content (TPC) and total antioxidants significantly affected, while pH of juice, SSC, TA, reducing sugars and non-reducing sugars showed non- significant results.

Aboutalebi (2013) recommended application of 250 g of ammonium sulfate for every tree in soil and spraying 10 mgL^{-1} iron sulfate during June to improve the quantity and quality characteristics as well as increased yield of sweet lime in calcareous soil. The above results are according to the findings of Tucker *et al.* (1995);Sing(1984);Hassan (1995); Devi *et al.* (1997) and Rajput *et al.*(1991) but in relation to effect of nitrogen did not conform to the finding of Dasbery *et al.* (1988).

Ashraf *et al*. (2013)reported that Citrus, especially Kinnow (*Citrus deliciosa* x *Citrus nobilis*) with application of Zinc ($ZnSO_4$@1%), K (K_2SO_4 @ 1%) and Zn+K (solution containing 0.5% each of $ZnSO_4$ and K_2SO_4) sprayed at the onset of spring and flush of leaves or flowers, fruit formation and at color initiation on fruit improved the nutrient uptake, yield and quality parameters of citrus fruit at all sites. Fruit dropping was also reduced by the foliar spray of Zn, K or Zn+K but the most promising results were recorded with foliar spray containing both Zn and K.

Chaudhari *et al*. (2016) reported in Sweet Orange that application of balanced dose of NPK along with multi micronutrient increased number of fruits per tree, weight of fruit, juice content, TSS, fruit girth, ascorbic acid content, reducing and non-reducing sugar, whereas acidity is low in balance nutrient application in field.

Khera et *al.* (1985) applied micronutrients to plants through soil as well as foliar route for correcting micronutrient deficiencies in citrus cv. 'Blood Red' applied zinc (as zinc sulphate) at the rate of 0.4 per cent as foliar spray, 3times in 12 months and at 500 g per tree of $ZnSO_4$ as soil application in arch: He obtained highest yield of good quality fruits from trees receiving zinc as soil application.

Karim *et al*. (2017) reported deficiency of boron (B) in citrus has serious consequences for tree health and crop production. Foliar application appeared to increase leaf boron concentration (r= 0.50, p= 0.004). Fruit set was increased by 35% over control in Hamlin trees receiving bloom and post bloom applications of boron at the1000 ppm level. Previous studies indicate that boron influenced in vivo and in vitro pollen germination in many crops. A possible explanation for increased fruit yield may be that the applied boron was transported to the flowers where it exerted its influence of increased fruit set through an effect on pollen viability and/or pollen tube growth. However, clearly boron supplementation must be performed judiciously to avoid fruit drop from over -application of the element.

Manchanda et *al.* (1972) found on 'Blood Red' variety of Sweet Orange on 'Jatti Khatti' rootstock that the movement and accumulation of the soil applied zinc with lime at the lower soil depth was related to the amount of zinc applied. Soil application of zinc at the rate of 10 and 15 ppm per basin appeared to be effective only after 1 to 1 ½ years. However, in all the foliar spray treatments; there was poor translocation of zinc into the new flush of leaves indicating the need of repeated zinc sprays every year.

ABSTRACT

NUTRIENT MANAGEMENT IN KHASI MANDARIN (*Citrus reticulata* Blanco) UNDER SUBTROPICAL AGRO- CLIMATIC CONDITION IN MIZORAM

JENNY ZOREMTLUANGI

DEPARTMENT

OF

HORTICULTURE, AROMATIC AND MEDICINAL PLANTS

MIZORAM UNIVERSITY

Abstract

Apart from the disease or pests problems, the major short coming in NEH citrus industry is improper management of soil fertility and plant nutrition (Srivastava, 2012). Proper management of nutrition and soil fertility is considered as pivotal in successful and remunerative cultivation of citrus fruit which unless otherwise develop an unhealthy orchard that becomes susceptible to diseases and pests infestations. Therefore, systematic management of nutrition in Khasi Mandarin is of immense importance for its successful cultivation with high productivity. Continuous fertilization has failed to sustain the yield expectancy on a long term basis and consequently, multiple nutrient deficiencies have emerged due to depletion of soil carbon (Srivastava and Singh, 2009). Citrus is a highly nutrient responsive crop, the productivity of plants depends largely on fruit nutrition. Judicious application of fertilizers is based on leaf and soil analysis and has been used as an analytical tool in knowing the nutritional requirements (Montanes *et al*., 1993). In order to meet the nutrition requirement of fruit trees, soil and foliar application plays an important role but their mobility in plants and soil differ their efficacy significantly. However, soil application of inorganic fertilizer has failed to sustain the high yield expectancy on a long term basis due to depletion of soil carbon stock and consequently emerged multiple nutrient deficiencies (Khehra, 2014). Moreover, high rainfall hilly areas are prone to nutrient loss through leaching and erosion. Therefore proper management of plant nutrition involving inorganic coupled

with organic nutrition inputs and use of bio fertilizer has strong basis for remunerative Khasi mandarin production.

The present investigation entitled “Nutrient Management in Khasi Mandarin (*Citrus reticulata* Blanco) under Subtropical Agro- Climatic Condition in Mizoram” was carried out during 2016 and 2017 at Thiak village, Aizawl District, Mizoram to study the effect of Integrated Nutrient Management (INM) on growth, yield, quality and production economics of Khasi mandarin and to evaluate the effect of foliar application of micronutrients on growth, yield, quality and production economics of Khasi mandarin.

Two sets of experiments were conducted as given below:

1. **Experiment 1: Integrated Nutrient management of Khasi Mandarin**

The experiment was conducted during 2016 and 2017 at Thiak village of Aizawl District, Mizoram. The experiment was laid out in Randomised block design (RBD) with thirteen treatments *viz*.,T_1: Recommended dose of fertilizer (RDF) as 100% inorganic,T_2: Farm Yard Manure (FYM) to supply 50% K+ 50% RDF,T_3: Vermi compost (VC) to supply 50% K+ 50% RDF,T_4: Neem Cake (NC) to supply 50% K+ 50% RDF,T_5: Farm Yard Manure (FYM) to supply 50% K+ 50% RDF+ Azotobacter (AZ) + Phosphate Solubilizing Bacteria (PSB) + Potash Solubilizing Bacteria (KSB),T_6: VC to supply 50% K + 50% RDF+AZ+PSB+ KSB,T_7: NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB,T_8: FYM to supply 25% K + VC to supply 25% K+ 50% RDF+AZ+PSB+ KSB,T_9: FYM to supply 25% K + NC to supply 25% K+ 50%

RDF+AZ+PSB+ KSB,T_{10}: VC to supply 25% K + NC to supply 25% K+ 50% RDF+AZ+PSB+ KSB,T_{11}: FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF,T_{12}: FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB,T_{13}: Control (no fertilizer).The pooled data of two years experiment revealed that the integrated nutrient management obtained significant impact compared with control on growth, yield, quality and production economics of Khasi Mandarin.

Application of integrated nutrients improved plant growth and development. The highest plant height (5.59m) and stem girth (53.41cm) were observed with T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) while maximum canopy spread N-S(2.94m) and E-W(3.11m) were observed with T_{11}: FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF. However, looking to per cent promotion of growth over initial in terms of plant height, stem girth and plant canopy spread E-W, T_{12}: FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB recorded highest values (10.45%),(13.86%) and (25.73%), respectively, while T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) recorded maximum value of per cent promotion of growth over initial of plant canopy spread N-S(22.33%).

Maximum days from fruit set to maturity (307.24days), highest fruit set percentage (64.26%), maximum yield (35.98kg per tree and 39.97 tonnes per hectare), lowest fruit drop per cent at 60DAFS (16.39%),120DAFS (18.21 %),240 DAFS (2.17%)

and total fruit drop (42.00%) and maximum retention percentage at 60DAFS (83.61%), 120DAFS (65.40 %), 180 DAFS (63.55%), 240 DAFS (60.99 %), pre harvest and total retention percentage (58.00%) were obtained with T_{12}: FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB. However, maximum number of fruits per plant was observed with T_3:Vermi compost (VC) to supply 50% K+ 50% RDF (232.27).

Results indicated that maximum fruit diameter (7.30cm), fruit volume (170.83cc), fruit weight (158.25g), juice content(65.63ml), seed weight (1.02g),TSS content of fruit(11.23°Brix), TSS/Acid ratio (17.09), reducing sugar (6.91%) and lowest acidity (0.66 %) were recorded with T_{12}: FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB. Whereas, maximum fruit length (5.95cm),lowest number of seeds(10.60) and highest value of ascorbic acid (51.55mg/100g of pulp) were observed with T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB). Highest specific gravity (1.08) of fruit was observed with T_1: Recommended dose of fertilizer (RDF) as 100% inorganic, while T_{11}: FYM to supply 25% K + VC to supply 25% K+ NC to supply 25% K + 25% RDF recorded minimum peel weight (22.28g) and T_4: Neem Cake (NC) to supply 50% K+ 50% RDF recorded minimum peel thickness (0.21 cm) and maximum total sugar content (8.75 %).

Integrated nutrient management significantly improved soil and leaf nutrients. Maximum soil total Nitrogen (1180.49kg/ha), available Phosphorus (69.53 kg/ha), maximum soil *Azotobacter* count (64.56×10^{6} cfu / g of soil), leaf Nitrogen

(2.63%),leaf Phosphorus (0.16 %), leaf Potassium (1.64%), leaf Manganese content(81.27ppm), leaf carbohydrate content (8.24%) were recorded with application of T_{12}: FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB.

However, plants which received (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB)T_7 recorded maximum value of soil available Potassium (600.03kg/ha),soil micronutrients like Mn (24.36mg/kg),Cu (1.92mg/kg),Zn (4.78 mg/kg), soil microbial count like PSB (72.12 X 10^6 cfu / g of soil) and KSB(106.82 X 10^6 cfu / g of soil), leaf Phosphorus content (0.16%), leaf Fe content (227.55ppm) and leaf Zn content (29.22ppm).

T_4: Neem Cake (NC) to supply 50% K+ 50% RDF recorded highest value of soil Fe content (116.34mg/kg),leaf copper content(20.53ppm) and leaf C:N ratio (3.36).

The highest gross income (Rs 31,97,600.00) and net income (Rs 23,70,402.09) were obtained with T_{12}: FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB. However, T_7 (NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB) recorded highest B:C ratio (3.95).

Hence, from the investigation given above, we may conclude that NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB (T_7) and FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB (T_{12}) were found to be the two best performing treatments among all in terms of plant growth characters, soil health improvement and leaf nutrient status, high net income and high Benefit : Cost ratio.

Among all the treatments, FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB (T_{12}) was the best treatment in respect of yield and quality parameters of Khasi Mandarin.

In respect of C: N ratio, application of Neem Cake (NC) to supply 50% K+ 50% RDF (T_4) recorded as the best treatment. However, the two best performing treatments *viz*, FYM to supply 25% K+ VC to supply 25% K+ NC to supply 25% K + 25% RDF +AZ+PSB+ KSB (T_{12}) and NC to supply 50% K+ 50 % RDF+AZ+PSB+ KSB (T_7) also recorded reasonably high C: N ratio.

2.Experiment 2: Foliar application of micro nutrients on growth, development and fruit quality of Khasi Mandarin

The experiment was conducted during 2016 and 2017 at Thiak village of Aizawl District, Mizoram. The experiment was laid out in Randomised block design (RBD) with sixteen treatments *viz*., T_1: Foliar application of Zinc (Zn),T_2: Foliar application of Manganese (Mn),T_3: Foliar application of Copper (Cu),T_4: Foliar application of Boron (B),T_5: Foliar application of Zn + Mn,T_6: Foliar application of Zn + Cu,T_7: Foliar application of Zn + B,T_8: Foliar application of Mn + Cu,T_9: Foliar application of Mn + B,T_{10}: Foliar application of Cu +B,T_{11}: Foliar application of Zn + Mn + Cu,T_{12}: Foliar application of Zn + Mn + B,T_{13}: Foliar application of Zn + Cu + B,T_{14}: Foliar application of Mn + Cu + B,T_{15}: Foliar application of Zn + Mn + Cu + B,T_{16}: Control (no micro nutrients).The pooled data of both the years revealed that significant variation was observed due to effect of foliar application of micro nutrients on Khasi Mandarin.

Maximum plant height (5.56m), stem girth (52.44cm), plant canopy spread N-S(2.92m), plant canopy spread E-W(3.08m) and per cent promotion of growth over initial in terms of plant height (9.14%), stem girth (13.77%), plant canopy spread E-W(21.54%) were resulted with plants which received foliar application of Zn + Cu + B(T_{13}), whereas,

T_{12}: Foliar application of Zn + Mn + B recorded maximum per cent promotion of growth over initial on plant canopy spread N-S (21.04%).

Significant difference were also observed in fruit growth and development. Highest fruit set per cent (59.90%), Number of fruits per plant (143.02), yield (19.03kg per tree and 21.14tonnes per ha), minimum fruit drop per cent at 60DAFS (15.85%), 180DAFS (1.47%), pre harvest drop (0.94%), total fruit drop per cent (40.16%), with maximum fruit retention percentage at 60 DAFS (84.15%), 120DAFS (65.46%) 180 DAFS (63.99%), 240 DAFS (60.36%), pre harvest and total retention (59.84%) were observed with plants which received foliar application of Zn + Cu + B (T_{13}). However, T_{12}: Foliar application of Zn + Mn + B recorded maximum days from fruit set to maturity (308.14 days) and minimum fruit drop per cent at 120DAFS (18.45%).

Fruit physico-chemical properties were also markedly influenced with application of micronutrients spray. Maximum fruit length (6.01cm), fruit diameter (6.98cm), fruit weight (147.81g),TSS content (10.83),TSS/Acid ratio (23.46) and minimum seed weight (1.11g) were recorded with application of foliar application of Zn + Mn + Cu + B (T_{15}). However, T_{13}: Foliar application of Zn + Cu + B observed maximum in fruit volume (148.75cc), juice content (64.48ml), total sugar (9.18%), reducing sugar (7.11%) and minimum peel weight (26.46g), peel thickness (0.21cm), number of seeds(11.58nos.) and acidity (0.45) whereas T_{12}: Foliar application of Zn + Mn + B recorded maximum ascorbic acid content (51.82mg/100g of pulp).

Regarding soil and leaf analysis, significant variation were also observed as compared with control. Maximum content were observed with plants which received foliar application of Zn + Cu + B (T_{13}) in respect of soil nitrogen(725.69kg/ha),soil potassium (421.35kg/ha), soil micronutrients like Zinc(2.98mg/kg), Boron (1.67 mg/kg) and leaf potassium(1.53 %), leaf carbohydrate (6.42%) and leaf C:N ratio (2.97). Whereas, T_{15}: Foliar application of Zn + Mn + Cu + B recorded high soil phosphorus (72.43 kg/ha), soil iron (95.63mg/kg) and leaf nitrogen (2.19%).However, soil copper (1.62mg/kg) and leaf phosphorus (0.198%) were recorded with maximum T_{12}: Foliar application of Zn + Mn + B. T_4: Foliar application of Boron (B) obtained maximum soil manganese (16.45mg/kg) and leaf boron (57.21ppm). T_1: Foliar application of Zinc (Zn) recorded highest leaf zinc (41.46ppm), T_2: Foliar application of Manganese (Mn) recorded highest leaf manganese (92.34ppm), T_3: Foliar application of Copper (Cu) obtained maximum leaf copper (26.81ppm) and T_{10}: Foliar application of Cu + B obtained maximum leaf iron (209.76ppm).

The highest gross income (Rs 16,91,200.00), net income (Rs 13,40,685.82) and BC ratio (3.82) were observed with plants which received T_{13}: Foliar application of Zn + Cu + B.

Hence, from the present investigation, it may be conclude that among all treatments, application of Zn + Cu + B (T_{13}) was the best treatment in respect of vegetative growth parameters, yield, C: N ratio, income and benefit : Cost ratio.

In terms of fruit quality parameters, treatment with application of Zn + Cu + B (T_{13}) and application of Zn + Mn + Cu + B (T_{15}) were found to be the two best performing treatments among all the other treatments.

Regarding the leaf nutrient status particularly leaf macro nutrients content differed significantly among different treatments as leaf Total N was found highest with application of Zn + Mn + Cu + B (T_{15}), leaf P content with application of Zn + Mn + B (T_{12}), leaf K content with application of Zn + Cu + B (T_{13}),. Though leaf Zn content with application of Zinc (Zn)(T_1), leaf B with application of Boron (B) (T_4) , leaf Cu with application of Copper (Cu) (T_3), leaf Mn content with application of Manganese (Mn) (T_2) and leaf Fe with Foliar application of Cu +B (T_{10}) scored highest but combination application also caused high content of these micro elements in T_{13} & T_{15} against control.