DEVELOPMENT OF MULTI NUTRIENT FERTILIZER TABLET AND ITS EVALUATION IN TOMATO

by

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"DEVELOPMENT OF MULTI NUTRIENT FERTILIZER TABLET AND ITS EVALUATION IN TOMATO"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associate ship, fellowship or other similar title, of any other University or Society.

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LIST OF ABBREVIATIONS AND SYMBOLS USED

%	Per cent
$\mu g\ g^{-1}$	Microgram per gram
B	Boron
Ca	Calcium
CD	Critical difference
cm	Centimetre
CRD	Completely randomized design
DAT	Days after transplanting
$dS\ m^{-1}$	deciSiemens per metre
Fig	Figure
FYM	Farmyard manure
g	Gram
g $plant^{-1}$	Gram per plant
g pot^{-1}	Gram per pot
ha	Hectare
K	Potassium
Kg ha^{-1}	Kilogram per hectare
MAP	Months after planting
Mg	Magnesium
mg $100g^{-1}$	Milligram per 100 gram
mg kg^{-1}	Milligram per kilogram
N	Nitrogen
P	Phosphorous
RDF	Recommended dose of fertilizers
S	Sulphur
SE	Standard error
TSS	Total soluble solids
Zn	Zinc

INTRODUCTION

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1. INTRODUCTION

Tomato (*Lycopersicon esculentum*) belonging to the genus Lycopersicon under Solanaceae family is a native of Peruvian and Mexican region. Tomato is grown worldwide with China, India and the United States ranking as the top three tomato producing nations in the world.

In India, it is mainly grown in Madhya Pradesh, Andhra Pradesh, Karnataka, Orissa, Gujarat and West Bengal. It is grown extensively in an area of 0.79 million ha with a total production of 19.76 million metric tons. Kerala shares 0.31 percentage of total production.

Tomato is one among the popular vegetables consumed by most people. It is widely used in Indian culinary tradition and is rich in nutrients. Soup, salad, pickles, ketchup, puree, sauces are prepared using tomato. It is also a salad vegetable rich in minerals, vitamins, organic acid, essential amino acids and dietary fibers. It is a rich source of vitamin A and C, also a source of minerals like iron, phosphorus and thus called as protective food. Tomato contains lycopene and beta-carotene pigments.

Nutrients are essential for growth, metabolism and yield of plants. Plants are unique and has an ideal nutrient range as well as least requirement level. Plants start to show nutrient deficiency symptoms below these minimum level. Yield, nutrient content, taste, and post-harvest storage quality of tomato are influenced by the amount and type of nutrients supplied. N, P, K, Ca, Mg and S are some of the nutrients needed in large amounts by tomato plant for normal growth and reproduction. Tomato is highly responsive to nutrients especially secondary and micronutrients and shows specific symptoms in nutrient deficient soils.

Nitrogen (N) occupies a prominent place in plant metabolism. Proteins that are associated with all vital processes constitutes nitrogen. Nitrogen is required in large amount for the growth and optimum yield of crops. Optimum rate of N increases photosynthetic processes, leaf area production, leaf area duration as well as net assimilation rate. Nitrogen deficiency causes yellowing and premature death of older leaves.

Phosphorus aids to initiate root growth of plants which helps in early establishment of the plant immediately after transplanting or seeding. Lack of phosphorus results in stunted growth of plants. Vigorous growth of tomato, early flowering and fruit set are stimulated by potassium which in turn increases the number of fruits per plant. Potassium deficiency in tomato results in brown marginal scorching with interveinal chlorosis.

Calcium plays an essential role in many of biochemical functions in plant, in addition it activates various enzymatic systems contributing to the proper development of plants. It is also a component of plant cell wall and affects the permeability of cell membranes. But calcium deficiency can cause a well-known disorder, called "blossom-end rot" in tomato fruits.

Boron plays a significant role in reproductive growth of plants. It influences the production of flowers and fruits in tomato. Boron deficiency causes leaf chlorosis and distortion. Iron is an integral component of many enzymes involved in nutritional metabolism of plants. Proteins and amino acids contain sulfur. Magnesium is a constituent of chlorophyll, pectin, and organic acids. Application of Mg fertilizer can improve fruit production in tomato. Lack of iron, sulfur and magnesium causes interveinal chlorosis in tomato.

Kerala depends upon its neighboring states for bulk of its vegetable requirements which are heavily treated with pesticides which cause serious health hazards. Recently there has been an emphasis on the intensification of vegetable cultivation by the general public through kitchen gardens, terrace gardens and homestead cultivation. Grow bag or container cultivation is popular among these groups. As the plant roots have a very limited medium for nutrient exploitation in grow bag or container cultivation precise application of nutrients is important to avoid deficiency or toxicity of nutrients. So it is important to produce fertilizers in such a form that can be applied to the soil in as exact amounts as possible. As the nutrients are applied in precise quantities, wastage and environmental pollution can be prevented.

Slow release fertilizers have been in common use for decades. They are effective compared to conventional fertilizers due to their gradual pattern of nutrient release which better meets plant needs, minimizes leaching and therefore increases fertilizer use efficiency. It possess high maximum percentage recovery in order to attain a higher return to the production input and it has minimum adverse effects on soil, water and air. The nutrient use efficiency of commonly used fertilizer materials is low and it is the urgent need to evolve technologies to increase the fertilizer use efficiency.

Development of multi nutrient fertilizer tablets which release nutrients slowly over a longer period of time is a step in this direction. Hence the present study on "Development of multi nutrient fertilizer tablet and its evaluation in tomato" gains relevance in this context with the following objective.

- To develop multi nutrient fertilizer tablet containing major, secondary and micronutrients and to evaluate its effect on nutrient use efficiency, yield and quality of tomato.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Controlled-release fertilizer are those fertilizers in which the factors dominating the rate, pattern and duration of release are well known and controllable during their preparation. Slow release fertilizers involve the release of the nutrient at a slower rate than is usual but the rate, pattern and duration of release are not well controlled. Multi nutrient fertilizer tablets are one among these category. Slow, controlled-release and stabilized fertilizers can contribute to improved nutrient efficiency, minimizing negative environmental effects. This chapter attempts to review the available literature on effects of multinutrient fertilizer tablets and slow release fertilizers in soil properties, nutrient availability, growth, yield, content, uptake and nutrient use efficiency.

2.1 DEVELOPMENT AND CHARACTERIZATION OF MULTINUTRIENT FERTILIZER TABLETS

Austin and Strand (1962) developed a unitary fertilizer product containing urea formaldehyde and phosphorus containing controlled release fertilizer compound for forest fertilization and found that about 42 % increase in the growth of pine seedlings.

Barron (1968) prepared fertilizer tablet containing urea formaldehyde, calcium phosphate and fritted potash as fertilizer componuds, expanded vermiculite as disintegrant and sodium lignine sulfonate as binder which are soluble when water is added to it.

Slow release fertilizer spike containing urea formaldehyde, potassium oxide, trace fertilizer compounds containing boron, iron, manganese, molybdenum, nickel, vanadium and zinc, ground coke and binder cement was developed for ornamental trees and shrubs (Messman, 1972).

Grano (1977) prepared fertilizer rods for house plants as well as green house plants comprising water soluble polyvinyl alcohol and fertilizer materials containing nitrogen, phosphorus, potassium and calcium.

Gallant (1992) prepared slow release granular fertilizer composition by spraying urea formaldehyde resin on fertilizer materials namely muriate of potash and mono ammonium phosphate.

Controlled release urea fertilizers were developed by coating granular urea with kraft pine lignin and they differ in coating thickness and linseed oil was used as a sealing agent (Garcia *et al.*, 1996)

Kerrigen (2002) developed fertilizer tablets containing ammonium sulfate, potash, triple super phosphate as fertilizer source, microcrystalline cellulose as disintegrant, polyvinyl pyrillidone as binder, hydrogenated vegetable oil and graphite powder as lubricant, calcium silicate as flow aid and lathanol lal powder as surfactant and used in fertigation.

Jarosiewicz and Tomaszewska (2003) evaluated the polymer coated fertilizer granules on the release rate of macroelements. Fertilizer coatings prepared from polymers of different degradability namely cellulose acetate > polyacrylonitrile ≥ polysulfone were compared. It was observed that the release rate of components from the fertilizer coated with biodegradable coating of cellulose acetate was the highest. In the case of coatings prepared from polyacrylonitrile and polysulfone, the release rate of nutrients was much lower. These coatings are not biodegradable, but their presence in soil can improve the soil structure and quality.

Bansiwal *et al.* (2006) studied the feasibility of surfactant-modified zeolite as a carrier and to investigate the slow release nature of phosphorus and reported that it is a good sorbent for phosphate and has a great potential as the fertilizer carrier for slow release of P.

Flores *et al.* (2006) suggested that slow release boron micronutrients can be developed through pelletization with suitable raw materials, hardening temperature and size of pellets.

Jintakanon *et al.* (2008) prepared controlled-release materials of urea by spray coating of urea granulates with lactic acid based homo- and co-polymers solutions and studied the feasibility of utilizing lactic acid-based polymers in the preparation of controlled-release materials and found that poly (lactic acid-co-ethylene terephthalate) showed comparable urea-retaining efficiency compared to commercially available forms.

Khan *et al.* (2008) prepared charcoal coated fertilizer containing 20:9:20 NPK with other seven micro-nutrients like magnesium, iron, boron, manganese, zinc, copper, and molybdenum and leaching study revealed that the release of N, P, and K from impregnated charcoal were found to be slow and steady and thus it can be used for developing slow-release type fertilizer.

Gonzalez *et al.* (2011) developed a controlled release fertilizer named FERLENT containing urea formaldehyde produced from a polymer material which ensured the nutrient availability for longer period of time compared to conventional fertilizers.

Xie *et al.* (2011) prepared a slow release fertilizer containing nitrogen and boron using urea and borax as sources. The product possessed a core/shell structure where core was urea in attapulgite and alginate matrix, and the shell was chemically modified wheat straw-g-poly (acrylic acid)/attapulgite super absorbent composite containing urea and borax which was slow-release in nature and also showed water-retention capacity.

Subramanian and Rahale (2012) developed slow release zinc fertilizer from ball milled zeolite loaded zinc sulphate.

A series of novel coated urea, which do no harm to soil, were prepared by the method of melt atomizing coating and studied the influence of coating content on nutrient release properties. The coating composed of paraffin wax, rosin and the $CaHPO_4$ powder as additive. The surface and cross-section morphology of the coated urea were studied by scanning electronic microscopy and found that the nutrient release rate decreases significantly as the coating increases (Hao *et al.*, 2013).

Abat *et al.* (2014) conducted an experiment to develop slow release boron fertilizers using boron phosphate as raw material.

Compressed fertilizer tablets containing N, P and K using calcium phosphate, potassium sulphate, urea formaldehyde and magnesite were prepared (Fernandez-Sanjurjo *et al.*, 2014)

Controlled-release fertilizers were prepared using two different copolyesters, aliphatic poly (butylene succinate-co-dilinoleate) and aliphatic-aromatic poly (ethylene succinate-co-terephthalate) (Lubkowski *et al.*, 2015). The properties of the resulting polymer-coated materials were examined via scanning electron microscopy and strength testing machinery. Both polymer-coated materials were proven to be more resistant toward crushing strength than the initial fertilizer.

A novel double coated slow release fertilizer was developed using ethyl cellulose as inner coating and starch-based superabsorbent polymer as outer coating (Qiao *et al.*, 2016).

Wang *et al.* (2016) formulated a new double-coated controlled-release fertilizer by using food-grade microcrystalline wax and marine polysaccharide derivatives (calcium alginate and chitosan-glutaraldehyde copolymer). The controlled-release properties of the fertilizer were improved dramatically after coating with microcrystalline wax and the marine polysaccharide derivatives.

Mubarak (2017) developed nutrient stick which is a complete fertilizer composite containing factamphos, potassium sulphate, gypsum, magnesium sulphate, zinc sulphate, borax, copper sulphate, and manganese sulphate to supplement ten essential nutrients such as nitrogen, phosphorous, potassium, calcium, magnesium, sulphur, zinc, boron, iron cupper and manganese at needed concentration and was evaluated in oriental pickling melon.

Hermida and Agustian (2018) developed slow release urea fertilizer by incorporating urea into local natural bentonite with binders i.e. corn starch and hydroxypropyl methylcellulose.

Rop *et al.* (2018) formulated a slow release NPK fertilizer by incorporating nano-hydroxyapatite and water soluble fertilizers (urea, $(NH_4)2HPO_4$ and K_2SO_4) into water hyacinth cellulose-graft-poly (acrylamide) polymer hydrogel.

Liu *et al.* (2019) developed elastic polyurethane coated urea fertilizer using low-cost, biodegradable, and renewable waste palm oil.

2.2 EFFECT ON SOIL PROPERTIES

Engelsjord *et al.* (1997) conducted an experiment to study the effect of temperature on the release of N, P and K from slow release fertilizers viz., urea formaldehyde, sulphur coated urea and coated calcium nitrate by increasing the temperature and found that the rate of release was significantly different at different temperatures.

Guo *et al.* (2006) reported that granular urea-formaldehyde slow-release fertilizer with super absorbent and moisture preservation decreased the water transpiration rate of soil. The reason was that, the superabsorbent polymer in the product could absorb and store a large amount of the water in soil, and let the water absorbed in it to be slowly released out with the decrease of the soil moisture.

Golden *et al.* (2011) reported that N release from polymer coated urea was increased by the increase in soil temperature and complete release was achieved at temperature > 20°C.

A novel slow-release fertilizer containing urea and potassium dihydrogen phosphate were developed based on natural attapulgite clay as a matrix, guar gum as an inner coating and guar gum-g-poly (itaconic acid-co-acrylamide)/ humic acid superabsorbent polymer as an outer coating. A study with this product indicated regulated soil acidity and alkalinity level (Ni *et al.*, 2012). This is because the superabsorbent polymers contain large amounts of −COOH and −COO− groups, which can react with OH^- and H^+ of the soil solution under basic and acidic conditions, respectively and the super absorbents can buffer soil acidity or alkalinity so as to develop a more optimal pH for plant growth.

vanGeel *et al.* (2015) reported that slow release fertilizers showed significantly higher growth of arbuscular mycorrhizal fungi compared to inorganic fertilizers.

Zhou *et al.* (2015) conducted an incubation experiment using biochar-modified polyacrylate-like polymers as coating for controlled release and found that the activity and functional diversity of soil culturable microbial community during the early stage of incubation were reduced by biochar modified membranes due to the release of small amount of soluble organic materials but were both recovered in the 12th month of the incubation period.

2.3 EFFECT ON NUTRIENT AVAILABILITY IN SOIL

A study was conducted by Holcomb (1981) to determine the release of potassium from different slow release NPK fertilizers *viz.,* Osmocote (14-6.3-11.6), MagAmp (7-18-5), Choice (10-4.3-8.3), Scotts (21-3-5.8) and Unimix (10-8.7-4.2) and observed that during the 63th day of experiment osmocote and scotts showed linear rates while the release rate from the other fertilizers was rapid linearly and decreased over time.

Lamont *et al.* (1987) reported that the release rate of soluble salts from three resin coated controlled release fertilizers namely nutricote, osmocote type A and osmocote type B was affected by both incubation temperature and time and the percentage availability of nutrients are found to be increased as the time as well as temperature increases.

Shoji *et al.* (1990) conducted an experiment to determine dissolution from polyolefin coated urea and found that the cumulative nitrogen release reached 80 % of the total N content at 126 days after application and cumulative air temperature of 2300 °C.

Shoji and Kanno (1992) observed that the use of polyolefin-coated fertilizers containing NPK reduced nitrate leaching and nitrous oxide emissions from cultivated soils with heavy fertilization.

Pino *et al.* (1995) conducted a comparative study on the release of P and K from two zeolite fertilizers and from soild KH_2PO_4. Zeolite fertilizers supply available P after more than 70 days whereas P from KH_2PO_4 exhausted after 50 days. All fertilizers supplied available K throughout the whole experimental period, but unlike KH_2PO_4, both zeolite fertilizers provided controlled release of potassium.

Release rates of 13 commercially available soluble and controlled release K fertilizers were determined in sand column and found that the all the soluble K fertilizers were completely exhausted after 4 weeks and that of controlled release fertilizers varied in release rates and was available from 5 months and 2 to 3 years (Broschat, 1996).

Hanafi *et al.* (2002) compared the release of a compound controlled release fertilizer containing N, P, K , Ca, Mg, Cu coated with natural rubber, polyvinyl chloride, polyacrylamide, and polylactic acid with uncoated fertilizers and observed that the nutrient loss from uncoated fertilizers was higher compared to the coated fertilizers.

Du *et al.* (2006) studied the differential release of nutrients from polymer coated N P K compound controlled release fertilizers in free water, water saturated with sand and sand alone at field capacity. It was observed that nitrate release was the fastest followed by ammonium and potassium whereas phosphate was significantly slower in free water. Release in free water was faster compared to that in water saturated with sand and sand alone at field capacity.

Jagadeeswaran *et al.* (2007) reported that potassium placed in the form of tablets enhanced potassium availability significantly than other slow release NPK sources. The tablet form of NPK sources maintained a desirable level of NPK availability at various stages of turmeric growth. Placement of tablets near the rhizopshere soil ensured a higher concentration of phosphorus in the soil in the immediate vicinity of roots. Thus higher concentration gradient was set up for the phosphorus from the tablets to diffuse faster to the roots as compared to other sources.

A comparison on relative release rates of boron from nine soluble and controlled release B fertilizer sources were conducted and the leachate analysis revealed that solubor being the soluble form got completely leached within 5 weeks whereas the release from controlled release forms namely granubor extended upto three months (Broschat, 2008).

Yang *et al.* (2012) reported that application of controlled release urea to rice seeds without additional fertilizer application during the entire growing season significantly increased N availability in soils.

Subbarao *et al.* (2013) prepared and evaluated water soluble polymer coated fertilizer having a core of soluble nutrients surrounded by a polymer coating of polyacrylamide and observed that the polymer coating slows down the release of fertilizer and also reduces soil erosion.

The solubility of slow release fertilizer developed from boron phosphate were found to be decreasing with decrease in pH so that these compounds have the potential to continuously supply B to crops over the growing period (Abat *et al.*, 2015)

Azeem *et al.* (2014) developed controlled release coated urea that not only reduces nitrogen loss caused by volatilization and leaching, but also alters the kinetics of nitrogen release, which in turn, provides nutrients to plants at a pace that is more compatible with their metabolic needs.

Fernández-Sanjurjo *et al.* (2014) compared the release rate of the fertilizer tablet containing nitrogen, phosphorus, potassium (11-18-11) and (8-8-16) composition, calcium phosphate, potassium sulphate, N as amide and urea-formaldehyde and magnesite and found that formulation 11–18–11 would be more suitable for crops with a strong initial demand.to release the nutrients.

Leaching studies of microencapsulated NPK fertilizer suggest that it can provide longer nutrient availability than urea or ammonium nitrate (Neamtu *et al.*, 2015).

Zareabyaneh and Bayatvarkeshi (2015) evaluated the effect of slow release fertilizers on nitrate leaching and observed that the application of nano-nitrogen chelate, sulfur- coated nano-nitrogen chelate and sulfur-coated urea at three levels of nitrogen reduced nitrate leaching compared to urea.

Combined application of polymer coated potassium chloride with potassium sulphate in cotton improved the availability of potassium in soil (Yang *et al.*, 2017).

El-Sharkawi *et al.* (2018) reported that the slow release fertilizer developed from rice –hull based biochar reduced nitrogen loss in sandy soils.

2.4 EFFECT ON NUTRIENT CONTENT AND UPTAKE IN PLANT

Jagadheeswaran *et al.* (2007) reported that tablet placement at a depth of 5 cm nearer to the rhizosphere, slow release coupled with reduced losses of N by leaching and volatilization maintained the N status as well as N uptake from the tablets.

Kiran *et al.* (2010) compared the performance of six different types of controlled release urea in flooded rice and observed that the N accumulations in rice straw and grain were significantly greater than control.

Zebarth *et al.* (2012) studied the response of potato towards controlled release fertilizers and found that there was increased availability of N in plant for the treatments applied with polymer coated urea.

Kaplan *et al.* (2013) reported that the highest nutrient consumption by chrysanthemum was observed in plants applied with Basacote 6M which is a controlled release fertilizer.

Khan *et al.* (2015) observed that slow release fertilizers like sulfur and urease (agrotain) coated urea, significantly enhanced the N uptake of two rice cultivars in two different soils as compared to granular urea. The dissolution rate of urea alone was faster as compared to sulfur and urease (agrotain) coated urea.

El- Ghamry *et al.* (2016) conducted an experiment in maize by comparing five slow release N fertilizers namely, urea formaldehyde, sulfur coated urea, sulfur and inhibitors coated urea, cement coated urea and cement and inhibitors coated urea. The results revealed that the highest percentage of N, P and K in shoot and flag leaves were found to be the highest in sulfur and inhibitors coated urea.

A study conducted was with maize in vertisol, inceptisol, alfisol and aridisol for evaluating the efficacy of pine oleoresin coated urea and found to have increased nitrogen uptake compared to uncoated urea (Kundu *et al.*, 2016).

Controlled-release fertilizer were found to increase nutrient uptake in early ripening rapeseed (Tian *et al*., 2016). The nitrogen accumulation was increased by 13.66% compared to straight fertilizers. Controlled-release fertilizer significantly promoted the growth of rapeseed by providing sufficient N in the later growth stages. Similar trend was observed in case of phosphorus and potassium.

Jiang *et al*. (2014) prepared three types of slow release urea fertilizers namely polymer coated urea with pore constriction, polymer coated urea with enzyme inhibitor and polymer coated urea with pore constriction and enzyme inhibitor and evaluated in tomato. The results from soil analysis indicated that the content of NH_3/NH_4^+ nitrogen in slow release urea treated pots was 25%-61% higher than that in soil from urea-treated pots during the growing period while the content of NO_3 nitrogen was nearly 50% lower after the tomato had been harvested. Slow release urea fertilizer increased nitrogen uptake and reduced loss of applied nitrogen.

Jadon *et al*. (2018) reported that the N uptake in shoot and grain were significantly higher over the control when treated with neem coated urea and pine resin coated urea.

2.5 EFFECT ON GROWTH AND YIELD OF CROPS

Plant growth tests were made in pea to compare agronomic response of micronutrient coated on granular fertilizer versus micronutrient incorporated in the granules and found that the increase in yield was higher for those coated with micronutrients viz., zinc sulphate, zinc slag, zinc carbonate and zinc EDTA (Philen, 1970).

Slow release boron fertilizers were applied in nineteen varieties of vegetables in three different soils and found that the yield ratio remained adequately high in fertilizer treated plots compared with organic fields (Eguchi and Yamada, 1997).

Ombodi and Saigusa (2000) compared the broadcast and banded application of polyolefin coated fertilizer on pepper and found that both treatment gave similar yield.

Fashola *et al.* (2001) reported that the application of polyolefin coated urea increased the plant height and number of tillers and also the grain yield in rice.

A polyolefin-coated urea increased potato marketable yield of 3.3 Mg ha $^{-1}$ compared to uncoated urea (Zvomuya and Rosen, 2001).

Singh and Shivay (2003) conducted a field experiment to study the effect of coated prilled urea with eco-friendly neem (*Azadirachta indica* A. Juss.) formulations in hybrid rice and found a significant increase in the number of effective tillers hill $^{-1}$, panicle length and panicle weight as the result of applying modified urea materials compared to prilled urea.

Dunn and Stevens (2008) evaluated the response of polymer coated phosphate fertilizers on yield of rice and reported that at the 25 lb acre P_2O_5 rate the polymer coated treatments produced greater yields than equivalent non coated treatments.

The wet rhizome yield of turmeric was significantly increased by the application of slow release NPK fertilizer tablets. The uptake of N, P and K in shoot and rhizome also increased significantly up to 125% fertilizer level applied as tablets and was significantly superior to conventional fertilizer sources (Jagadheeswaran *et al.*, 2008).

A study was conducted to compare different formulations of methylene-urea, a slow release fertilizer with a conventional fertilizer to determine their impact on yield and growth of bell pepper. Treatments were compared with the recommended rate of 200 kg ha^{-1} nitrogen (N) and a high-input fertilizer rate of 300 kg ha^{-1} N (Reyes *et al.*, 2008). The slow-release granular formulation at 200 lb/acre N produced the highest marketable yield.

El-Tohamy *et al.* (2009) investigated the effects of different levels of slow release fertilizer (Ensyabine: a slow release N fertilizer contains 40% of N) on vegetative growth and yield of snap bean. Five levels of Ensyabine were applied (30, 60, 90, 120 and 150 kg). The highest level of Ensyabine resulted in higher growth and yield compared to control plants that received the conventional nitrogen application of ammonium sulfate.

Osman and El-Rahman (2009) studied the effect of sulfur coated urea, phosphorus coated urea and urea formaldehyde on guava trees and reported that urea formaldehyde was found to be superior to sulfur coated urea, phosphorus coated urea in terms of growth and yield.

Ziadi *et al.* (2011) reported that controlled-release urea is a promising N source for increasing the yield of potato to 12 percentage compared to different levels of calcium ammonium nitrate.

Attapulgite coated fertilizers prepared and evaluated in maize revealed the soil mineral N and available P of attapulgite-coated fertilizer has a slow-release behavior that allows a better synchronization between nutrient availability and plant needs. Attapulgite-coated fertilizer increased the grain yield by 15.1–18.4 % (Guan *et al.*, 2013).

Abou-Zied *et al.* (2014) reported that application of slow release fertilizers like sulphur coated urea, phosphogypsum coated urea and bentonite coated urea significantly increased the plant height, 100-seed weight and seed yield per plant in maize and soybean compared to uncoated urea.

A study conducted to assess the impact of two rates of urea fertilizers coated agrotain on growth and yield of maize crop showed a maximum grain yield of 3.56 t ha^{-1} in plot fertilized with 115 kg N ha^{-1} as urea, coated with agrotain applied in two splits. It was concluded that agrotain coating of urea delayed the urea hydrolysis and made the maximum N availability to plants and increased yield of maize crop (Khan *et al.*, 2015).

Application of sulfur and urease inhibitor (agrotain) coated urea to silt loam and clay soil gave the highest dry matter yield of rice cultivars (Khan *et al.*, 2015).

Encapsulated urea fertilizer applied to kale plant increased fresh weight, root fresh weight, stem dry weight and root dry weight. (Pinpeangchan and Wanapu, 2015).

Zareabyaneh and Bayatvarkeshi (2015) reported that the application of nano-nitrogen chelate, sulfur coated nanonitrogen chelate and sulfur coated urea at three levels of nitrogen in potato increased the yield by 56.10, 59.61, and 49.76 % respectively comared to urea application.

A study conducted to evaluate polymer coated di-ammonium phosphate (DAP) to enhance growth and yield of wheat revealed that increased growth (plant height, root length, number of tillers, inter-nodal distance), yield (number of grains per spike, 1000 grain weight, grain yield and biological yield) and phosphorus acquisition by wheat was observed with 100% polymer coated DAP than 50 and 75 % polymer coated DAP (Ali *et al.*, 2016).

Kundu *et al.* (2016) reported that the biomass yield of maize was increased by the application of pine resin coated urea.

Tian *et al.* (2016) studied the effects of controlled-release fertilizer on seed yield and plant growth of rapeseed and reported that higher seed yields and growth of rapeseed were obtained in CRF than soluble fertilizers.

Shivay *et al.* (2016) conducted a field experiment on rice and found that sulphur coated urea produced the tallest plants, significantly taller than gypsum coated urea and phospho gypsum coated urea. Same trend was also observed in leaf area index and yield.

An experiment was carried out to study the effect of slow releasing nitrogen fertilizers on growth and yield of sugarcane. Application of 125 % nitrogen through neem coated urea recorded significantly maximum plant height (304.1 cm) and higher millable cane yield (125.3 t/ha) and which was onpar with the application of 125 % nitrogen through sulphur coated urea (302.5 cm and 123.1 t/ha, respectively) and application of 125 % nitrogen through coal tar coated urea (300.2 cm and 121.4 t/ha, respectively) (Bhanuvally *et al.*, 2017).

Khandey *et al.* (2017) reported that the 125% neem coated urea performed significantly better with respect to agronomic yield attributing characters like number of tillers, number of panicle, panicle length, filled grain per panicle and test weight of 1000 seeds of rice.

Yang *et al.* (2017) reported that the application of 70 % polymer coated potassium chloride mixed with 30% potassium sulphate increased the fibre yield and seed yield in cotton.

Ha *et al.* (2018) studied the effect of controlled release fertilizer developed using acryl based polymers in *Phalaenopsis* and the maximum leaf length, leaf width, fresh weight and root weight were the highest in treatment applied with controlled release fertilizer at 1.5 g pot^{-1}.

Jadon *et al.* (2018) conducted a field experiment on maize and found that the application of neem coated urea and pine oleoresin coated urea at 100 and 75 % of recommended dose increased the grain yield to 30.1 % and 25.4 % respectively.

2.6 EFFECT ON QUALITY OF CROPS

Valencia (2003) conducted an experiment to determine the impact of "slow release fertilizer" on fruit quality of tomatoes and found that slow release nitrogen fertilizer in combination with a potassium source had a significantly increased soluble solids content (°Brix).

El-Tohamy *et al.* (2009) observed that the application of slow release N fertilizer can provide nitrogen to bean plants all over the growing season which help to improve protein content of pods.

Effect of slow release nitrogen fertilizers like sulfur coated urea, phosphorus coated urea and urea formaldehyde on quality parameters of Guava were studied and found that application of urea formaldehyde recorded the highest total soluble sugars, ascorbic acid, reducing and non-reducing sugars (Osman and El- Rahman, 2009).

Taoukis and Assimakopoulos (2010) reported that the lycopene content was found to be increased by the application of slow release fertilizers when compared with the conventional fertilizers.

Li *et al.* (2013) conducted a greenhouse test to evaluate the effect of zeolite as a slow release fertilizer on spinach and found that vitamin C content was increased significantly.

Singh and Tiwari (2013) reported that the maximum T.S.S. % and ascorbic acid (mg/100 g) in tomato were found with the application of treatment containing Boric acid + Zinc sulphate + Copper sulphate @ 250 ppm each.

A study was conducted to assess the effect of microalgal bacterial flocs treated aquaculture wastewater as organic slow-release fertilizers on tomato cultivation and observed that microalgal fertilizers improved the fruit quality through an increase in sugar and carotenoid content (Coppens *et al.*, 2015).

Gao *et al.* (2015) studied the effect of controlled release urea on the quality of potato (Solanum tuberosum L.) on silt loamy soil and reported that N fertilization significantly enhanced the vitamin C, soluble protein and starch content.

Protein content in rice grains were significantly higher in sulfur and agrotain coated urea as compared to granular urea and control treatments (Khan *et al.*, 2015).

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Maharjan *et al.* (2016) reported that the chlorophyll content in corn was increased by the application of polymer coated urea in comparison with urea ammonium- nitrate and was significantly correlated with grain yield and the results suggests that it can be more than or equally effective as conventional fertilizers.

Jiang *et al.* (2014) found that the chlorophyll content of tomato plants at maturity and harvest was increased by slow release urea fertilizer.

Bhanuvally *et al.* (2017) reported that the pol %, brix, purity coefficient and commercial cane sugar were found to be the highest in treatment applied with neem coated urea and was on par with sulphur coated urea as well as coaltar coated urea.

Li *et al.* (2017) studied the effects of two slow-release nitrogen fertilizers namely polymer-coated urea and carbon-based urea on quality of greenhouse tomato and found that the treatment with the two slow-release nitrogen fertilizers increased soluble sugar and lycopene contents and reduced nitrate content in fruits.

2.7 NUTRIENT USE EFFICIENCY

Shoji and Kanno (1992) reported that the polyolefin-coated fertilizers with accurate controlled release properties can increase fertilizer efficiency and the recovery of basal N was increased to 23 %.

Garcia *et al.* (1997) reported that the nutrient use efficiency of urea is low compared to that of coated urea in rye grass.

Wen et al. (2001) reported that the highest recovery percentage for nitrogen in peanut was recorded in treatments applied with coated nitrogen due to the fact that the release of nitrogen matched crop nitrogen uptake and placement of fertilizer that allowed immediate uptake.

A study investigated the effects of different rates and blends of urea and Polymer coated urea on onion yield and N use efficiency for two cropping seasons indicated that more N was retained in polymer coated urea treated onion beds than in urea-treated beds, which improved nitrogen use efficiency. The use of polymer coated urea can dramatically improve N use efficiency and productivity in direct-seeded onions (Drost *et al.,* 2002).

A study by Singh and Shivay (2003) suggested that to achieve higher rice yields, more N uptake by rice, higher NUE and apparent N recovery, hybrid rice should be grown at higher levels of nitrogen along with indigenous coating materials. The coating of urea with neem formulations not only increases NUE and apparent N recovery but also helps in reducing the environmental hazards associated with the use of large amounts of urea.

Zvomuya *et al.* (2003) compared polyolefin-coated urea and urea on potato and obtained NUE values ranging from 35 to 145 kg tubers kg^{-1} N for urea and from 38 to 168 kg tubers kg^{-1} N for polyolefin-coated urea due to the application of 140 kg N ha^{-1}.

Jagadheeswaran *et al.* (2005) observed that the nutrient use efficiencies *viz.,* agronomic efficiency, apparent recovery and partial factor productivity were significantly enhanced by the application of NPK sources containing urea formaldehyde, ammonium sulphate, amophos, rock phosphate, muriate of potash and clay in tablet form to turmeric.

Du *et al.* (2006) reported that polymer coated N–P–K controlled release fertilizer can contribute to improved NUE and minimize negative environmental effects.

Pack *et al.* (2006) conducted a comparative study in potato using controlled release fertilizer and ammonium nitrate and found that the nutrient removal efficiency was found to be the highest in treatments applied with controlled release fertilizers.

The effectiveness of two polyolefin coated products, 'Meister 70' and 'Meister 270', as slow-release sources of nitrogen (N) for irrigated cotton, and uncoated calcium carbide as a source of acetylene to inhibit nitrification of urea-N and reduce losses by denitrification were studied. Meister 70 maintained a higher concentration of ammonium in the soil than urea, resulted in lower soil nitrate concentrations and increased the apparent recovery efficiency of fertilizer N (Chen *et al.*, 2007).

Ni *et al.* (2011) observed that slow-release N fertilizer formulations of urea, ammonium chloride and ammonium sulphate prepared using attapulgite clay, ethylcellulose film and sodium carboxy methylcellulose, hydroxy ethylcellulose hydrogel was effective in reducing nutrient losses and improving water use efficiency.

Higher values of NUE were observed for controlled release urea treated potatoes when compared with that of potatoes treated with calcium ammonium nitrate (Ziadi *et al.*, 2011).

The use of attapulgite coated fertilizers improved partial factor productivity of N fertilizer by 10.0–26.7 % and P fertilizer by 11.0–26.7 %, compared to control in maize (Guan *et al.*, 2013).

Li *et al.* (2015) suggested that polyolefin-coated urea to replace regular or non-coated urea might be an option to achieve maximization of nutrient use efficiency and to optimize N application rate. A decrease of 46 –50% N inputs could be achieved in polyolefin-coated urea.

Gao *et al.* (2015) reported that the application of polymer coated urea and polymer sulphur coated urea markedly improved the N agronomic efficiency and apparent N use efficiency of potato.

Commercial DAP and polymer coated DAP (50%, 75% and 100% of recommended dose) were tested in wheat and found that 100% polymer coated DAP increased phosphorus recovery and agronomic efficiency compared to other treatments (Ali *et al.*, 2016).

Kundu *et al.* (2016) reported that the nitrogen use efficiency in maize was increased when pine resin coated urea was applied in different soils.

NUE was increased by the application of sulphur coated urea than gypsum coated urea and phospho gypsum coated urea rice (Shivay *et al.*, 2016).

Tian *et al.* (2016) reported that the fertilizer use efficiency and partial factor productivity were found to be increased by the application of controlled release NPK fertilizer in early ripening rapeseed.

Xiang *et al.* (2017) reported that polymer coated potassium chloride mixed with 30 % potassium sulphate increased the potassium recovery efficiency from 3.38 to 40.90 % in cotton compared to other potassium fertilizer treatments.

A study conducted on maize by applying the coated fertilizers namely neem coated urea and pine oleoresin coated urea at 100 and 75 % was found to increase the agronomic efficiency, recovery efficiency and partial factor productivity than treatment applied with normal urea (Jadon *et al.*, 2018).

Yang *et al.* (2019) reported that dimethylolurea can be used as a slow release fertilizer that was found to increase the N use efficiency of maize and wheat.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study entitled "Development of multi nutrient fertilizer tablet and its evaluation in tomato" was carried out in the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani during October 2018-January 2019 with the objective of developing multi nutrient fertilizer tablet containing major, secondary and micronutrients and evaluate its effect on nutrient use efficiency, yield and quality of tomato. The three parts of the study were

1. Development of multi nutrient fertilizer tablets 2. Incubation study 3. Evaluation of multi nutrient tablets in tomato. The materials and methods used for study are described in this chapter.

3.1. DEVELOPMENT OF MULTI NUTRIENT FERTILIZER TABLETS

Multinutrient tablets required for the study were prepared using compatible fertilizer materials, binding agents and filler material by following standard protocol for preparing tablet formulation.

Treatment details

Fertilizer materials – 3

Binding materials – 3

Total number of tablets – 9

Design – CRD

Replication – 3

Multinutrient tablets were prepared by dry compression method, using fertilizers, binding agents and filler materials and the quantity of fertilizers required were calculated based on per plant requirement as per POP recommendation of KAU, 2016.

3.1.1 Treatment combinations

T_1 – Urea (14.68 g), dicalcium phosphate (8.76 g) , potassium sulphate (4.69 g), calcium sulphate (27.27 g), magnesium oxide (1.08 g) , zinc EDTA (1.56 g), boric acid (1.05 g), methyl cellulose (7.5 g) and filler material (33.41 g).

T_2 –Fertilizer materials as in T_1, binding agent gelatin (7.5 g) and filler material (33.41 g).

T_3 – Fertilizer materials as in T_1, binding agent polyvinyl pyrrolidone (7.5 g) and filler material (33.41 g).

T_4 – Urea (14.68 g), diammonium phosphate (7.28 g), muriate of potash (3.75 g), calcium sulphate (27.27 g), magnesium sulphate (7 g), zinc EDTA (1.56 g), borax (1.62 g), binding agent methyl cellulose (7.5 g) and filler material (29.34g)

T_5 – Fertilizer materials as in T_4, binding agent gelatin (7.5 g) and filler material (29.34 g).

T_6 – Fertilizer materials as in T_4, binding agent polyvinyl pyrrolidone (7.5 g) and filler material (29.34 g).

T_7 – Neem coated urea (14.68 g), factomphos (18 g), muriate of potash (3.75 g), magnesium oxide (1.08 g), phosphogypsum (27.27 g), zinc sulphate (0.9 g), borax (1.63 g), binding agent methyl cellulose (7.5 g) and filler material (25.19 g).

T_8 – Fertilizer materials as in T_7, binding agent gelatin (7.5 g) and filler material (25.19 g).

T_9 – Fertilizer materials as in T_7, binding agent polyvinyl pyrrolidone (7.5 g) and filler material (25.19 g).

Clay was used as filler material in all treatments.

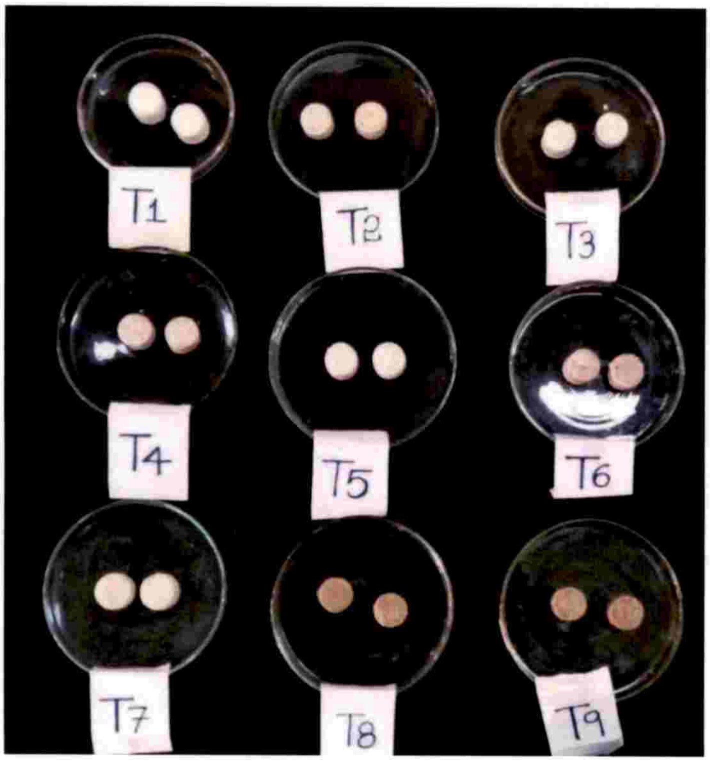

Plate 1: Multinutrient tablets

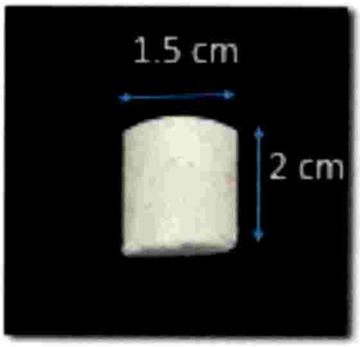

Plate 2: Multinutrient tablet size and dimension

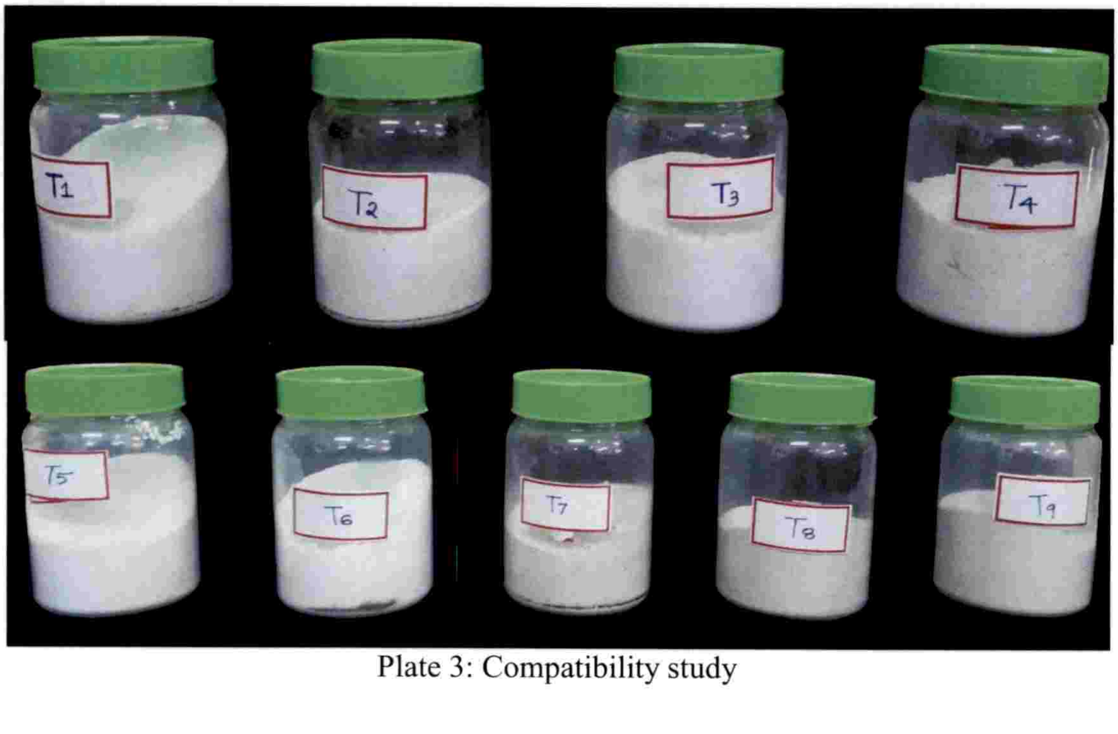

Plate 3: Compatibility study

Multinutrient fertilizer material blends of 100 grams each as per above treatment combinations were prepared. Compatibility of prepared multinutrient fertilizer material blends were studied and nine multinutrient tablets each of 5 gram weight, 1.5 cm diameter and 2 cm length were prepared using tablet press.

The multinutrient tablets prepared were tested for stability, disintegration time, pH, EC, moisture and nutrient content as per standard methods detailed in table 1.

Table 1. Standard analytical methods for tablet characterization

Parameters	Method	Reference
Stability	Simple finger test	Hignett (1985)
Disintegration time	Disintegration test using distilled water	Hignett (1985)
pH (1:10)	pH meter	FAI (2017)
EC (1:10)	EC meter	FAI (2017)
Moisture content	Oven dry method	FAI (2017)
N	Microkjeldahl digestion and distillation	FAI (2017)
P	Volumetric Ammonium phospho-molybdate method	FAI(2017)
K	Sodium tetraphenyl boron method	FAI (2017)
Ca, Mg	Estimation using Versanate titration method	FAI (2017)
S	Diacid (HNO_3: $HClO_4$ in the ratio 9:4) digestion and turbidimetry	Massoumi and Cornfield (1963)
Zn	Atomic absorption spectrophotometry	FAI (2017)
B	Spectrophotometry - Azomethine-H method	Roig *et al.* (1996)

3.2 INCUBATION STUDY

An incubation study was conducted under laboratory conditions for 90 days to test the nutrient release pattern of different tablets. Two tablets each of 5 gm were placed in the soil at a depth of 5 cm and 10 cm apart and incubated for 90 days at field capacity. Soil samples will be drawn at 15 days interval up to three months and analysed for availability of nitrogen, phosphorus, potassium, calcium, magnesium, boron and zinc.

Design – CRD

Replications – 3

Number of tablets – 9

From the 9 multinutrient tablets tested in the incubation study, four promising tablets were selected for the pot culture study. They were

Tablet 1 containing urea, dicalcium phosphate, potassium sulphate, calcium sulphate, magnesium oxide, zinc EDTA, boric acid and binding agent polyvinyl pyrrolidone

Tablet 2 containing urea, diammonium phosphate, muriate of potash, calcium sulphate, magnesium sulphate, zinc EDTA, borax and binding agent methyl cellulose

Tablet 3 containing urea, diammonium phosphate, muriate of potash, calcium sulphate, magnesium sulphate, zinc EDTA, borax and binding agent gelatin

Tablet 4 containing neem coated urea, factamphos, muriate of potash, magnesium oxide, phosphogypsum, zinc sulphate, borax and binding agent methyl cellulose

These fertilizers are superior with respect to compatibility, stability, disintegration time and nutrient content.

A) Tablet 1

B) Tablet 2

C) Tablet 3

D) Tablet 4

Plate 4: Tablets selected for pot culture experiment

T_3R_2	T_9R_2	T_5R_1
T_7R_1	T_1R_2	T_8R_3
T_6R_1	T_7R_2	T_2R_3
T_4R_2	T_3R_2	T_4R_1
T_1R_1	T_5R_3	T_9R_1
T_6R_3	T_2R_2	T_7R_3
T_2R_1	T_6R_2	T_1R_3
T_3R_3	T_4R_3	T_8R_1
T_8R_2	T_9R_3	T_5R_2

Fig 1: Layout of incubation study

Plate 5: General view of incubation study

3.3 POT CULTURE EXPERIMENT: EVALUATION OF MULTINUTRIENT TABLETS IN TOMATO

3.3.1 Experimental site and season

A pot culture experiment was conducted at Instructional Farm College of Agriculture, Vellayani to study the effect of multinutrient tablets using tomato variety Vellayani vijay as the test crop. The experiment was conducted from October 2018 to January 2019.

3.3.2 Weather parameters

The weather parameters during the crop period are presented in Appendix 1 and graphically represented in Fig 2.

3.3.3. Treatment details

The treatments of pot culture study are given below.

T_1- 75% recommended dose of fertilizers as tablet 1

T_2- 100 % recommended dose of fertilizers as tablet 1

T_3-75% recommended dose of fertilizers as tablet 2

T_4- 100% recommended dose of fertilizers as tablet 2

T_5- 75% recommended dose of fertilizers as tablet 3

T_6- 100% recommended dose of fertilizers as tablet 3

T_7- 75% recommended dose of fertilizers as tablet 4

T_8-100% recommended dose of fertilizers as tablet 4

T_9-Soil test based POP recommendation

T_{10}-T_9 + secondary and micronutrient mixture

T_{11}- Control (No fertilizers)

The multi nutrient tablets were applied in two splits as basal and one month after planting. The quantity of nutrients required for 75 % of recommended dose of

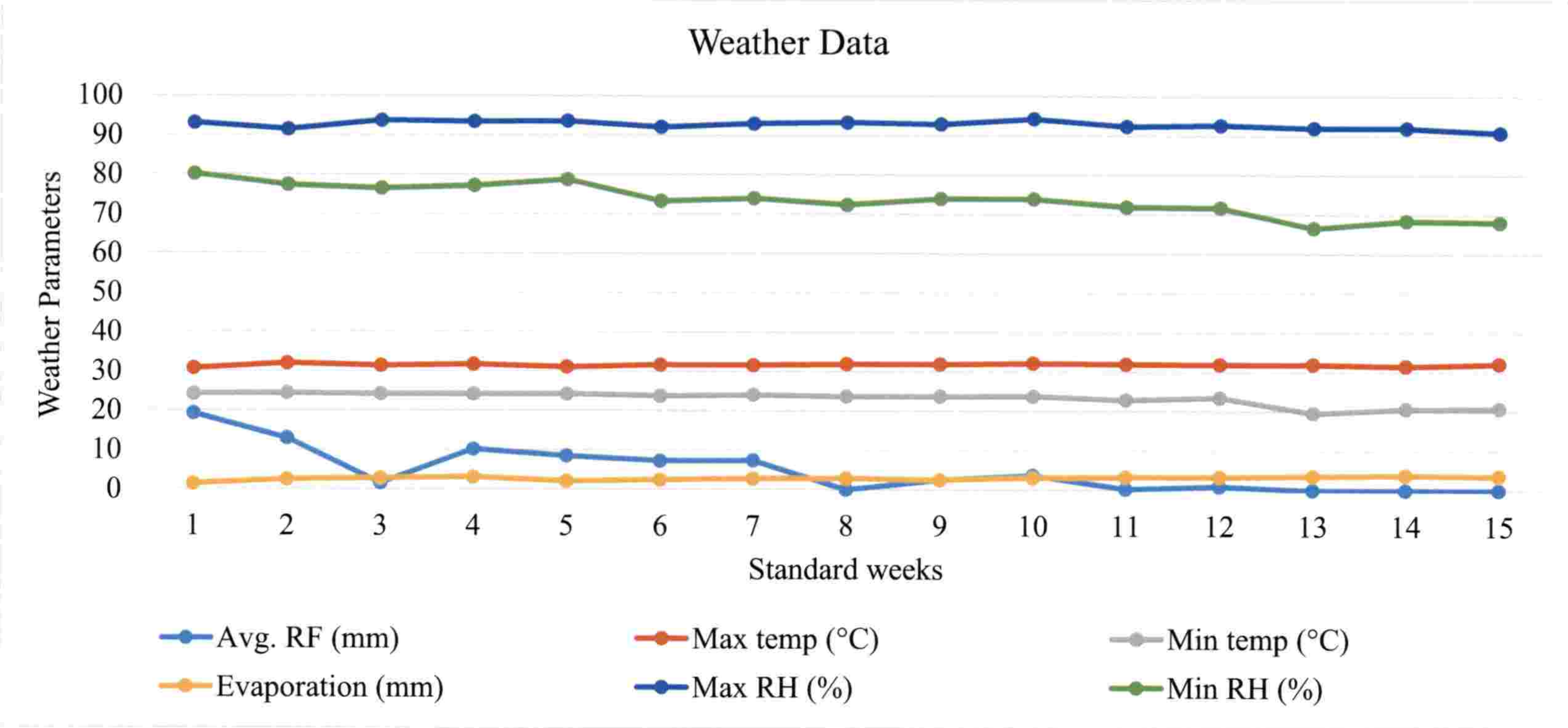

Fig 2: Weather data for the cropping period: October 2018 to January 2019

T_6R_3	T_1R_1	T_5R_3
T_5R_1	$T_{10}R_1$	T_3R_3
T_7R_2	T_3R_2	T_9R_2
T_1R_2	T_2R_5	T_8R_3
T_1R_3	T_7R_1	T_8R_1
T_2R_1	$T_{10}R_3$	T_6R_1
$T_{11}R_1$	T_2R_2	T_8R_2
T_3R_1	T_9R_3	$T_{10}R_2$
T_4R_2	$T_{11}R_2$	T_9R_1
T_4R_3	T_4R_1	T_6R_2
T_2R_3	T_7R_3	$T_{11}R_3$

Fig 3: Layout of the pot culture experiment

Plate 6: Experiment view

Plate 7: Placement of tablets

fertilizers for each plant was satisfied with 6 tablets and 100 % of recommended dose of fertilizers was satisfied with 8 tablets.

Pots were filled with 10 kg soil and FYM as per POP recommendation of KAU, 2016 and tomato seedlings of 30 days old were transplanted and irrigation was given. All other management practices were done as per recommendation of POP, KAU 2016.

3.4 Soil analysis

Initial soil sample was collected before the conduct of experiment and was air dried and sieved through 2mm sieve and analysed for chemical properties such as pH, EC, organic carbon content, available N, P, K, Ca, Mg, S and micronutrients following standard procedures given in Table 3. The details on nutrient status of initial soil are tabulated in Table 2.

Table 2: Physical and chemical properties of initial soil

Sl No.	Soil parameters	Status	Rating
1	pH	5.5	Moderately acidic
2	EC (dS m^{-1})	0.12	Normal
3	Organic carbon (%)	0.89	Medium
4	Available N (kg ha^{-1})	260.3	Low
5	Available P (kg ha^{-1}	60.7	High
6	Available K (kg ha^{-1})	130.5	Low
7	Exchangeable Ca (mg kg^{-1})	263.2	Deficient
8	Exchangeable Mg (mg kg^{-1})	80.4	Deficient
9	Available S (mg kg^{-1})	4.12	Deficient
10	Available B (mg kg^{-1})	0.37	Deficient
11	Available Zn (mg kg^{-1})	4.3	Sufficient

Soil samples were also collected from the pot culture experiment at one month after transplanting and at harvest stage of the crop and were air dried and analysed for available N, P, K, Ca, Mg, S, Zn and B using standard procedures as given in Table 3.

Table 3. Standard analytical procedures for soil analysis

Sl No.	Parameter	Method	Reference
1	pH	pH meter	Jackson (1973)
2	EC	Conductivity meter	Jackson (1973)
3	Organic Carbon	Walkely and Black rapid titration method	Walkely and Black (1934)
4	Available N	Alkaline permanganate method	Subbiah and Asija (1956)
5	Available P	Bray No 1 extraction and estimation with spectrophotometer	Jackson (1973)
6	Available K	Neutral normal ammonium acetate extraction and estimation with flame photometer	Jackson (1973)
7	Available Ca and Mg	Versanate titration method	Hesse (1971)
8	Available S	Calcium chloride extraction and estimation by spectrophotometer	Massoumi and Cornfield (1963)
10	Available Zn	Extraction using 0.1 N HCl and estimation using atomic absorption spectrophotometer	O'Connor (1988)
11	Available B	Hot water extraction and estimation usingAzomethine- H spectrophotometer	Gupta (1967)

3.5 BIOMETRIC OBSERVATIONS

Three plants were selected from each treatment and the following observations were recorded.

3.5.1 Growth parameters

The following growth parameters were recorded

3.5.1.1 Plant height (cm)

The plant height of selected observational plants from each treatment and replications was measured from ground level to the top most leaf bud and the average plant height was recorded in cm.

3.5.1.2 Number of branches per plant

Number of branches in each observational plant was counted and mean value was computed and recorded as number of branches per plant.

3.5.1.3 Days to flowering

The number of days taken for the first flower to emerge after transplanting was recorded for each plant and the average was obtained.

3.5.1.4 Days to fruiting

The number of days taken for the fruit set after flowering was recorded for each observational plant and mean value was computed.

3.5.2 Yield parameters

3.5.2.1 Number of fruits per plant

Total number of fruits produced from each observational plant till the last harvest was counted and average was taken.

3.5.2.2 Fruit girth (cm)

Girth of fruit was taken using vernier caliper. The average was worked out and expressed in cm.

3.5.2.3 Fruit weight (g)

Weight of single fruit obtained from each observational plant was measured and expressed in g.

3.5.2.4 Yield (g plant^{-1})

The total weight of all fruits harvested from each plant was recorded at the time of harvest and expressed in g.

3.5.3 Quality parameters

3.5.3.1 TSS (%)

Total soluble solids in fruits were estimated using Abbe hand refractometer after crushing the fruits in a muslin cloth and expressed in % (Sadasivam and Manickam, 1992).

3.5.3.2 Lycopene (µg g^{-1})

The content of lycopene in full ripe fruits were estimated by colorimetric method and expressed in µg g^{-1} of fresh ripe fruits (Sadasivam and Manickam, 1992).

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

Ascorbic acid content of fruits was estimated by 2, 6 dichlorophenol indophenol redox titration method and expressed as mg 100g^{-1} of fresh ripe fruits (Sadasivam and Manickam, 1992).

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3.6 PLANT ANALYSIS

Tomato fruit samples were collected at the time of harvest and index leaves were taken during vegetative stage for analysing the nutrient content. Plant samples were dried in oven and then powdered and analysed for N, P, K, Ca, Mg, S, B and Zn. The standard procedures used are given in table 4. Uptake of above nutrients were also calculated.

Table 4. Standard analytical procedures for plant analysis

Sl No.	Element	Method	Reference
1	Total N	Kjeldahl method	Jackson (1973)
2	Total P	Vanado molybdate yellow colour method	Piper (1966)
3	Total K	Flame photometery	Jackson (1973)
4	Total Ca and Mg	Versanate titration method	Hesse (1971)
5	Total S	Calcium chloride extraction and estimation by turbidimetry	Chesnin and Yien (1950)
6	Total Zn	Atomic absorption spectroscopy	Jackson (1973)
7	Total B	Dry ashing, extraction in 0.36 N H_2SO_4, filtration and photoelectric colorimetry using Azomethine-H.	Gupta (1967)

3.9 NUTRIENT USE EFFICIENCY

3.9.1 Agronomic efficiency

The nutrient use efficiency with respect to agronomic efficiency was calculated as the response in yield per unit quantity of nutrient applied (Malathi, 2002).

$$\frac{\text{Yield in fertilized pot (g pot}^{-1}\text{) - Yield in unfertilized pot (g pot}^{-1}\text{)}}{\text{Quantity of nutrient applied (g pot}^{-1}\text{)}}$$

3.9.2 Apparent Nutrient Recovery (ANR):

$$\frac{\text{Uptake in fertilized pot (g pot}^{-1}\text{) - Uptake in control pot (g pot}^{-1}\text{)}}{\text{Quantity of fertilizer nutrient applied (g pot}^{-1}\text{)}}$$

3.9.3 Partial factor productivity (Pfp)

It is the ratio of yield to applied nutrients

Pfp = Y/Nr

Y is the yield in g plant^{-1}

Nr is the amount of fertilizer nutrients in g plant^{-1}.

3.9.3 B: C ratio

Benefit – cost ratio was computed by using the formula

$$\text{B: C ratio} = \frac{\text{Gross income}}{\text{Total expenditure}}$$

4. Statistical analysis

The result of various parameters obtained from experiments were analysed statistically for the test of significance by standard procedures using OPSTAT software.

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RESULTS

4. RESULTS

A study entitled "Development of multinutrient fertilizer tablet and its evaluation in tomato" was conducted at the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani. The results pertaining to compatibility, properties, nutrient content and nutrient release pattern of multinutrient tablets and their effect on available nutrients in soil, growth parameters, nutrient content and uptake, yield and quality of tomato are presented in this chapter.

4.1 DEVELOPMENT OF MULTINUTRIENT FERTILIZER TABLETS

Multinutrient tablets were prepared using compatible fertilizer materials and binding agents and were evaluated for compatibility, properties and nutrient content.

4.1.1 Compatibility of multinutrient fertilizer tablets

Compatibility of multinutrient fertilizer tablet blends were studied by observing the hygroscopicity, caking, noxious gas formation and colour change of blends. As depicted in Table 5, T_8 and T_9 were hygroscopic whereas others were non hygroscopic, caking was observed in T_2 and T_6. There was no noxious gas formation in any of the tablet blends but colour change was observed in T_6 (light pink), T_8 (light brown) and T_9 (light brown) but rest of the tablet blends remained white in colour.

4.1.2 Properties of multinutrient fertilizer tablets

Properties of multinutrient tablets are given in Table 6. The stability of multinutrient tablets tested revealed that the tablets T_1, T_2 and T_6 were soft and unstable and others were hard and stable. The disintegration time of tablet T_1, T_2 and T_6 ranged from 0.5 to 1 hour and others were 10 to 12 hours. Moisture content varied significantly between the treatments and was found to be the highest in tablet T_6 (9.24 %) and lowest in T_4 (6.46 %).

Table 5. Compatibilty of multinutrient fertilizer tablet blends

Treatments	Treatment details	Hygroscopicity	Caking	Noxious gas formation	Colour change
T_1	Urea, DCP, K_2SO_4, $CaSO_4$, MgO, zinc EDTA, boric acid and binding agent methyl cellulose	Nil	Nil	Nil	Nil
T_2	Fertilizer materials as in T_1 and binding agent gelatin	Nil	Caking observed	Nil	Nil
T_3	Fertilizer materials as in T_1 and binding agent polyvinyl pyrrolidone	Nil	Nil	Nil	Nil
T_4	Urea, DAP, MOP, $CaSO_4$, $MgSO_4$, zinc EDTA, borax and binding agent methyl cellulose	Nil	Nil	Nil	Nil
T_5	Fertilizer materials as in T_4 and binding agent gelatin	Nil	Nil	Nil	Nil
T_6	Fertilizer materials as in T_4 and binding agent polyvinyl pyrrolidone	Nil	Caking observed	Nil	Light pink
T_7	Neem coated urea, factamphos,MOP, MgO, phosphogypsum, $ZnSO_4$, borax and binding agent methyl cellulose	Nil	Nil	Nil	Nil
T_8	Fertilizer materials as in T_7 and binding agent gelatin	Hygroscopic	Nil	Nil	Light brown colour
T_9	Fertilizer materials as in T_7 and binding agent polyvinyl pyrrolidone	Hygroscopic	Nil	Nil	Light brown colour

Table 6: Properties of multinutrient fertilizer tablets

Treatments	Treatment details	Stability	Disintegration time (Hours)	Moisture content (%)	pH	EC (dS m^{-1})
T_1	Urea, DCP, K_2SO_4, $CaSO_4$, MgO, zinc EDTA, boric acid and binding agent methyl cellulose	Unstable	0.5	9.08	8.25	10
T_2	Fertilizer materials as in T_1 and binding agent gelatin	Unstable	1	8.17	9.10	12.14
T_3	Fertilizer materials as in T_1 and binding agent polyvinyl pyrrolidone	Stable	12	7.65	8.21	9.75
T_4	Urea, DAP, MOP, $CaSO_4$, $MgSO_4$, zinc EDTA, borax and binding agent methyl cellulose	Stable	10	6.46	6.42	20.10
T_5	Fertilizer materials as in T_4 and binding agent gelatin	Stable	10	7.74	6.43	19.93
T_6	Fertilizer materials as in T_4 and binding agent polyvinyl pyrrolidone	Unstable	30	9.24	6.40	20.50
T_7	Neem coated urea, factomphos,MOP, MgO, phosphogypsum, $ZnSO_4$, borax and binding agent methyl cellulose	Stable	12	8.01	6.59	27.67
T_8	Fertilizer materials as in T_7 and binding agent gelatin	Stable	10	8.59	6.47	27.93
T_9	Fertilizer materials as in T_7 and binding agent polyvinyl pyrrolidone	Stable	10	8.52	6.53	29.10
SEm (±)				0.088	0.410	0.14
CD				0.264	1.227	0.43

The different multinutrient tablets vary significantly with respect to pH and EC. The pH of tablets T_1, T_2 and T_3 were slightly alkaline whereas tablets T_4, T_5, T_6, T_7, T_8 and T_9 were slightly acidic in nature and the highest pH was recorded for T_2 (9.10). The EC was found to be the highest in T_9 (29.10 dS m^{-1}) and the lowest value was reported for T_3 (9.75 dS m^{-1}).

4.1.3 Nutrient content of multinutrient fertilizer tablets

4.1.3.1 Major nutrients

Major nutrient content in fertilizer tablets are presented in Table 7. The highest N content was recorded in T_3 (8.69 %) which was on par with T_2 (8.31 %), T_4 (8.42 %), T_5 (8.23 %), T_7 (8.55%) and T_8 (8.51%) and the lowest value was recorded in T_1 (7.69 %). The phosphorus content was the highest in T_2 (4.82%) and all other tablets were found to be on par with T_2 except T_1 (4.43%). The potassium content of tablets were significantly higher for T_2 (3.20%) followed by T_3 (3%) and the lowest in T_9 (2.13 %).

4.1.3.2 Secondary nutrients

Secondary nutrient contents of multinutrient tablets are presented in Table 7. The highest calcium content of 6.45 % was registered in T_5, which was on par with all other treatments except for T_6 (5.81%) and T_9 (5.82 %). The tablet T_6 (0.68%) recorded highest magnesium content and was significantly superior over all other treatments and T_8 (0.65%) recorded the lowest value. The sulphur content varied significantly among the different tablets with T_7 registering the highest value of 3.27 % whereas, T_3, T_8 and T_9 were found to be on par with T_7 and the lowest value was recorded in T_5 (2.37%).

4.1.3.3 Micronutrients

The micro nutrient contents of various tablets developed are presented in Table 7. The boron content of multinutrient tablets ranged between 0.21 and 0.22 %. The Zn content varied between 0.21 and 0.25 % and the highest Zn content in T_8 (0.25%) which was on par with T_7 and T_9 (0.24%) and the lowest in T_6 (0.21 %).

Table 7. Nutrient content in multinutrient fertilizer tablets

Treatments	Treatment details	N %	P %	K %	Ca %	Mg %	S %	B %	Zn %
T_1	Urea, DCP, K_2SO_4, $CaSO_4$, MgO, zinc EDTA, boric acid and binding agent methyl cellulose	7.69	4.43	2.40	6.25	0.66	2.91	0.22	0.22
T_2	Fertilizer materials as in T_1 and binding agent gelatin	8.30	4.82	3.20	6.35	0.66	2.93	0.22	0.22
T_3	Fertilizer materials as in T_1 and binding agent polyvinyl pyrrolidone	8.69	4.81	3.00	6.20	0.67	3.09	0.21	0.23
T_4	Urea, DAP, MOP, $CaSO_4$, $MgSO_4$, zinc EDTA, borax and binding agent methyl cellulose	8.42	4.67	2.43	6.29	0.66	2.42	0.22	0.21
T_5	Fertilizer materials as in T_4 and binding agent gelatin	8.23	4.80	2.40	6.45	0.66	2.37	0.22	0.22
T_6	Fertilizer materials as in T_4 and binding agent polyvinyl pyrrolidone	8.01	4.81	2.40	5.81	0.68	2.97	0.22	0.21
T_7	Neem coated urea, factomphos,MOP, MgO, phosphogypsum, $ZnSO_4$, borax and binding agent methyl cellulose	8.55	4.72	2.40	6.33	0.66	3.27	0.22	0.24
T_8	Fertilizer materials as in T_7 and binding agent gelatin	8.51	4.61	2.40	6.28	0.65	3.22	0.22	0.25
T_9	Fertilizer materials as in T_7 and binding agent polyvinyl pyrrolidone	8.10	4.62	2.10	5.82	0.66	3.20	0.22	0.24
SEm (±)		0.17	0.08	0.05	0.09	0.003	0.09	0.001	0.004
CD		0.51	0.25	0.16	0.29	0.009	0.28	0.003	0.011

4.2 INCUBATION STUDY: NUTRIENT RELEASE PATTERN OF MULTINUTRIENT FERTILIZER TABLETS

4.2.1 Soil pH

There was no significant influence of different treatments on pH of soil during incubation (Table 8). The pH of initial soil ranged from 5.74 to 5.84. A slight increase was observed in all treatments on the 15th day of incubation thereafter it decreased.

Table 8: Effect of multinutrient tablets on pH of soil

Treatments	Days of incubation						
	0	15	30	45	60	75	90
T_1	5.76	6.03	5.81	5.31	5.33	5.64	5.78
T_2	5.76	6.06	5.81	5.43	5.44	5.93	5.64
T_3	5.85	6.04	5.82	5.35	5.38	5.74	5.29
T_4	5.76	5.90	5.83	5.46	5.41	5.58	5.69
T_5	5.84	5.92	5.83	5.32	5.37	5.39	5.44
T_6	5.83	5.90	5.97	5.32	5.30	5.52	5.32
T_7	5.78	5.92	5.91	5.38	5.38	5.37	5.37
T_8	5.74	5.86	5.83	5.32	5.36	5.39	5.54
T_9	5.74	6.03	6.00	5.38	5.37	5.47	5.40
SEm (±)	0.01	0.03	0.02	0.01	0.02	0.01	0.01
CD (0.05)	NS	NS	NS	NS	NS	NS	NS

4.2.2 Soil EC

A significant difference was observed with respect to EC of the soil due to the application of multinutrient tablets on 15, 30, 75 and 90th day of incubation (Table 9). The EC in initial soil ranged between 0.11-0.14 dS m^{-1}. After the application of treatments EC increased upto 60th day in T_1, T_4, T_5 and T_9 and upto 75th day in T_2, T_3, T_6, T_7, T_8 and then found to be decreasing towards the end of incubation study. The highest EC of 1.55 dS m^{-1} was recorded in T_5 at 60th day. On 15th day EC was the highest for T_1 (1.49 dS m^{-1}) which was on par with T_2 and T_8. T_9 recorded the highest EC on 30th day of incubation which was on par with T_5, T_6, T_7 and T_8 and lowest in T_2. On 45th and 60th

day of incubation there was no significant influence of treatments on EC of soil. The treatment T_6 recorded the highest EC of 1.53 dS m^{-1} on 75th day which was found to be on par with all other treatments except T_1. On 90th day of incubation also T_6 recorded the highest EC of 1.48 dS m^{-1} which was on par with T_2, T_3, T_5, T_8 and T_9.

Table 9: Effect of multinutrient tablets on EC of soil, dS m^{-1}

Treatments	Days of incubation						
	0	15	30	45	60	75	90
T_1	0.13	1.49	0.95	1.08	1.36	0.82	0.70
T_2	0.14	1.40	0.80	1.20	1.25	1.48	1.23
T_3	0.12	0.56	0.87	1.37	1.11	1.48	1.28
T_4	0.12	1.22	0.88	1.05	1.47	1.30	1.18
T_5	0.14	0.77	1.02	1.15	1.55	1.52	1.38
T_6	0.11	1.28	1.16	1.27	1.50	1.53	1.48
T_7	0.11	1.12	1.26	1.31	1.42	1.45	1.11
T_8	0.13	1.33	1.27	1.38	1.29	1.45	1.32
T_9	0.13	1.18	1.29	1.45	1.52	1.51	1.40
SEm (±)	0.01	0.06	0.09			0.09	0.09
CD (0.05)	0.02	0.18	0.27	NS	NS	0.25	0.28

4.2.3 Soil available N

The available nitrogen in soil was influenced significantly by multinutrient tablets as presented in Table 10. The available nitrogen content in initial soil ranged between 188.95 to 197.43 kg ha^{-1} which was followed by a gradual increase upto 60th day of incubation in T_1, T_2, T_6, T_7 and T_9 and 75th day of incubation in T_3, T_4, T_5 and T_8. The highest available nitrogen was recorded in T_7 on 60th day (685.74 kg ha^{-1}). On 15th, 30th and 45th days T_5 recorded the highest available nitrogen of 430.68 kg ha^{-1}, 486.12 kg ha^{-1} and 556.12 kg ha^{-1} respectively. The treatment T_7 recorded the highest value on 60th, 75th and 90th day of incubation. On 75th day T_4, T_5 and T_8 were found to be on par with T_7 (685.64 kg ha^{-1}). The highest value of 649.74 kg ha^{-1} was recorded by T_7 on 90th day followed by T_3, T_4, T_5, T_8 and T_9 which were on par.

Table 10: Effect of multinutrient tablets on available nitrogen in soil, kg ha^{-1}

Treatments	Days of incubation						
	0	15	30	45	60	75	90
T_1	189.74	254.83	280.88	340.88	560.3	485.77	481.06
T_2	192.28	275.97	295.06	325.06	526.85	492.49	467.78
T_3	188.95	409.04	429.04	442.04	581.21	595.94	622.31
T_4	189.74	351.58	400.04	439.04	577.02	656.47	627.20
T_5	197.43	430.68	486.12	556.12	564.48	643.93	606.29
T_6	194.46	292.69	380.5	430.5	632.29	600.29	577.02
T_7	197.25	349.57	418.49	528.49	685.74	685.64	649.74
T_8	193.07	326.5	383.59	459.59	609.57	669.01	640.5
T_9	193.07	259.13	351.23	451.23	626.47	593.57	620.74
SEm (±)		24.82	14	20.02		14.8	17.53
CD (0.05)	NS	74.45	42.00	60.07	NS	44.44	52.06

4.2.4 Soil available P

The effect of different multinutrient tablets on available phosphorus in soil is given in Table 11. The available P in initial soil ranged from 36.77 kg ha^{-1} to 39.25 kg ha $^{-1}$, thereafter a gradual increase was observed upto 60th day with the highest content of 66.94 kg ha^{-1} recorded in treatment T_7. On 15th day T_5 recorded the highest available P of 46.40 kg ha^{-1}. On 30th and 45th day T_6 registered the highest value of 54.95 kg ha^{-1} and 58.28 kg ha^{-1} respectively. The highest available P in 60th, 75th and 90th day of incubation was observed in T_7.

4.2.5 Soil available K

The available potassium in soil was significantly influenced by the application of various multinutrient tablets. The data are given in Table 12. In initial soil the available K ranged between 97.07 and 100.80 kg ha^{-1}. A gradual increase in available K was observed from 15th day to 90th day of incubation. The highest available K was recorded in T_7 which was found to be on par with T_5 during entire period of incubation. The highest value of 250.15 kg ha^{-1} was recorded in T_7 on 90th day of incubation.

Table 11: Effect of multinutrient tablets on available phosphorus in soil, kg ha^{-1}

Treatments	Days of incubation						
	0	15	30	45	60	75	90
T_1	38.45	43.04	45.31	43.57	48.24	51.37	50.66
T_2	39.12	44.54	49.77	56.08	54.92	50.85	53.35
T_3	39.25	44.87	52.38	55.25	56.71	61.60	59.62
T_4	37.78	43.97	51.28	49.95	56.93	65.78	63.17
T_5	38.26	46.40	51.28	52.56	49.06	63.45	59.88
T_6	38.92	43.53	54.95	58.28	63.95	60.37	53.20
T_7	37.7	42.15	48.30	45.84	66.94	66.04	64.10
T_8	39.08	44.05	47.34	54.84	58.38	51.71	56.97
T_9	36.77	44.76	48.24	52.68	58.61	56.60	58.32
SEm (±)	0.56	0.34	1.43	2.68	2.53	2.85	1.80
CD (0.05)	1.67	1.01	4.29	8.03	7.58	8.52	5.39

Table 12: Effect of multinutrient tablets on available potassium in soil, kg ha^{-1}

Treatments	Days of incubation						
	0	15	30	45	60	75	90
T_1	100.80	158.59	181.52	207.71	219.85	227.85	230.00
T_2	100.80	155.82	198.92	212.82	224.81	232.89	235.55
T_3	97.07	160.00	202.97	215.74	228.85	236.00	240.00
T_4	100.80	162.96	203.92	218.44	230.00	237.96	240.62
T_5	97.07	169.14	211.00	224.77	235.81	244.85	248.00
T_6	100.80	150.48	193.00	206.52	218.00	226.29	229.78
T_7	100.80	171.00	214.00	226.48	238.62	246.51	250.15
T_8	97.07	150.51	193.56	205.45	217.00	225.00	228.44
T_9	97.07	152.57	196.55	208.41	221.18	228.48	231.00
SEm (±)		0.97	1.28	1.04	1.08	0.96	0.86
CD (0.05)	NS	2.91	3.87	3.13	3.23	2.89	2.57

4.2.6 Soil exchangeable Ca

The exchangeable Ca in soil was significantly influenced by the application of multinutrient tablets. The data are given in Table 13. In initial soil the exchangeable Ca ranged between 214 to 228 mg kg^{-1}. A gradual increase in Ca was noticed in 15^{th} day to 90^{th} day of incubation. The highest exchangeable Ca was recorded in T_7 on 75^{th} day (474 mg kg^{-1}) which was found to be on par with T_3, T_4, T_5 and T_9. At the end of incubation T_8 recorded the highest value of 472.63 mg kg^{-1} which was on par with T_3 (469.00 mg kg^{-1}) and T_4 (471.92 mg kg^{-1}).

Table 13: Effect of multinutrient tablets on exchangeable calcium in soil, mg kg^{-1}

Treatments	Days of incubation						
	0	15	30	45	60	75	90
T_1	215.00	250.00	340.00	386.67	409.00	422.00	433.00
T_2	218.00	254.67	338.00	385.00	408.00	450.85	431.00
T_3	228.00	288.67	369.33	416.81	439.86	471.30	469.00
T_4	214.00	289.00	364.00	411.00	435.00	470.98	471.92
T_5	225.00	291.00	371.67	418.85	441.00	472.36	464.89
T_6	217.00	275.67	330.33	377.82	400.00	413.48	423.48
T_7	214.00	296.67	381.67	428.46	451.00	474.00	464.19
T_8	227.00	282.67	350.67	397.41	421.00	454.00	472.63
T_9	228.67	279.33	345.00	391.53	435.78	470.81	438.81
SEm (±)	0.70	1.11	1.03	0.84	0.90	1.09	1.21
CD (0.05)	2.09	3.33	3.12	2.52	2.68	3.28	3.64

4.2.7 Soil exchangeable Mg

The effect of multinutrient tablets on exchangeable Mg content of soil is given in Table 14. In initial soil it varied form 37.85 mg kg^{-1} to 52 mg kg^{-1}. A gradual increase in Mg content was observed from 15^{th} to 90^{th} day of incubation. The highest available Mg was recorded in T_5 which was found to be on par with T_3 during the entire period of incubation. The highest value of 184.59 mg kg^{-1} was recorded in T_5 on 90^{th} day of incubation.

Table 14: Effect of multinutrient tablets on exchangeable magnesium in soil, mg kg $^{-1}$

Treatments	Days of incubation						
	0	15	30	45	60	75	90
T_1	37.85	67.00	105.86	129.93	148.64	160.00	169.04
T_2	42.00	61.82	103.00	126.00	144.00	155.82	159.00
T_3	48.00	84.48	124.00	148.00	166.63	179.00	181.70
T_4	52.00	82.45	122.00	147.14	164.38	179.30	179.85
T_5	42.00	87.00	126.00	151.00	168.00	180.00	184.59
T_6	48.00	78.86	118.35	142.00	160.00	173.74	178.00
T_7	38.00	82.82	122.00	146.00	164.00	178.78	182.46
T_8	48.00	70.79	110.49	134.49	152.00	163.82	170.00
T_9	38.00	74.56	113.42	138.78	156.00	178.82	183.85
SEm (±)		1.10	1.60	1.22	0.88	0.41	1.07
CD (0.05)	NS	3.31	4.81	3.67	2.65	1.23	3.24

4.2.8 Soil available S

The available sulphur in soil was significantly influenced by the application of multinutrient tablets (Table 15). In initial soil the available S ranged between 1.0 mg kg $^{-1}$ and 1.17 mg kg $^{-1}$. A gradual increase in available S content was observed from 15 th to 90 th day of incubation. The highest available S content was recorded in T_5 throughout the incubation period except the 15 th day of incubation. The highest value of 18.28 mg kg $^{-1}$ was recorded in T_5 on 75th day of incubation and was significantly different from all other treatments.

4.2.9 Soil available B

The effect of multinutrient tablets on available boron in soil is given in Table 16. In initial soil the available B was 0.05 mg kg $^{-1}$. A gradual increase in available B was observed from 15 th to 90 th day of incubation. The highest available B was recorded in T_7 which was found to be on par with T_5 from 45 th day to 75 th day of incubation. The highest value of 0.97 mg kg $^{-1}$ was recorded in T_7 on 90 th day of incubation.

Table 15: Effect of multinutrient tablets on available sulphur in soil, mg kg $^{-1}$

Treatments	Days of incubation						
	0	15	30	45	60	75	90
T_1	1.17	3.03	6.45	9.75	14.54	16.09	16.32
T_2	1.00	2.89	5.34	8.64	13.42	14.98	15.21
T_3	1.00	3.40	8.23	11.53	16.31	17.87	18.12
T_4	1.17	3.50	8.33	11.63	16.41	17.97	18.20
T_5	1.00	3.60	8.39	11.71	16.47	18.03	18.28
T_6	1.17	2.90	6.50	9.80	14.58	16.13	16.37
T_7	1.08	3.80	8.20	11.50	16.29	17.84	18.08
T_8	1.13	2.89	7.01	10.31	15.08	16.65	16.89
T_9	1.17	2.90	6.86	10.21	14.98	16.54	16.77
SEm (±)		0.02	0.02	0.01	0.01	0.008	0.02
CD (0.05)	NS	0.058	0.070	0.036	0.047	0.026	0.069

Table 16: Effect of multinutrient tablets on available boron in soil, mg kg $^{-1}$

Treatments	Days of incubation						
	0	15	30	45	60	75	90
T_1	0.05	0.06	0.32	0.54	0.77	0.80	0.81
T_2	0.05	0.06	0.30	0.59	0.79	0.81	0.82
T_3	0.05	0.06	0.32	0.65	0.85	0.87	0.87
T_4	0.05	0.06	0.28	0.67	0.90	0.92	0.92
T_5	0.05	0.06	0.28	0.66	0.91	0.93	0.94
T_6	0.05	0.06	0.28	0.57	0.87	0.89	0.90
T_7	0.05	0.06	0.29	0.68	0.92	0.95	0.97
T_8	0.05	0.06	0.29	0.57	0.89	0.90	0.93
T_9	0.05	0.06	0.28	0.57	0.89	0.89	0.90
SEm (±)			0.009	0.01	0.005	0.007	0.005
CD (0.05)	NS	NS	0.03	0.04	0.02	0.02	0.02

4.2.10. Soil available Zn

The available zinc in soil was significantly influenced by the application of multinutrient tablets as given in Table 17. In initial soil the available Zn ranged between 1.41 mg kg^{-1} and 1.68 mg kg^{-1}. A gradual increase in available Zn content was observed from 15th to 90th day of incubation. The highest available Zn content was recorded in T_7 upto 60th day of incubation. T_5 recorded the highest value of 5.22 mg kg^{-1} on 90th day. Treatment T_3 (4.99 mg kg^{-1}) recorded the highest value on 75th day which was on par with T_4 (4.88 mg kg^{-1}) and T_5 (4.91 mg kg^{-1}). On 90th day the highest value was noticed in T_5 (5.22 mg kg^{-1}) which was on par with T_4 (5.12 mg kg^{-1}) and T_7 (5.12 mg kg^{-1}).

Table 17: Effect of multinutrient tablets on available Zn in soil, mg kg^{-1}

Treatments	Days of incubation						
	0	15	30	45	60	75	90
T_1	1.61	2.46	2.77	3.44	3.85	4.28	4.73
T_2	1.49	2.53	2.90	3.58	3.78	4.18	4.43
T_3	1.53	2.77	3.16	3.93	4.23	4.99	5.04
T_4	1.41	2.83	2.92	3.83	4.16	4.88	5.12
T_5	1.50	2.90	2.97	3.82	4.18	4.91	5.22
T_6	1.53	2.54	2.58	3.34	3.81	4.19	4.33
T_7	1.68	3.05	3.80	4.13	4.32	4.65	5.12
T_8	1.42	2.69	3.38	4.06	4.12	4.23	4.88
T_9	1.50	2.66	3.06	4.12	4.14	4.23	4.65
SEm (±)	0.02	0.06	0.06	0.06	0.07	0.06	0.05
CD (0.05)	0.08	0.21	0.19	0.18	0.22	0.19	0.17

4.3. POT CULTURE EXPERIMENT: EVALUATION OF MULTI NUTRIENT TABLETS IN TOMATO

4.3.1 Plant growth parameters

4.3.1.1 Plant height

The effect of multinutrient tablets on plant height at harvest is presented in table 18. All the treatments were found to be superior to absolute control. Among the treatments the highest plant height was recorded by T_7 (63 cm) and T6 was found to be on par (58 cm) with T_7. The lowest height was observed in T_{11} (38.67 cm).

4.3.1.2 Number of branches per plant

Table 18 indicates the results of number of branches per plant. It is evident from the table that treatment T_7 recorded the maximum number of branches of 6.67 which was found to be significantly superior to all other treatments. The lowest value was recorded by T_{11} (2.67).

4.3.1.3 Number of days to flowering

The data on number of days to flowering in Table 18 revealed that early flowering was observed in T_9 (30 days) and all other treatments were found to be on par with T_9 except T_{11}.

4.3.2 Yield and yield attributes

4.3.2.1 Number of days to fruiting

The effect of treatments on number of days to fruiting is shown in Table 19. Early fruiting was observed in T_9 which was found to be on par with all other treatments except T_{11} (absolute control).

4.3.2.2 Number of fruits per plant

The data on number of fruits per plant is presented in Table 19. The different treatments significantly influenced the number of fruits per plant. Maximum number of fruits per plant was observed in T_7 (16) which was on par with T_8 (15). The lowest value was recorded in T_{11} (control).

4.3.2.3 Fruit girth

Table 19 shows the effect of multinutrient tablets on fruit girth. Maximum fruit girth was observed in T_5 (11.20 cm) while the lowest was noticed in T_{11} (9.52 cm). There was no significant difference observed between the treatments

Table 18. Effect of multinutrient tablets on growth parameters of tomato

Treatments	Treatment details	Plant height (cm)	Number of branches plant^{-1}	Number of days to flowering
T_1	75% RDF as tablet 1	52.67	4.00	31.33
T_2	100% RDF as tablet 1	52.67	3.67	30.33
T_3	75% RDF as tablet 2	49.00	4.00	32.33
T_4	100% RDF as tablet 2	49.33	4.00	32.00
T_5	75% RDF as tablet 3	47.67	5.00	31.00
T_6	100% RDF as tablet 3	58.00	4.67	31.00
T_7	75% RDF as tablet 4	63.00	6.67	31.67
T_8	100% RDF as tablet 4	45.00	4.33	32.00
T_9	Soil test based POP recommendations	44.67	3.67	30.00
T_{10}	T_9 + secondary and micronutrient mixture	46.33	4.00	31.00
T_{11}	Control(No fertilizers)	38.67	2.67	36.00
SEm (±)		2.45	0.49	0.88
CD (0.05)		7.2	1.45	2.59

RDF- Recommended Dose of Fertilizers

4.3.2.4 Fruit weight

The data on the effect of multinutrient tablets on fruit weight of tomato are illustrated in Table 19. The maximum fruit weight of 33.77 g was observed in T_7 which was on par with T_8 (32.27 g).

4.3.2.5 Yield

The tomato fruit yield was significantly influenced by the treatments as depicted in Table 19. The highest fruit yield of 502.02 g per plant was recorded in T_7 which was followed by T_8 (495.66 g) both were on par. All other treatments were also found to be significantly higher than control (343.33 g).

Table 19. Effect of multinutrient tablets on yield and yield attributes of tomato

Treatments	Treatment details	Number of days to fruiting	No of fruits per plant	Fruit girth (cm)	Fruit weight (g)	Yield (g plant $^{-1}$)
T_1	75% RDF as tablet 1	34.33	12.00	10.80	28.09	387.51
T_2	100% RDF as tablet 1	33.33	13.00	10.24	27.54	403.99
T_3	75% RDF as tablet 2	35.33	12.67	10.79	27.87	438.90
T_4	100% RDF as tablet 2	35.00	13.33	10.74	27.24	416.35
T_5	75% RDF as tablet 3	34.00	12.67	11.20	28.47	410.00
T_6	100% RDF as tablet 3	34.00	12.67	10.90	31.32	419.29
T_7	75% RDF as tablet 4	34.67	16.00	10.45	33.77	502.02
T_8	100% RDF as tablet 4	35.00	15.00	9.93	32.27	495.66
T_9	Soil test based POP recommendations	33.00	12.67	10.80	27.91	434.77
T_{10}	T_9 + secondary and micronutrient mixture	34.00	13.67	10.41	29.51	467.23
T_{11}	Control (No fertilizers)	39.00	11.00	9.52	22.24	343.33
SEm (±)		0.88	0.56		0.63	13.12
CD (0.05)		2.59	1.69	NS	1.87	38.73

RDF- Recommended Dose of Fertilizers

4.4. EFFECT OF MULTINUTRIENT TABLETS ON SOIL PROPERTIES AND NUTRIENT AVAILABILITY

The soil samples collected at one month after planting and at harvest were analyzed and the results are as follows.

4.4.1 Soil pH

Table 20 shows the effect of multinutrient tablets on pH of soil at one month after planting and at harvest which ranged from 5.75 to 6.16 and 5.65 to 5.94 respectively. There was no significant difference observed with respect to soil pH due to the application of multinutrient tablets at both the stages.

4.4.2 Soil EC

The EC of soil was found to be influenced significantly by treatments as depicted in Table 20. The treatment T_6 recorded the highest EC in both stages i.e 0.4 dS m^{-1} and 0.33 dS m^{-1} respectively. The treatments T_1 (0.37 dS m^{-1}), T_3 (0.36 dS m^{-1}), T_5 (0.37 dS m^{-1}) and T_8 (0.37 dS m^{-1}) were found to be on par with T_6 at one month after planting and T_6 was on par with T_2 (0.29 dS m^{-1}) and T_{10} (0.30 dS m^{-1}) at harvest.

4.4.3 Soil organic carbon

The data on organic carbon content of soil are given in Table 20 and it ranged from 0.83 % to 0.88 % at one month after planting and 0.55 % to 0.58 % at harvest. There was no significant difference observed between the treatments with respect to organic carbon status of soil.

4.4.4 Soil available N

Table 21 shows the available N in soil at different stages. The available nitrogen of the soil was significantly influenced by different treatments. The highest available nitrogen was recorded by treatment T_6 (380.50 kg ha^{-1}) which was on par with T_5 (359.60 kg ha^{-1}) at one month after planting.

At harvest the highest value was noticed in treatment T_8 (321.96 kg ha^{-1}) and treatments T_4 (312.21 kg ha^{-1}), T_6 (315.46 kg ha^{-1}), T_7 (319.17 kg ha^{-1}) and T_{10} (318.85 kg ha^{-1}) were found to be on par with T_8.

4.4.5 Soil available P

The data furnished in Table 21 revealed that the highest available phosphorus in soil was recorded in T_2 with 90.96 kg ha^{-1}at one month after planting while treatments T_1 (88.93 kg ha^{-1}), T_4 (89.54 kg ha^{-1}), T_6 (86.99 kg ha^{-1}), T_9 (85.68 kg ha^{-1}) and T_{10} (87.91 kg ha^{-1}) were found to be on par.

At harvest treatment T_8 (88.18 kg ha^{-1}) receiving 100 % recommended dose of fertilizer as tablet 4 recorded the highest value. The treatments T_6 (83.81 kg ha^{-1}), T_7 (84.75 kg ha^{-1}) and T_{10} (83.81 kg ha^{-1}) were found to be on par with T_8 and the lowest was recorded in control (T_{11}).

Table 20: Effect of multiutrient tablets on pH, EC and OC of soil at different stages

Treatments	Treatment details	pH		EC (dS m^{-1})		OC (%)	
		1 MAP	Harvest	1 MAP	Harvest	1 MAP	Harvest
T_1	75% RDF as tablet 1	6.15	5.94	0.37	0.24	0.87	0.58
T_2	100% RDF as tablet 1	6.12	5.91	0.35	0.29	0.88	0.57
T_3	75% RDF as tablet 2	6.07	5.84	0.36	0.21	0.85	0.56
T_4	100% RDF as tablet 2	6.04	5.87	0.26	0.28	0.85	0.57
T_5	75% RDF as tablet 3	6.16	5.87	0.37	0.28	0.87	0.56
T_6	100% RDF as tablet 3	5.75	5.65	0.40	0.33	0.86	0.56
T_7	75% RDF as tablet 4	5.94	5.87	0.35	0.26	0.86	0.55
T_8	100% RDF as tablet 4	5.84	5.77	0.37	0.27	0.87	0.56
T_9	Soil test based POP recommendations	6.05	5.81	0.27	0.18	0.86	0.55
T_{10}	T_9 + secondary and micronutrient mixture	6.05	5.88	0.26	0.30	0.86	0.56
T_{11}	Control (No fertilizers)	6.13	5.90	0.18	0.12	0.83	0.56
SEm (±)				0.01	0.01		
CD (0.05)		NS	NS	0.04	0.04	NS	NS

RDF – Recommended Dose of Fertilizer, MAP – Month After Planting

4.4.6 Soil available K

From table 21, it was found that the available potassium was significantly influenced by the treatments. The highest available potassium was noticed in T_8 (273.47 kg ha^{-1}) which was on par with T_6 (269.73 kg ha^{-1}) at one month after planting.

At harvest also the highest value was recorded in T_8 with 216.53 kg ha^{-1} which was on par with T_5 (209.47 kg ha^{-1}), T_6 (209.47 kg ha^{-1}), T_7 (212.80 kg ha^{-1}) and T_{10} (209.07 kg ha^{-1}). The lowest value was recorded by T_{11} (120.40 kg ha^{-1}).

Table 21: Effect of multiutrient tablets on available major nutrients in soil at different stages, kg ha^{-1}

Treatments	Treatment details	Available N		Available P		Available K	
		1 MAP	Harvest	1 MAP	Harvest	1 MAP	Harvest
T_1	75% RDF as tablet 1	317.78	286.81	88.93	74.67	215.73	168.00
T_2	100% RDF as tablet 1	342.87	303.51	90.96	77.28	232.13	186.67
T_3	75% RDF as tablet 2	334.51	295.48	83.03	64.95	215.20	178.00
T_4	100% RDF as tablet 2	347.05	312.21	89.54	69.03	235.20	190.40
T_5	75% RDF as tablet 3	359.60	303.54	74.18	80.11	251.80	205.73
T_6	100% RDF as tablet 3	380.50	315.46	86.99	83.81	269.73	209.47
T_7	75% RDF as tablet 4	343.31	319.17	76.86	84.75	261.47	212.80
T_8	100% RDF as tablet 4	347.47	321.96	83.95	88.18	273.47	216.53
T_9	Soil test based POP recommendations	330.32	307.48	85.68	74.85	247.60	182.93
T_{10}	T_9 + secondary and micronutrient mixture	344.57	318.85	87.91	83.81	254.07	209.07
T_{11}	Control (No fertilizers)	252.60	246.70	55.08	52.99	126.57	120.40
SEm (±)		9.53	4.02	2.04	1.99	2.36	7.33
CD (0.05)		28.58	11.85	6.03	5.98	7.08	21.64

RDF – Recommended Dose of Fertilizer, MAP – Month After Planting

4.4.7 Soil exchangeable Ca

The data on available Ca in soil are illustrated in Table 22. The treatment T_8 recorded the highest available Ca in both stages i.e 416.67 mg kg^{-1} and 342.56 mg kg^{-1} and was significantly higher than all other treatments. The lowest value was recorded by treatment T_{11}.

4.4.8 Soil exchangeable Mg

Table 22 shows the effect of treatments on soil available Mg at one month after planting and at harvest. At one month after planting, T_6 recorded the highest available Mg in soil (178 mg kg^{-1}) which was followed by T_4 (170.33 mg kg^{-1}) both were on par and all other treatments were found to be significantly different.

At harvest T_6 (107 mg kg^{-1}) recorded the highest value, which was on par with T_1 (103.67 mg kg^{-1}), T_2 (104.81 mg kg^{-1}), T_5 (106 mg kg^{-1}) and T_8 (101.45 mg kg^{-1}) and the lowest value was obtained in control (T_{11}).

4.3.9 Soil available sulphur

The data with respect to available S in soil are given in Table 22. It was observed that T_6 was significantly superior to all other treatments at one month after planting (10.33 mg kg^{-1}) and at harvest (8.35 mg kg^{-1}). The lowest value was recorded by treatment T_{11}.

Table 22: Effect of multiutrient tablets on available secondary nutrients in soil at different stages, mg kg^{-1}

Treatments	Treatment details	Available Ca		Available Mg		Available S	
		1 MAP	Harvest	1 MAP	Harvest	1 MAP	Harvest
T_1	75% RDF as tablet 1	326.67	301.84	144.00	103.67	7.17	5.27
T_2	100% RDF as tablet 1	343.33	312.00	158.00	104.81	8.00	5.32
T_3	75% RDF as tablet 2	321.67	273.62	162.33	98.00	7.61	5.81
T_4	100% RDF as tablet 2	331.00	280.82	170.33	99.73	8.00	6.42
T_5	75% RDF as tablet 3	326.67	281.19	157.33	106.00	9.18	7.72
T_6	100% RDF as tablet 3	350.00	296.43	178.00	107.00	10.33	8.35
T_7	75% RDF as tablet 4	343.33	324.00	160.33	99.51	8.03	5.35
T_8	100% RDF as tablet 4	416.67	342.56	157.33	101.45	8.33	5.46
T_9	Soil test based POP recommendations	318.33	298.10	136.67	96.00	7.09	4.72
T_{10}	T_9 + secondary and micronutrient mixture	300.00	302.86	152.00	98.00	9.44	5.05
T_{11}	Control(No fertilizers)	259.00	250.59	117.67	76.47	3.90	2.29
SEm (±)		19.44	5.24	3.89	1.91	0.29	0.08
CD (0.05)		58.33	15.47	11.69	5.65	0.87	0.24

RDF – Recommended Dose of Fertilizer, MAP – Month After Planting

4.4.10 Soil available B

The data pertaining to available B in soil at one month after planting and at harvest are presented in Table 23. The treatment (T_2) receiving 100 % of recommended dose of fertilizer as tablet 2 recorded the highest value of 0.46 mg kg^{-1} and was found to be on par with T_6 (0.44 mg kg^{-1}) and T_8 (0.44 mg kg^{-1}).

At harvest the highest value was recorded by treatment T_8 (0.34 mg kg^{-1}) while treatments T_4 (0.30 mg kg^{-1}), T_5 (0.30 mg kg^{-1}), T_6 (0.31 mg kg^{-1}), T_7 (0.31 mg kg^{-1}) and T_{10} (0.30 mg kg^{-1}) were found to be on par.

Table 23: Effect of multiutrient tablets on available micronutrients in soil at different stages, mg kg^{-1}

Treatments	Treatment details	Available B		Available Zn	
		1 MAP	Harvest	1 MAP	Harvest
T_1	75% RDF as tablet 1	0.39	0.23	4.22	3.90
T_2	100% RDF as tablet 1	0.46	0.29	4.67	4.04
T_3	75% RDF as tablet 2	0.36	0.27	4.87	3.86
T_4	100% RDF as tablet 2	0.43	0.30	4.85	4.02
T_5	75% RDF as tablet 3	0.43	0.31	4.29	4.04
T_6	100% RDF as tablet 3	0.44	0.30	4.96	4.08
T_7	75% RDF as tablet 4	0.42	0.31	5.00	4.12
T_8	100% RDF as tablet 4	0.44	0.34	5.48	4.21
T_9	Soil test based POP recommendations	0.27	0.26	4.27	3.92
T_{10}	T_9 + secondary and micronutrient mixture	0.43	0.30	5.04	4.21
T_{11}	Control (No fertilizers)	0.23	0.21	3.99	3.76
SEm (±)		0.01	0.02	0.11	0.05
CD (0.05)		0.03	0.05	0.32	0.13

RDF – Recommended Dose of Fertilizer, MAP – Month After Planting

4.4.11 Soil available Zn

Table 23 represents the data on available Zn in soil at both stages. Significant difference was observed between the treatments with respect to available Zn. The treatment T_8 (5.48 mg kg^{-1}) receiving 100 % recommended dose of fertilizers as tablet 4 recorded the highest available Zn and all other treatments were found to be significantly different. The lowest value was recorded by T_{11} (3.99 mg kg^{-1}).

At one month after planting T_8 and T_{10} recorded the highest available Zn of 4.21 mg kg^{-1}.

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4.5 NUTRIENT CONTENT AND UPTAKE IN PLANT

4.5.1 Nitrogen

The results on the N content and uptake of shoot and fruit is represented in Table 24. Significant difference was noticed between the treatments with respect to nitrogen content in shoot. The highest value of 3.14 % was recorded by treatment (T_7) while treatments T_1 (2.82 %), T_3 (2.84 %), T_5 (2.91 %), T_6 (2.88%), T_8 (2.97 %) and T_9 (2.76 %) were on par.

Table 24. Effect of multinutrient tablets on the content and uptake of nitrogen in tomato

Treatments	Treatment details	N content (%)		N uptake (g plant^{-1})		
		Shoot	Fruit	Shoot	Fruit	Total uptake
T_1	75% RDF as tablet 1	2.82	4.14	1.24	0.77	2.01
T_2	100% RDF as tablet 1	2.46	4.48	1.19	0.91	2.10
T_3	75% RDF as tablet 2	2.84	4.22	1.22	0.95	2.17
T_4	100% RDF as tablet 2	2.54	4.42	1.32	0.94	2.26
T_5	75% RDF as tablet 3	2.91	4.28	1.31	0.91	2.23
T_6	100% RDF as tablet 3	2.88	4.57	1.72	0.90	2.62
T_7	75% RDF as tablet 4	3.14	4.98	2.72	1.38	4.10
T_8	100% RDF as tablet 4	2.97	4.61	1.64	1.04	2.67
T_9	Soil test based POP recommendation	2.76	3.81	1.23	0.70	1.93
T_{10}	T_9 + secondary and micronutrient mixture	2.41	3.47	1.08	0.80	1.86
T_{11}	Control(No fertilizers)	2.09	3.36	0.67	0.45	1.13
SEm (±)		0.15	0.08	0.08	0.04	0.09
CD (0.05)		0.43	0.25	0.25	0.13	0.27

RDF – Recommended Dose of Fertilizers

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Effect of treatments on nitrogen content of fruit was also found to be significant. The highest value was recorded by treatment T_7 (4.98 %) and all other treatments were found to be significantly different from T_7. The lowest value was recorded by T_{11} (3.36 %).

The data on nitrogen uptake revealed that the uptake in shoot, fruit and also total uptake were significantly influenced by the treatments. The uptake of nitrogen in shoot was the highest in T_7 (2.72 g plant^{-1}) and lowest in T_{11} (0.45 g plant^{-1}). Regarding the fruit uptake T_7 (1.38 g plant^{-1}) recorded the highest value. Total uptake was also found to be the highest in T_7 (4.10 g plant^{-1}). All the treatments were found to be significantly different from T_7.

4.5.2 Phosphorus

Significant difference was observed between the different treatments with respect to phosphorus content (Table 25). The phosphorus content in shoot was found to be the highest in T_7 (0.20 %), which was on par with T_3 (0.18 %) and T_4 (0.18%). With respect to phosphorus content in fruit T_7 (0.57 %) recorded the highest value while treatments T_1 0.45 %), (T_2 (0.53 %), T_4 (0.49 %), T_5 (0.49 %), T_6 (0.55 %), T_8 (0.54 %) and T_9 (0.45%) were found to be on par with T_7.

With respect to phosphorus uptake in tomato, T_7 recorded the highest uptake in shoot (0.15 g plant^{-1}) and in fruit (0.16 g plant^{-1}). Similar trend was also observed in case of total P uptake (0.31 g plant^{-1}).

Table 25: Effect of multinutrient tablets on the content and uptake of phosphorus in tomato

Treatments	Treatment details	P content (%)		P uptake (g plant^{-1})		
		Shoot	Fruit	Shoot	Fruit	Total uptake
T_1	75% RDF as tablet 1	0.12	0.45	0.05	0.08	0.14
T_2	100% RDF as tablet 1	0.12	0.53	0.06	0.11	0.16
T_3	75% RDF as tablet 2	0.18	0.44	0.09	0.10	0.19
T_4	100% RDF as tablet 2	0.18	0.49	0.09	0.10	0.20
T_5	75% RDF as tablet 3	0.16	0.49	0.07	0.11	0.18
T_6	100% RDF as tablet 3	0.16	0.55	0.10	0.11	0.21
T_7	75% RDF as tablet 4	0.20	0.57	0.15	0.16	0.31
T_8	100% RDF as tablet 4	0.16	0.54	0.07	0.12	0.19
T_9	Soil test based POP recommendation	0.14	0.45	0.06	0.09	0.15
T_{10}	T_9 + secondary and micronutrient mixture	0.14	0.38	0.06	0.09	0.15
T_{11}	Control (No fertilizers)	0.10	0.36	0.03	0.05	0.08
SEm (±)		0.01	0.05	0.01	0.01	0.01
CD (0.05)		0.04	0.13	0.02	0.03	0.03

RDF – Recommended Dose of Fertilizers

4.5.3 Potassium

The data on content and uptake of potassium is given in Table 26. It is evident from the table that treatments had significant influence on K content and uptake due to the application of multinutrient tablets. The highest K content in shoot was observed in T_7 (1.6 %) and T_8 was found to be on par (1.44 %) with T_7 and all the other treatments were found to be significantly different. The lowest value was obtained by T_{11} (0.57 %).

Regarding the fruit potassium content T_7 (3.83 %) and T_9 (3.83 %) recorded the highest value while treatments T_1 (3.52%), T_4 (3.73%), T_5 (3.76%) and T_8 (3.76 %) were found to be on par with T_7 and T_9.

Table 26. Effect of multinutrient tablets on the content and uptake of potassium in tomato

Treatments	Treatment details	K content (%)		K uptake (g $plant^{-1}$)		
		Shoot	Fruit	Shoot	Fruit	Total uptake
T_1	75% RDF as tablet 1	0.65	3.52	0.29	0.66	0.94
T_2	100% RDF as tablet 1	1.03	2.76	0.49	0.56	1.05
T_3	75% RDF as tablet 2	0.97	3.32	0.43	0.74	1.17
T_4	100% RDF as tablet 2	1.00	3.73	0.52	0.80	1.32
T_5	75% RDF as tablet 3	0.73	3.79	0.33	0.81	1.14
T_6	100% RDF as tablet 3	1.01	3.76	0.61	0.74	1.36
T_7	75% RDF as tablet 4	1.60	3.83	1.39	1.06	2.45
T_8	100% RDF as tablet 4	1.44	3.76	0.80	0.84	1.64
T_9	Soil test based POP recommendation	1.13	3.83	0.50	0.71	1.20
T_{10}	T_9 + secondary and micronutrient mixture	1.03	3.40	0.46	0.78	1.24
T_{11}	Control (No fertilizers)	0.57	2.73	0.18	0.37	0.55
SEm (±)		0.09	0.11	0.02	0.04	0.04
CD (0.05)		0.27	0.32	0.06	0.10	0.11

RDF- Recommended Dose of Fertilizers

As indicated in Table 26, the uptake of potassium in shoot was found to be the highest in T_7 (1.39 g $plant^{-1}$) which was found to be significantly superior to all other treatments. Potassium uptake in fruit was also the highest in T_7 (1.06 g $plant^{-1}$). With respect to total uptake, the highest value was noticed in T_7 (2.45 g $plant^{-1}$) and the lowest value was recorded in T_{11} (0.55 g $plant^{-1}$).

4.5.4 Calcium

The effect of treatments on calcium content and uptake is illustrated in Table 27. The highest Ca content of 1.52 % in shoot was recorded by treatment T_7 which received 75 % recommended dose of fertilizers as tablet 4. This was found to be on par with T_2 (1.37 %), T_8 (1.33 %) and T_{10} (1.39 %). The lowest value was observed in T_{11} (1.09 %).

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With respect to Ca content in fruit, T_7 recorded the highest content of 0.68 % which was on par with T_8 (0.66 %), T_9 (0.65 %) and T_{10} (0.61%). The lowest value was observed in T_{11} (0.37%).

Table 27. Effect of multinutrient tablets on the content and uptake of calcium in tomato

Treatments	Treatment details	Ca content (%)		Ca uptake (g plant^{-1})		
		Shoot	Fruit	Shoot	Fruit	Total uptake
T_1	75% RDF as tablet 1	1.19	0.48	0.60	0.09	0.69
T_2	100% RDF as tablet 1	1.37	0.32	0.66	0.07	0.73
T_3	75% RDF as tablet 2	1.04	0.48	0.45	0.11	0.56
T_4	100% RDF as tablet 2	1.23	0.48	0.64	0.10	0.74
T_5	75% RDF as tablet 3	1.20	0.43	0.54	0.09	0.63
T_6	100% RDF as tablet 3	1.04	0.51	0.62	0.10	0.72
T_7	75% RDF as tablet 4	1.52	0.68	1.32	0.19	1.51
T_8	100% RDF as tablet 4	1.33	0.66	0.74	0.15	0.88
T_9	Soil test based POP recommendation	1.15	0.65	0.52	0.12	0.63
T_{10}	T_9 + secondary and micronutrient mixture	1.39	0.61	0.62	0.14	0.76
T_{11}	Control (No fertilizers)	1.09	0.37	0.36	0.05	0.41
SEm (±)		0.09	0.04	0.05	0.01	0.04
CD (0.05)		0.28	0.11	0.13	0.02	0.13

RDF- Recommended Dose of Fertilizers

The different treatments significantly influenced the calcium uptake in tomato. The highest uptake of 1.32 g plant^{-1} in shoot and 0.19 g plant^{-1} in fruit was also found in treatment T_7. Regarding the total uptake T_7 (1.51 g plant^{-1}) recorded the highest value which was significantly superior to all other treatments.

4.5.5 Magnesium

The content and uptake of magnesium in shoot and fruit are presented in table 28 and were significantly influenced by different treatments. The highest value of 1.44 % in shoot was noticed in treatment T_7 which was on par with T_1 (1.28 %), T_2 (1.31

%), T_6 (1.25 %) and T_8 (1.34 %). With respect to Mg content in fruit T_7 (0.96%) recorded the highest value while T_4 (0.67%), T_8 (0.90%) and T_9 (0.67 %) were found to be on par.

Table 28. Effect of multinutrient tablets on the content and uptake of magnesium in tomato

Treatments	Treatment details	Mg content (%)		Mg uptake (g plant^{-1})		
		Shoot	Fruit	Shoot	Fruit	Total uptake
T_1	75% RDF as tablet 1	1.28	0.51	0.56	0.10	0.66
T_2	100% RDF as tablet 1	1.31	0.61	0.63	0.12	0.76
T_3	75% RDF as tablet 2	1.12	0.51	0.49	0.12	0.61
T_4	100% RDF as tablet 2	1.21	0.67	0.63	0.14	0.77
T_5	75% RDF as tablet 3	1.15	0.51	0.52	0.11	0.63
T_6	100% RDF as tablet 3	1.25	0.58	0.75	0.11	0.86
T_7	75% RDF as tablet 4	1.44	0.96	1.25	0.25	1.50
T_8	100% RDF as tablet 4	1.34	0.90	0.74	0.21	0.96
T_9	Soil test based POP recommendation	1.15	0.67	0.52	0.12	0.64
T_{10}	T_9 + secondary and micronutrient mixture	1.06	0.64	0.47	0.15	0.62
T_{11}	Control(No fertilizers)	0.99	0.35	0.32	0.05	0.37
SEm (±)		0.07	0.11	0.05	0.02	0.05
CD (0.05)		0.21	0.31	0.14	0.07	0.15

RDF- Recommended Dose of Fertilizers

The magnesium uptake in shoot, fruit and also total uptake were found to be significantly influenced by different treatments. The highest uptake in shoot was noticed in T_7 (1.25 g plant^{-1}). In fruit also T_7 (0.25 g plant^{-1}) recorded the highest uptake and T_8 (0.21 g plant^{-1}) was found to be on par. The total uptake was the highest in T_7 treatment (1.50 g plant^{-1}) which was significantly superior to all other treatments.

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4.5.6 Sulphur

With regard to sulphur content and uptake in shoot and fruit (Table 29), T_7 recorded the highest content of 0.57 % and 0.21 % respectively in shoot and fruit. With respect to uptake also, T_7 recorded the highest uptake of 0.47 and 0.06 g plant^{-1} respectively in shoot and fruit. In case of sulphur content in shoot T_7 was found to be on par with all other treatments except T_9, T_{10} and T_{11}.

Table 29. Effect of multinutrient tablets on the content and uptake of sulphur in tomato

Treatments	Treatment details	S content (%)		S uptake (g plant^{-1})		
		Shoot	Fruit	Shoot	Fruit	Total uptake
T_1	75% RDF as tablet 1	0.51	0.19	0.22	0.03	0.26
T_2	100% RDF as tablet 1	0.56	0.13	0.27	0.03	0.30
T_3	75% RDF as tablet 2	0.55	0.08	0.24	0.01	0.25
T_4	100% RDF as tablet 2	0.48	0.12	0.25	0.02	0.27
T_5	75% RDF as tablet 3	0.56	0.16	0.25	0.03	0.28
T_6	100% RDF as tablet 3	0.54	0.17	0.34	0.03	0.37
T_7	75% RDF as tablet 4	0.57	0.21	0.47	0.06	0.53
T_8	100% RDF as tablet 4	0.53	0.18	0.29	0.04	0.32
T_9	Soil test based POP recommendation	0.45	0.06	0.20	0.01	0.21
T_{10}	T_9 + secondary and micronutrient mixture	0.41	0.06	0.18	0.02	0.20
T_{11}	Control (No fertilizers)	0.26	0.09	0.08	0.01	0.09
SEm (±)		0.04	0.02	0.03	0.00	0.03
CD (0.05)		0.12	0.04	0.08	0.01	0.08

RDF- Recommended Dose of Fertilizers

The data pertaining to the content of sulphur in fruit revealed that T_7 (0.21 %) was on par with T_1 (0.19 %), T_6 (0.17 %) and T_8 (0.18 %). The lowest value was recorded in T_{11} (0.06 %).

With respect to shoot and fruit uptake, T_7 with 0.47 g plant^{-1} and 0.06 g plant^{-1} recorded the highest value respectively and total uptake of S, the highest value was recorded in T_7 (0.53 g plant^{-1}) which was found to be significantly superior to all other treatments.

4.5.7 Boron

On analyzing the result of B content and uptake in shoot and fruit represented in Table 30 it was noticed that the B concentration in shoot was the highest in T_7 (3.94 %) which was on par with T_1(3.42 mg kg $^{-1}$), T_2 (2.91 mg kg $^{-1}$) , T_3 (3.87 mg kg $^{-1}$), T_4 (3.48 mg kg $^{-1}$), T_5 (3.75 mg kg $^{-1}$) and T_6 (3.94 mg kg $^{-1}$) and the lowest value was recorded by T_{11} (1.08 mg kg $^{-1}$).

With respect to B content in fruit T_7 recorded the highest value of 15.02 mg kg $^{-1}$ which was on par with T_3 (12.01 mg kg $^{-1}$), T_4 (14.12 mg kg $^{-1}$), T_5 (12.31 mg kg $^{-1}$), T_8 (14.12 mg kg $^{-1}$), T_9 (13.21 mg kg $^{-1}$), and T_{10} (13.52 mg kg $^{-1}$). The lowest value was recorded by T_{11} (9.91 mg kg $^{-1}$).

Table 30. Effect of multinutrient tablets on the content and uptake of boron in tomato

Treatments	Treatment details	B content (mg kg $^{-1}$)		B uptake (mg plant^{-1})		
		Shoot	Fruit	Shoot	Fruit	Total uptake
T_1	75% RDF as tablet 1	3.42	10.21	0.15	1.91	2.05
T_2	100% RDF as tablet 1	2.91	10.81	0.14	2.21	2.35
T_3	75% RDF as tablet 2	3.87	12.01	0.17	2.69	2.86
T_4	100% RDF as tablet 2	3.48	14.12	0.18	3.21	3.39
T_5	75% RDF as tablet 3	3.75	12.31	0.17	2.11	2.28
T_6	100% RDF as tablet 3	3.94	11.71	0.24	2.31	2.54
T_7	75% RDF as tablet 4	3.99	15.02	0.35	3.92	4.27
T_8	100% RDF as tablet 4	2.55	14.12	0.14	3.14	3.28
T_9	Soil test based POP recommendation	1.29	13.21	0.05	2.44	2.49
T_{10}	T_9 + secondary and micronutrient mixture	1.65	13.52	0.07	3.08	3.15
T_{11}	Control(No fertilizers)	1.08	9.91	0.04	1.69	1.73
SEm (±)		0.40	1.033	0.02	0.23	0.23
CD (0.05)		1.18	3.049	0.07	0.68	0.67

RDF – Recommended Dose of Fertilizers

Boron uptake in tomato was also found to be significantly influenced by various treatments. The highest B uptake of 0.35 mg plant^{-1} in shoot was observed in T_7. With regard to uptake by fruit T_7 recorded the highest value of 3.92 mg plant^{-1} and was on par with T3 (2.69 mg plant^{-1}), T_4 (3.21 mg plant^{-1}), T_8 (3.14 mg plant^{-1}) and T_{10} (3.08 mg plant^{-1}). Regarding total uptake the highest value was noticed in T_7 with 3.92 mg plant^{-1} and 4.27 mg plant^{-1} respectively.

4.5.8 Zinc

A significant difference was noticed among different treatments with respect to the zinc content of tomato (table 31). In shoot, the highest Zn content was recorded in T_7 (30.27 mg kg^{-1}) which was found to be on par with T_8 (26.80 mg kg^{-1}). The lowest value was recorded in T_{11} (9.87 mg kg^{-1}). Similar trend was followed in case of Zn content in fruit where the highest value was noticed by T_7 with 36.67 mg kg^{-1} which was on par with T_6 (32.80 mg kg^{-1}) and T_8 (34.63 mg kg^{-1}).

Table 31. Effect of multinutrient tablets on the content and uptake of zinc in tomato

Treatments	Treatment details	Zn content (mg kg^{-1})		Zn uptake (mg plant^{-1})		
		Shoot	Fruit	Shoot	Fruit	Total uptake
T_1	75% RDF as tablet 1	14.40	27.73	0.63	5.19	5.33
T_2	100% RDF as tablet 1	14.53	30.93	0.70	6.26	6.40
T_3	75% RDF as tablet 2	13.47	27.07	0.58	6.07	6.23
T_4	100% RDF as tablet 2	15.73	25.33	0.82	5.41	5.59
T_5	75% RDF as tablet 3	12.13	30.13	0.55	6.39	6.56
T_6	100% RDF as tablet 3	14.13	32.80	0.86	6.47	6.71
T_7	75% RDF as tablet 4	30.27	36.67	2.62	10.19	10.54
T_8	100% RDF as tablet 4	26.80	34.63	1.49	7.72	7.86
T_9	Soil test based POP recommendation	13.33	26.80	0.60	4.93	4.98
T_{10}	T_9 + secondary and micronutrient mixture	13.73	27.60	0.61	6.32	6.39
T_{11}	Control (No fertilizers)	9.87	25.73	0.32	3.46	3.50
SEm (±)		1.40	1.43	0.10	0.34	0.34
CD (0.05)		4.13	4.22	0.29	1.00	1.01

RDF- Recommended Dose of Fertilizers

With respect to uptake T_7 recorded the highest uptake in shoot, fruit and total uptake with 2.62 mg kg^{-1}, 10.19 mg kg^{-1} and 10.54 mg kg^{-1} respectively, which was found to be significantly superior to all other treatments.

4.6 EFFECT OF MULTINUTRIENT TABLETS ON QUALITY OF TOMATO

4.6.1 Total soluble solids

The effect of multinutrient tablets on total soluble solids in tomato is shown in table 32.It was observed that treatments had no significant influence on TSS content of tomato. It ranges from 4.17 % (T_{11}) to 5.83% (T_3).

Table 32. Effect of multinutrient tablets on quality of tomato

Treatments	Treatment details	TSS %	Lycopene (μg g^{-1})	Ascorbic acid (mg 100g^{-1})
T_1	75% RDF as tablet 1	4.83	13.52	24.67
T_2	100% RDF as tablet 1	5.67	14.39	25.00
T_3	75% RDF as tablet 2	5.83	13.02	25.33
T_4	100% RDF as tablet 2	5.50	13.77	26.33
T_5	75% RDF as tablet 3	5.50	14.60	25.00
T_6	100% RDF as tablet 3	5.67	15.35	26.00
T_7	75% RDF as tablet 4	5.70	16.73	26.00
T_8	100% RDF as tablet 4	5.33	13.94	26.00
T_9	Soil test based POP recommendations as straight fertilizers	4.17	13.07	25.33
T_{10}	T_9 + secondary and micronutrient mixture	4.83	11.98	24.00
T_{11}	Control (No fertilizers)	4.17	11.03	25.33
SEm (±)			0.27	
CD (0.05)		NS	0.79	NS

RDF – Recommended Dose of Fertilizers

4.6.2 Lycopene

It was observed that the the multinutrient tablets had significant influence on lycopene content of tomato (Table 32). The highest lycopene content was noticed in treatment T_7 with a mean value of 16.73 µg g^{-1}. It was found to be significantly superior to all other treatments. The lowest value was noticed in T_{11} (11.03 µg g^{-1}).

4.6.3 Ascorbic acid

The application of multinutrient tablets did not show any significant effect on ascorbic acid content of tomato (Table 32). The highest content was recorded in the treatment T_4 (26.33 mg $100g^{-1}$) and the lowest content was observed in T_{10} (24 mg $100g^{-1}$).

4.7 NUTRIENT USE EFFICIENCY

4.7.1 Agronomic efficiency

The agronomic efficiency of major nutrients are given in table 33. The treatment T_7 receiving 75% of recommended dose of fertilizers as tablet 4 recorded the highest agronomic efficiency for nitrogen (58.77 g g^{-1}), phosphorus (55.10 g g^{-1}) and potassium (79.35 g g^{-1}) and T_8 was found to be on par with T_7.

4.7.2 Apparent nutrient recovery

The apparent nutrient recovery of major nutrients are given in Table 33. The highest recovery percentage was recorded by T_7 for N (96. 87%), P (90.53 %) and K (94.95 %).

4.7.3 Partial factor productivity

Table 33 shows the partial factor productivity from the applied nutrients. It revealed that treatment T_7 was found to be superior (27.71 g g^{-1}) while treatment T_1 (25.82 g g^{-1}), T_2 (25.50 g g^{-1}) were found to be on par.

Table 33: Effect of multinutrient tablets on nutrient use efficiency

Treatments	Treatment details	Agronomic efficiency			Apparent nutrient recovery			Partial factor productivity
		N	P	K	N	P	K	
T_1	75% RDF as tablet 1	16.36	15.34	22.09	32.66	19.56	19.57	25.82
T_2	100% RDF as tablet 1	22.47	21.06	30.33	35.78	39.38	24.79	20.17
T_3	75% RDF as tablet 2	35.40	33.18	47.79	38.52	47.21	31.20	25.50
T_4	100% RDF as tablet 2	27.05	25.35	36.51	41.80	51.20	38.54	18.52
T_5	75% RDF as tablet 3	24.69	23.15	33.34	40.65	43.09	29.53	24.30
T_6	100% RDF as tablet 3	28.13	26.38	37.98	55.30	54.21	40.34	18.61
T_7	75% RDF as tablet 4	58.77	55.10	79.35	96.87	90.53	94.95	27.71
T_8	100% RDF as tablet 4	56.42	52.89	76.17	57.20	47.65	54.52	20.50
T_9	KAU POP recommendations	33.87	31.75	45.72	29.71	32.39	32.61	24.75
T_{10}	T_9 + secondary and micronutrient mixture	45.89	43.02	61.95	27.09	34.75	34.42	21.50
T_{11}	Control (No fertilizers)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SEm (±)		2.93	2.74	3.94	4.08	8.86	3.34	0.75
CD (0.05)		8.76	8.22	11.85	12.05	26.66	10.04	2.26

4.8 B:C ratio

Benefit cost was significantly influenced by the treatments (Table 34). The highest B: C ratio of 1.17 was recorded in treatment T_7 receiving 75 % of recommended dose of fertilizers as tablet 4 and T_8 was found to be on par. The lowest BC ratio was recorded by T_{11} (0.82).

Table 34: Effect of multinutrient tablets on B:C ratio of tomato

Treatments	Treatment details	B:C ratio
T_1	75% RDF as tablet 1	0.90
T_2	100% RDF as tablet 1	0.93
T_3	75% RDF as tablet 2	1.00
T_4	100% RDF as tablet 2	0.96
T_5	75% RDF as tablet 3	0.95
T_6	100% RDF as tablet 3	0.97
T_7	75% RDF as tablet 4	1.17
T_8	100% RDF as tablet 4	1.14
T_9	Soil test based POP recommendations	1.03
T_{10}	T_9 + secondary and micronutrient mixture	1.09
T_{11}	Control (No fertilizers)	0.82
SEm (±)		0.03
CD (0.05)		0.079

RDF – Recommended Dose of Fertilizers

DISCUSSION

5. DISCUSSION

A study was conducted to develop multinutrient fertilizer tablets containing major, secondary and micronutrients and to evaluate its effect on nutrient use efficiency, yield and quality of tomato. The physical and chemical properties, nutrient content and nutrient release pattern of multinutrient tablets were studied. The influence of multinutrient tablets on nutrient availability in soil, nutrient use efficiency, yield and quality of tomato were also studied and the results obtained are discussed in this chapter.

5.1 DEVELOPMENT OF MULTINUTRIENT FERTILIZER TABLETS

The multinutrient tablets containing major, secondary and micro nutrients were prepared with different combination of compatible fertilizer materials (Urea, dicalcium phosphate, potassium sulphate, calcium sulphate, magnesium oxide, zinc EDTA, boric acid, diammonium phosphate, muriate of potash, magnesium sulphate, borax, neem coated urea, factomphos, phosphogypsum and zinc sulphate), binding agents (methyl cellulose, gelatin and polyvinyl pyrrolidone) and filler material (clay). Similar slow release NPK fertilizer tablets were prepared with urea formaldehyde, ammonium sulphate, amophos, rock phosphate, muriate of potash, phosphogypsum and clay (Jagadeeswaran *et al*., 2005). Ni *et al*. (2012) also developed a novel multinutrient slow release fertilizer tablet with KH_2PO_4, urea, borax, guar gum, humic acid and attapulgite clay. Fernandez-Sanjurjo *et al*. (2014) prepared compressed fertilizer tablets containing N, P and K using calcium phosphate, potassium sulphate, urea formaldehyde and magnesite.

5.1.1 Compatibility of multinutrient fertilizer tablets

Compatibility study of multinutrient tablets revealed that all the tablets developed were non hygroscopic except T_8 and T_9 but caking was observed in T_2 and T_6. There was no noxious gas formation in any of the tablet blends but colour change was observed in T_6, T_8 and T_9. This might be attributed to the physical make up of fertilizer materials, binding agents and clay used which were chemically compatible, having less moisture content and good drying maintained during the preparation to avoid caking and excessive hygroscopicity. Hignett (1985) reported that caking of fertilizers may be due to internal chemical reaction and also due to the presence of excessive moisture and heat or temperature during preparation. Chemical incompatibility of materials may also form heat development of blends, development of wetness, gas evolution or caking (Hignett, 1985). Kirilov (2005) also observed caking of fertilizer mixtures containing triple super phosphate and potassium sulphate due to the presence of free phosphoric acid from triple super phosphate.

5.1.2 Properties of multinutrient fertilizer tablets.

The physical and chemical properties of multinutrient tablet studies showed that the tablets T_3, T_4, T_5, T_7, T_8 and T_9 were hard and stable while others were soft and unstable and the disintegration time ranged between 10 to 12 hours in all the tablets except T_1, T_2 and T_6. This might be due to the high compactness and compressibility of multinutrient tablets and also the stability of binding agents used. The moisture content of tablets ranged between 6.46 and 9.08 %. High moisture content contribute to instability, caking tendency, hygroscopicity and easy disintegration of tablets.

The pH of tablets T_1, T_2 and T_3 were slightly alkaline whereas tablets T_4, T_5, T_6, T_7, T_8 and T_9 were slightly acidic. The alkaline or acidic nature of multinutrient tablets might be due to the presence of basic or acidic ions. The pH of aqueous solutions was increased by urea (Bull *et al.*, 1964). Merhaut *et al.* (2006) observed that the pH of leachate from controlled release fertilizers was found to be variable but constantly acidic this might be due to the influence of fertilizers used.

The electrical conductivity of multinutrient tablets ranged between 9.75 and 29.10 dS m^{-1}. This might be attributed to the presence of soluble salts in the multinutrient tablets. Merhaut *et al.* (2006) reported an elevation in electrical conductivity of leachates from controlled release fertilizers. This is due to the release of dissolved salts from the fertilizers.

5.1.3 Nutrient content of multinutrient fertilizer tablets

The various multinutrient tablets developed contains 7.69 to 8.69 % nitrogen, 4.43 to 4.82 % phosphorus, 2.1 to 3.2 % potassium, 5.81 to 6.45 % calcium, 0.65 to 0.68 % magnesium, 2.37 to 3.27 % sulphur, 0.21 to 0.22 % boron and 0.21 to 0.25 % zinc. Similar results were reported by Ni *et al.* (2012) in a novel multinutrient fertilizer tablet which contain 17.9 % N, 11.3 % P_2O_5 and 8.2 % K_2O content. Similar findings were reported by Merhaut *et al.* (2006) in controlled release fertilizers like osmocote, nutricote, polyon and multicote and Fernandez-Sanjurjo *et al.* (2014) in two compressed N, P, K fertilizer tablets having an 11-18-11 and 8-8-16 composition.

5.2 NUTRIENT RELEASE PATTERN OF MULTINUTRIENT FERTILIZER TABLETS

5.2.1 Soil pH

There was no significant influence of different tablets on pH of soil during incubation, however a slight increase was noticed on 15^{th} day of incubation and thereafter it decreased in all treatments. Fernandez-Sanjurjo *et al.* (2014) also conducted similar studies using compressed NPK fertilizer tablets and observed significant increase in pH.

5.2.2 Soil EC

A significant difference was observed with respect to EC of the soil due to the application of multinutrient tablets during the incubation period (fig 4). The EC was found to be increased upto 75^{th} day and thereafter decreasing towards the end of incubation study. However the EC values were within the permissible limit. This might be due to the continuous release of nutrients as ions from the multinutrient tablets. These findings corroborate with the findings of Merhaut *et al.* (2006) who reported an increased electrical conductivity due to the application of controlled release fertilizer osmocote. Fernandez-Sanjurjo *et al.* (2014) also reported similar findings of increase in EC due to the application of compound NPK fertilizer tablets and thereafter decreasing rapidly.

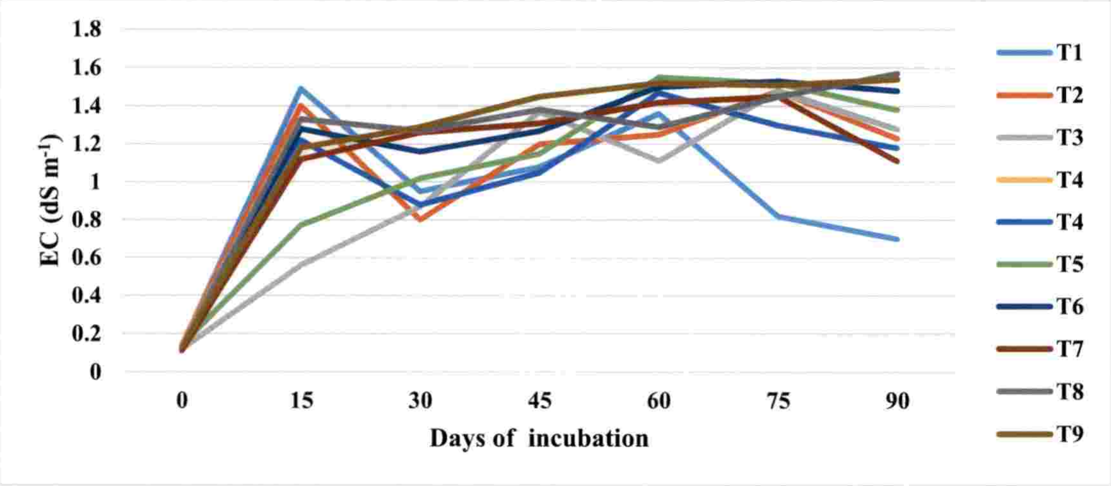

Fig 4: Effect of multinutrient tablets on EC of soil

5.2.3 Soil available N

The available nitrogen in soil was influenced significantly by multinutrient tablets as presented in Fig 5. The available nitrogen content in soil gradually increased upto 60th day of incubation in T_1, T_2, T_6, T_7 and T_9 and 75th day of incubation in T_3, T_4,

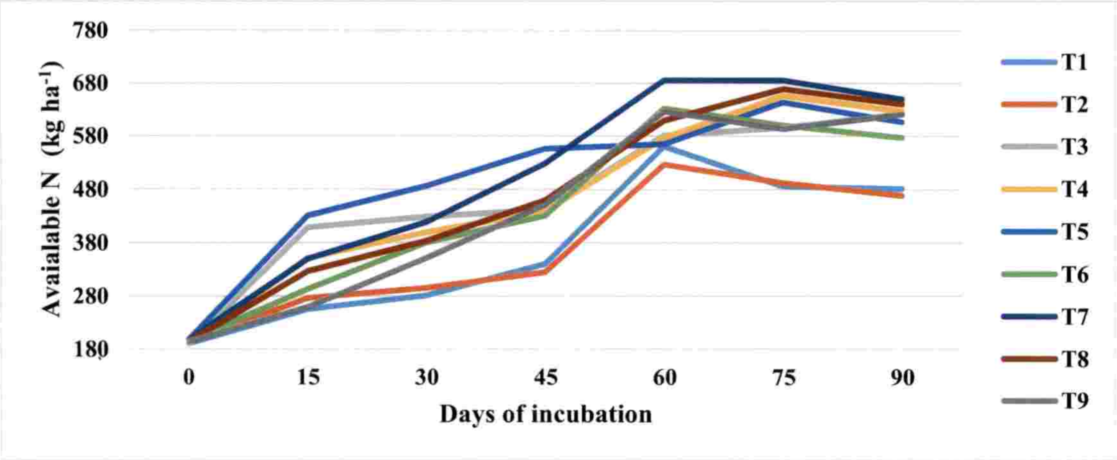

Fig 5: Effect of multinutrient tablets on available nitrogen

T_5 and T_8. The highest release of available nitrogen was recorded in T_7 on 60th day (685.74 kg ha^{-1}).

This might be due to the slow releasing property of neem coated urea used in the tablet. Merhaut *et al.* (2006) reported that the release of ammoniacal and nitrate nitrogen from controlled release fertilizers were found to be increased from 5th week to 9th week in a leachate study and a decline from 10th week onwards. Similar findings were reported by Guo et al. (2006) in slow release urea formaldehyde with super absorbent. Guan *et al.* (2013) reported that attapulgite coated fertilizers minimised the burst release effects of nutrients and allowed gradual release of N and P which will provide better synchronization between nutrient availability and plant needs of nutrients.

5.2.4 Soil available P

The effect of different multinutrient tablets on release of available phosphorus in soil is given in fig 6. The available P in soil showed a gradual increase upto 60th day. Phosphorus concentrations in leachates from controlled release fertilizers *viz.*, osmocote, nutricote, polyon and multicote fluctuated throughout the study but were higher during the first 10 weeks (70th day) and later declined (Merhaut *et al.*, 2006).

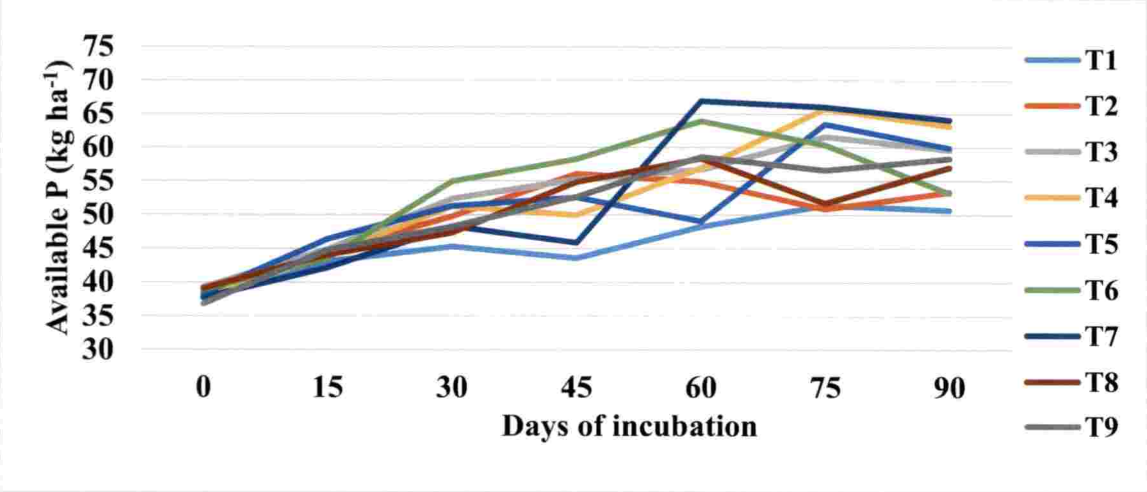

Fig 6: Effect of multinutrient tablets on available phosphorus

Fernandez-Sanjurjo *et al.* (2014) also reported an increase in available P concentration in soil column at the end of incubation due to the application of compressed NPK fertilizer tablets.

5.2.5 Soil available K

The various treatments had significant influence on available potassium in the soil (Fig 7). A gradual increase in available K was observed from 15th day to 90th day of incubation. The highest available K was recorded in T_7. Merhaut *et al.* (2006) also reported the availability of potassium from the controlled release fertilizers which were found to be higher during the first 20 weeks of study. Fernandez-Sanjurjo *et al.* (2014) also observed a steady release of K^+ in soil due to the application of compound NPK fertilizer compared to control.

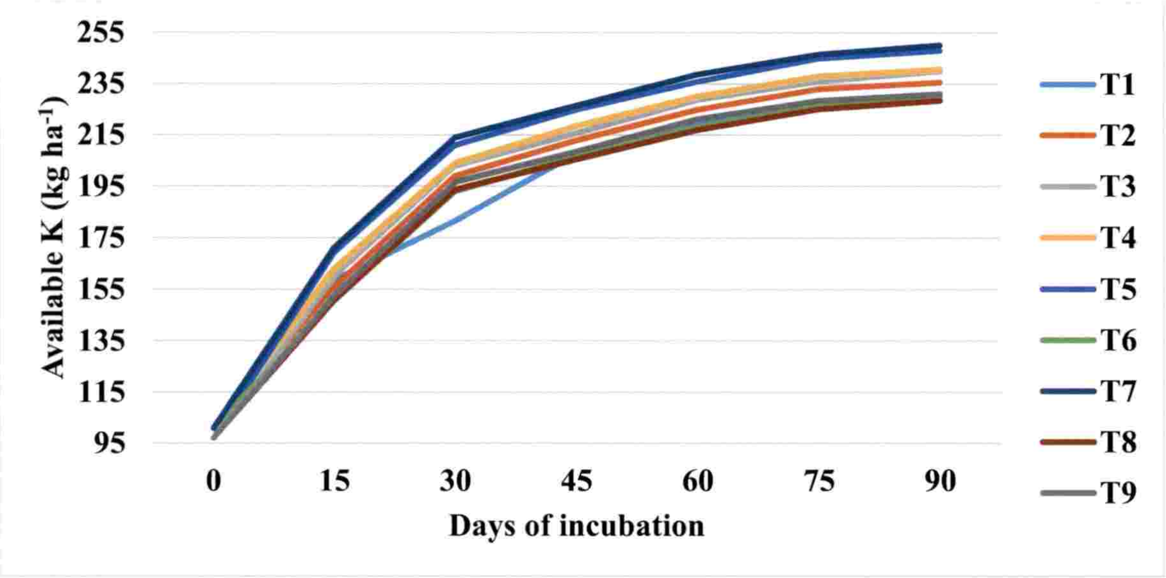

Fig 7: Effect of multinutrient tablets on available potassium

5.2.6 Soil exchangeable Ca

The exchangeable Ca in soil was significantly influenced by the application of multinutrient tablets (fig 8). A gradual increase in Ca was noticed in 15th day to 90th day of incubation. The highest exchangeable Ca was recorded in T_7 on 75th day (474 mg kg^{-1}). Calcium release from compressed fertilizer tablet containing calcium phosphate, potassium sulfate, N as amide, and urea-formaldehyde and magnesium carbonate were found to be increased throughout the experiment (Fernandez-Sanjurjo *et al.*, 2014).

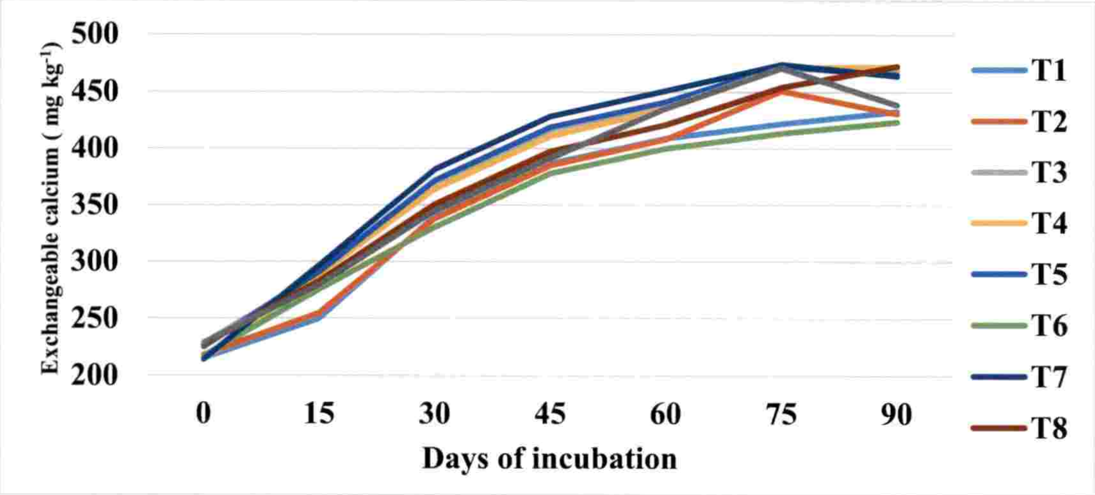

Fig 8: Effect of multinutrient tablets on exchangeable calcium

5.2.7 Soil exchangeable Mg

The application of multinutrient tablets had significant influence on exchangeable Mg in the soil (Fig 9). In initial soil it varied form 37.85 mg kg^{-1} to 52

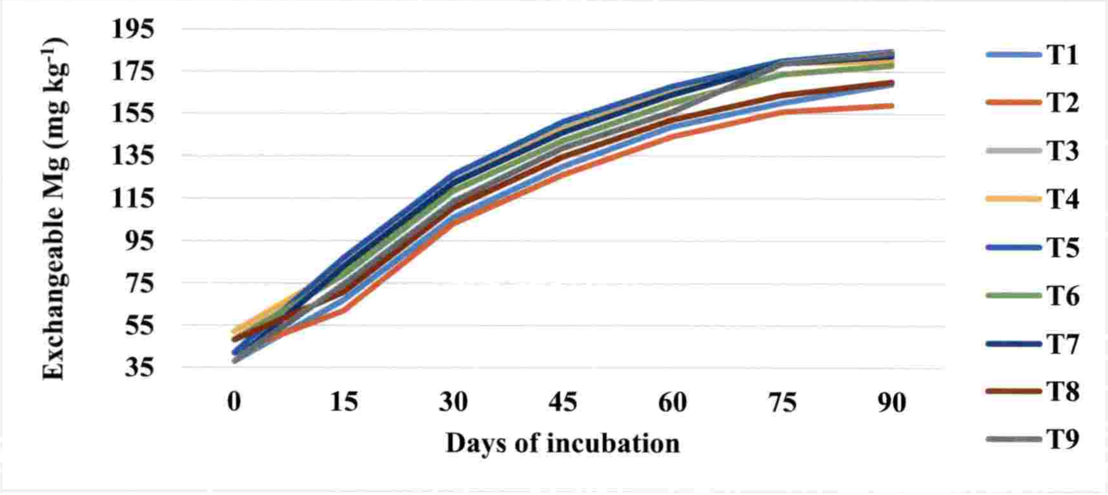

Fig 9: Effect of multinutrient tablets on exchangeable magnesium

mg kg^{-1}. A gradual increase in Mg content was observed from 15^{th} to 90^{th} day of incubation. The highest available Mg was recorded in T_7. Broschat (1996) reported that the release of magnesium from resin coated magnesium sulphate was found to be increased from initial day to the end of incubation. The percent release of magnesium from controlled release fertilizers was found to be increased from 0^{th} day to end of study period (Broschat and Moore, 2007). Similar results were also reported by Fernandez-Sanjurjo *et al*., (2014).

5.2.8 Soil available S

The available sulphur in soil was significantly influenced by the application of multinutrient tablets (fig 10). In initial soil the available S ranged between 1.0 mg kg^{-1} and 1.17 mg kg^{-1}. A gradual increase in available S content was observed from 15^{th} to 90^{th} day of incubation. The highest available S content was recorded in T_5 throughout the incubation period. The application of sulphate form of fertilizers like magnesium sulphate would have enhanced the availability of sulphate in soil. Similar results were reported by Parvathy (2018).

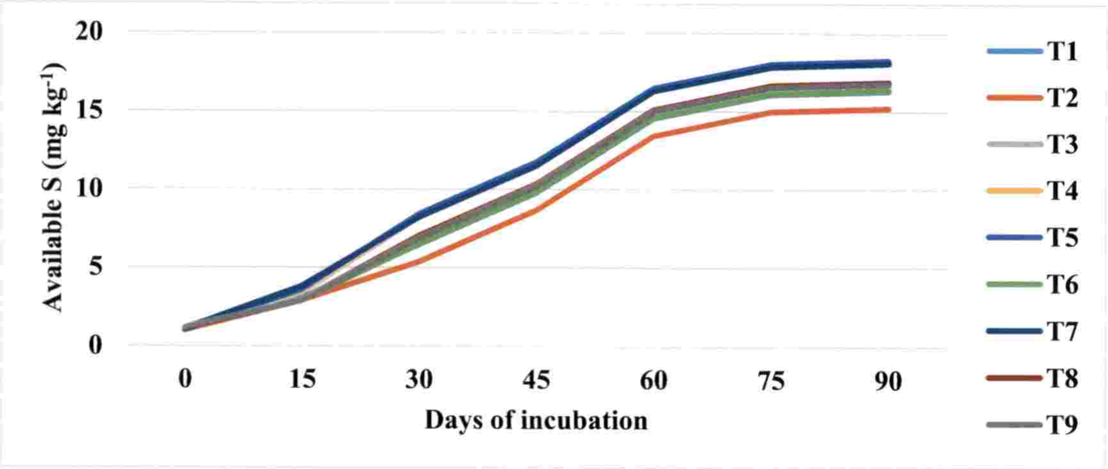

Fig 10: Effect of multinutrient tablets on available sulphur

5.2.9 Soil available B

The effect of multinutrient tablets on available boron in soil is given in fig 11. A gradual increase in available B was observed from 15th to 90th day of incubation. The highest available B was recorded in T_7. The release pattern of slow release fertilizer containing borax was found to release about 95.4 % by the end of incubation study (Xie, 2011).

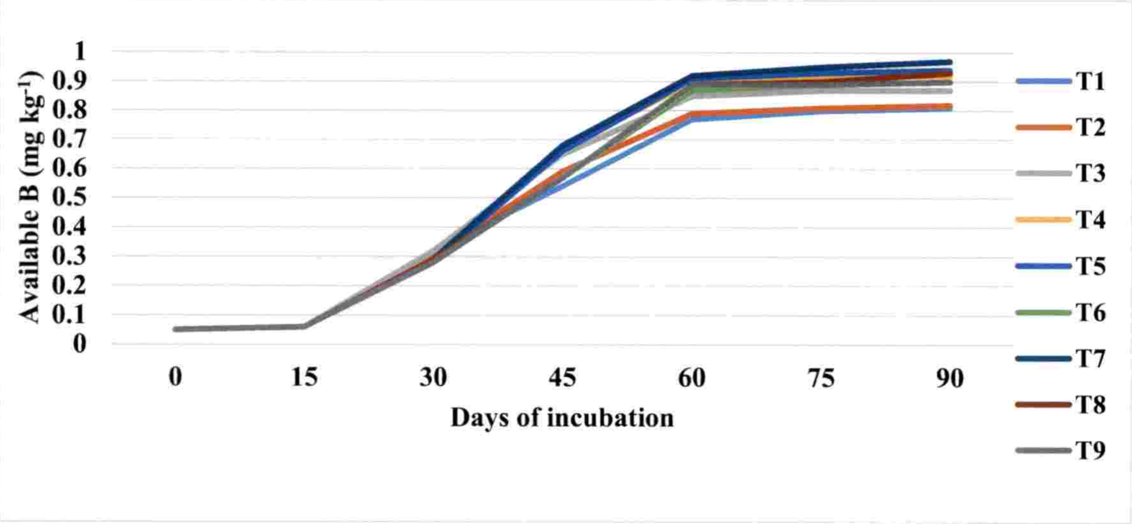

Fig 11: Effect of multinutrient tablets on available boron

5.2.10 Soil available Zn

The available zinc in soil was significantly influenced by the application of multinutrient tablets as given in fig 12. A gradual increase in available Zn content was observed from 15th to 90th day of incubation. The highest available Zn content was recorded in T_7 upto 60th day of incubation. Yuvaraj and Subramanian (2015) reported that the release of zinc from encapsulated zinc fertilizer was found to be increased compared to that of conventional zinc fertilizers.

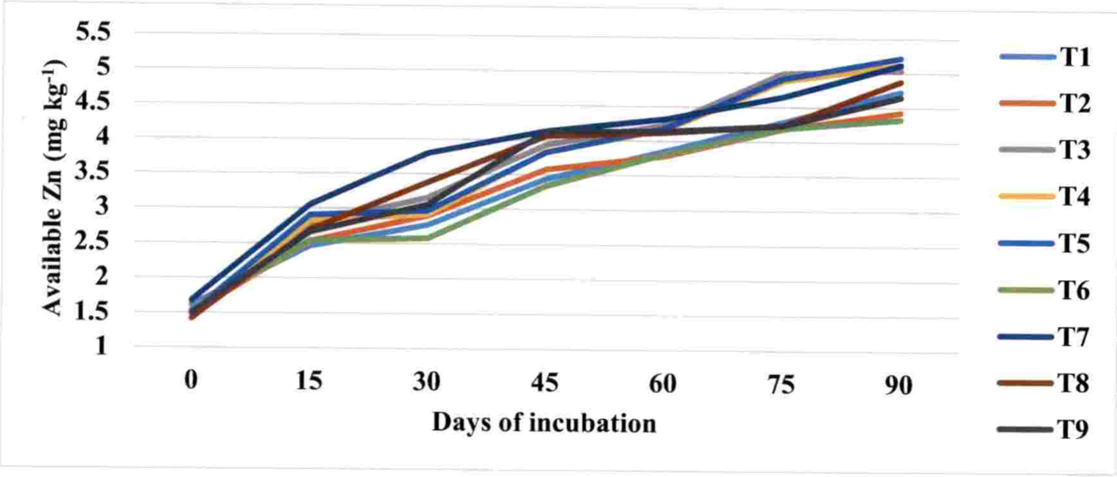

Fig 12: Effect of multinutrient tablets on available zinc

5.3 EFFECT OF MULTINUTRIENT TABLETS ON GROWTH AND YIELD PARAMETERS

Application of multinutrient tablets had a significant influence on growth parameters like plant height, number of branches per plant and number of days to flowering and fruiting.

The treatment T_7 which received 75 % of recommended dose of fertilizers as tablet 4 containing neem coated urea, factomphos, muriate of potash, magnesium oxide, phosphogypsum, zinc sulphate, borax and binding agent methyl cellulose recorded the highest plant height (Fig 13) and maximum number of branches per plant (Fig 14) and was superior to all other treatments. This might be due to the application of tablet form of fertilizers that release the nutrients slowly over the entire growth period of crop. Abou-Zied *et al.* (2014) reported similar results in maize and soybean, where slow release sulphur coated urea was used. Similar result were also reported by Ali *et al.* (2016), Shivay *et al.* (2016) and Bhanuvally *et al.* (2017).

From the study (fig. 15), it was observed that treatment (T_9) showed early flowering and fruiting which was followed by T_2. This might be due to the availability of different macro and micro nutrients at initial period of crop growth to initiate flowering and supplementation of nutrients in optimal doses that enhances flowering and thus reduces the duration of flowering thereby increasing the reproductive cycle as reported by Jin *et al*., (2015).

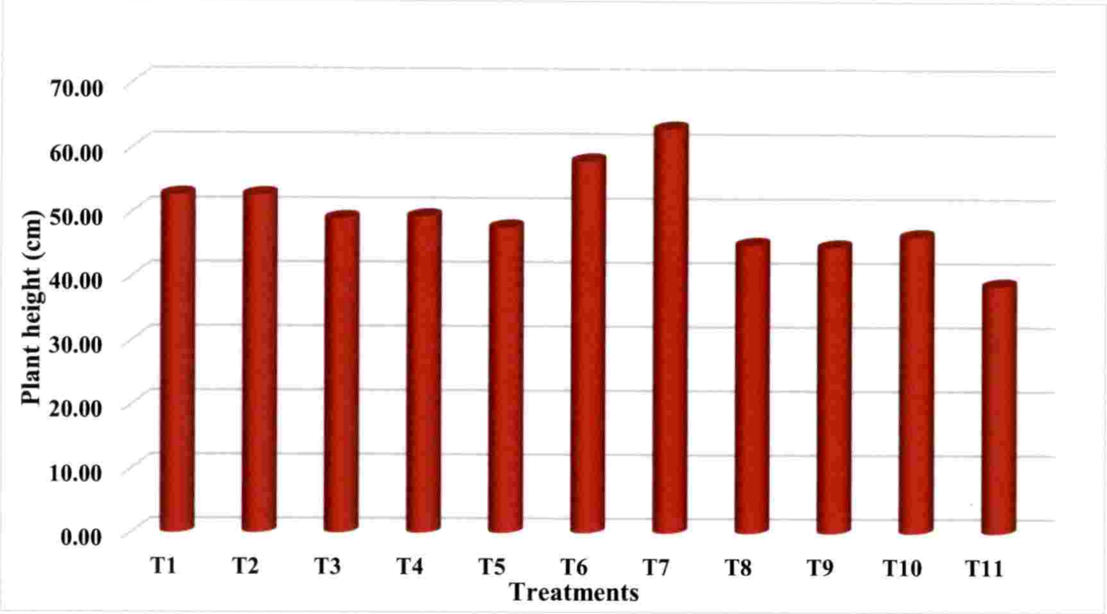

Fig 13: Effect of multinutrient tablets on plant height of tomato

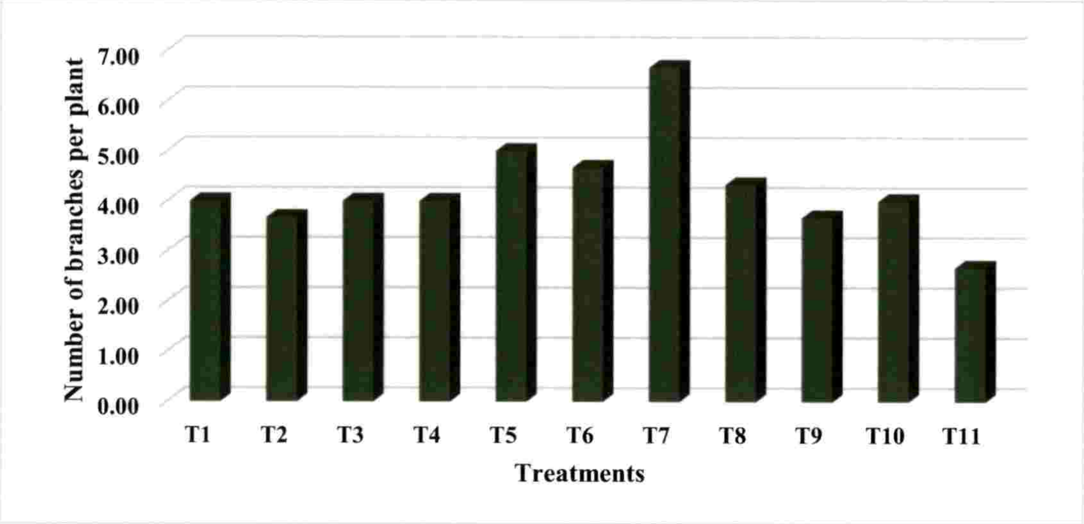

Fig 14: Effect of multinutrient tablets on number of branches per plant

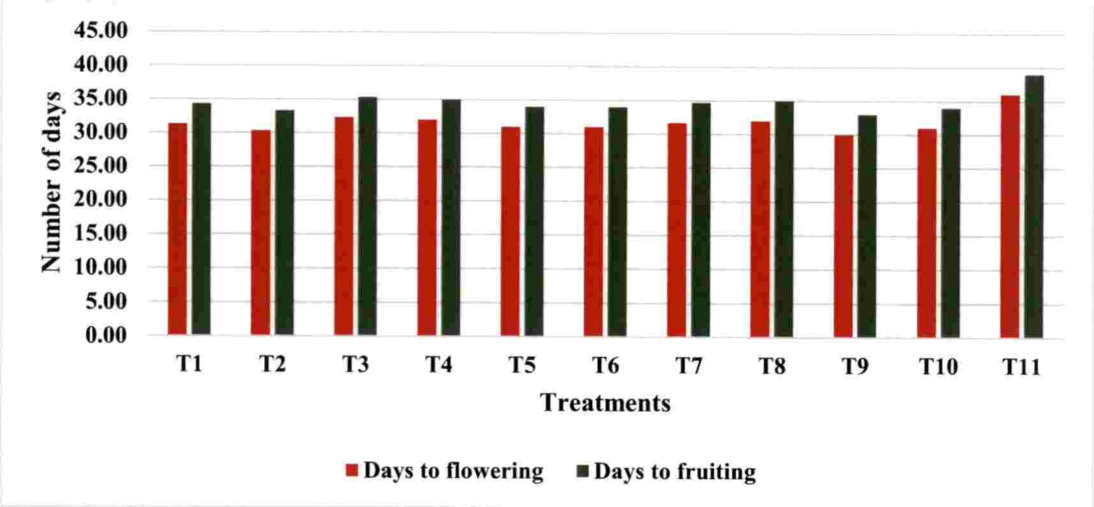

Fig 15: Effect of multinutrient tablets on number of days to flowering and fruiting

The effect of multinutient tablets had significant influence on yield and yield attributes of tomato except for fruit girth. The treatment (T_7) receiving 75 % of recommended dose of fertilizers as tablet 4 registered maximum number of fruits per plant (16), fruit weight (33.77 g) (fig.16) and fruit yield (502.02 g plant^{-1}) (fig 17). which was followed by treatment T_8. This might be attributed to maximum uptake of nutrients by crop that are released from the tablets. Increase in rhizome yield was reported by Jagadheeswaran *et al.* (2008) in turmeric by the application of tablet form of fertilizers. Ziadi *et al.* (2011) also reported that controlled-release urea increased the yield of potato. These findings are in line with those reported by Guan *et al.* (2013) in maize due to the application of slow release attapulgite coated fertilizers. This is attributed to the slow release of nutrients from coated fertilizers which allowed a better synchronization between nutrient availability and plant needs, thereby increasing crop production.

The tomato yield was significantly increased by 42.66 % in T_7 over control. This might be due to the increased number of fruits and fruit weight in the same treatment. Similar trends of results were reported by Guan *et al.* (2013) in maize due to the application of attapulgite coated fertilizers.

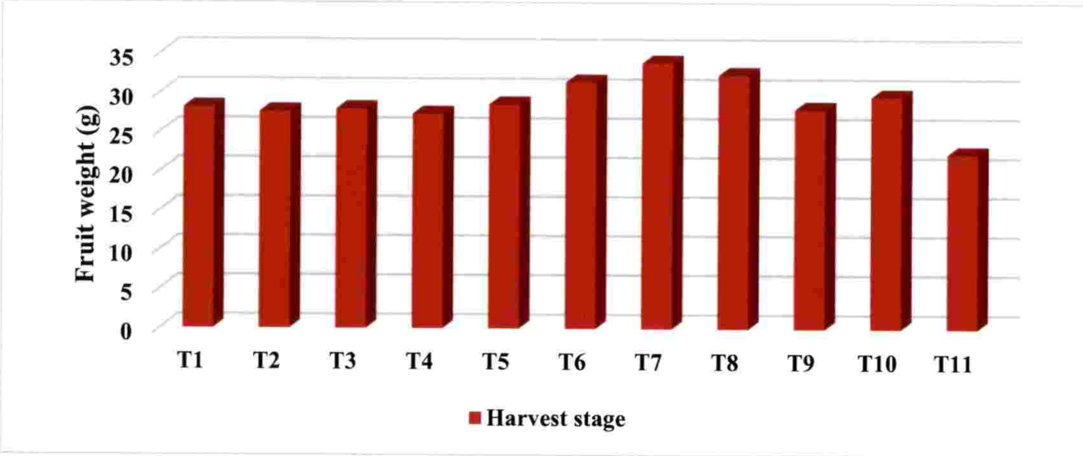

Fig 16: Effect of multinutrient tablets on fruit weight of tomato

Hutchinson *et al*. (2002) found significantly improved potato tuber yield due to application of polymer coated urea. Similar results were obtained by Guan *et al.* (2013) in *Radix hedysari* due to application of attapulgite coated fertilizrs. This is mainly attributed to the timely release of nutrients from coated fertilizers and reduced nutrient loss in early growing stage whch provided nutrients in the middle and late growing stage.

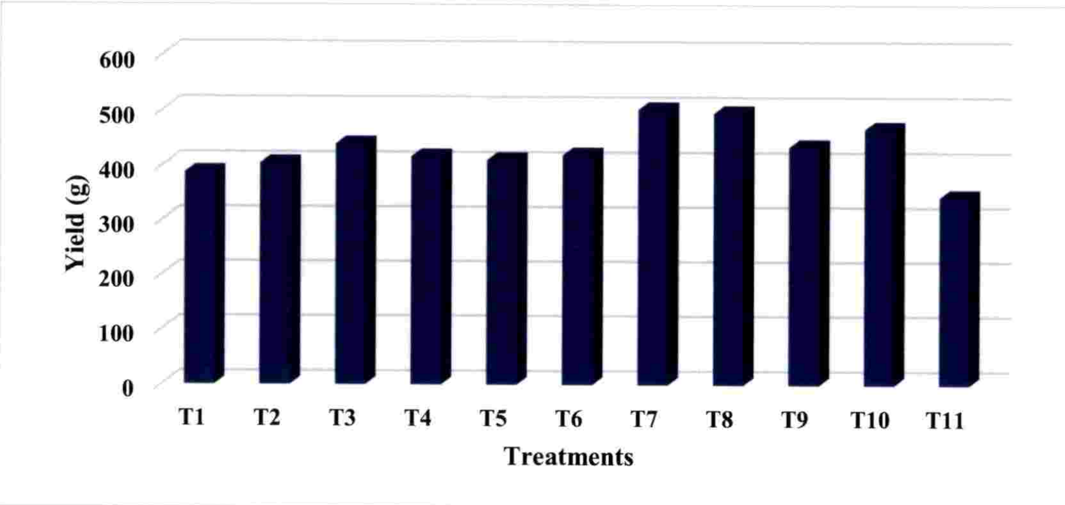

Fig 17: Effect of multinutrient tablets on yield of tomato

Yield was found to be positively correlated with available nitrogen ($p < 0.01$, $r = 0.823$), available phosphorus ($p < 0.05$, $r = 0.710$), available potassium ($p < 0.01$, $r = 0.814$), available calcium ($p < 0.01$, $r = 0.760$),available boron ($p < 0.01$, $r = 0.764$) and available zinc ($p< 0.01$, $r = 0.770$) in soil and also with the uptake of nitrogen ($p <0.05$, $r = 0.733$), phosphorus uptake ($p < 0.05$, $r = 0.716$), calcium uptake ($p < 0.01$, $r = 0.856$), magnesium uptake ($p <0.01$, $r = 0.740$), sulphur uptake ($p < 0.05$, $r = 0.634$), boron uptake ($p <0.01$, $r = 0.864$) and uptake of zinc ($p < 0.01$, $r = 0.824$) nutrients. The availability of nutrients in soil lead to uptake of nutrients by plants that ultimately increased the yield.

5.4 EFFECT OF MULTINUTRIENT TABLETS ON SOIL PROPERTIES AND NUTRIENT AVAILABILITY

5.4.1 Soil pH

With respect to soil pH no significant difference was observed between the treatments at both the stages. The pH of soil was found to be slightly acidic in all the treatments and was decreased from 1 MAP to harvest.

5.4.2 Soil EC

The EC of soil was found to be influenced significantly by the application of multinutrient tablets and T_6 recorded the highest EC at 1 MAP and at harvest (Fig. 18). This might be due to the continuous release of nutrients as ions from the tablets. However the EC of soil was decreased from 1 MAP to harvest and which was found to be at normal safe level. Increase in EC due to the release of nutrients from slow release fertilizer osmocote was reported by Husby *et al.* (2003) and Merhaut *et al.* (2006).

5.4.3 Soil organic carbon

There was no significant difference observed between the treatments with respect to organic carbon status of soil. the organic carbon % in soil was found to decreasefrom 1 MAP to harvest stage. This decrease is attributed to the uptake of nutrients by the crop.

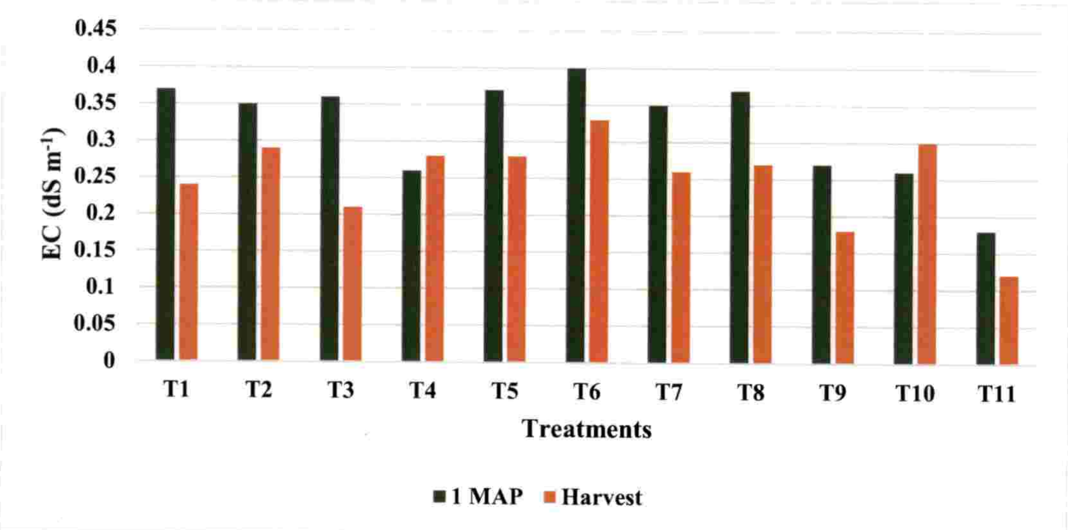

Fig 18 : Effect of multinutrient tablets on EC of soil at different stages

5.4.4 Available nitrogen

The available nitrogen of the soil was significantly influenced by different treatments (Fig 19). The highest available nitrogen was recorded by treatment T_6 at one month after planting and T_8 at harvest. Slow release of nitrogen from tablets coupled with reduced losses by volatilization and leaching maintained nitrogen availability in soil as reported by Jagadheeswaran *et al.* (2007). Similar results were reported in rice (Yang *et al.*, 2012) in rice. The available N content in all the treatments declined by the end of the growing season compared with initial content at sowing and at 1 MAP, which may be due to the increased uptake of nitrogen by crop. These findings are in line with those reported by Guan *et al.* (2013) in maize crop.

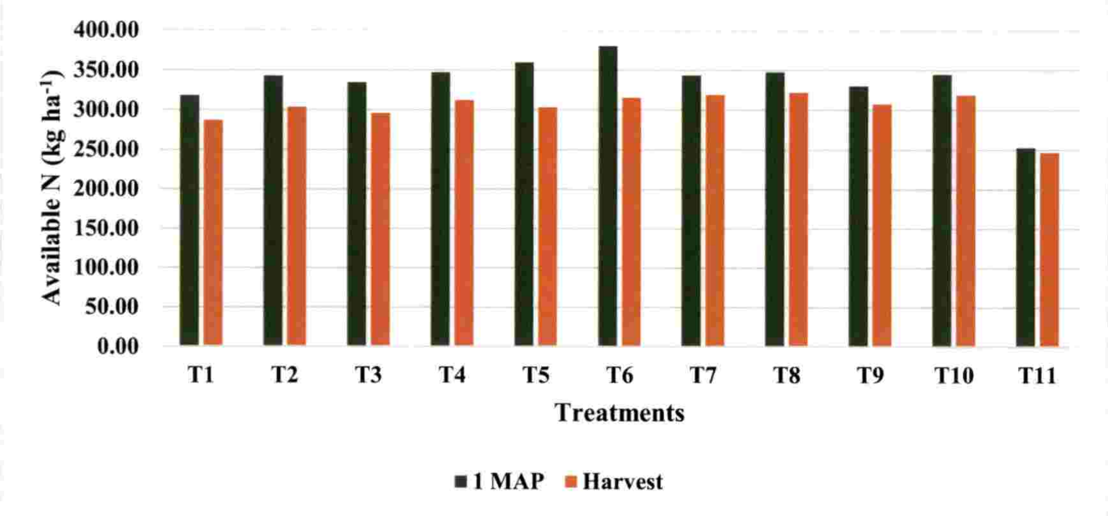

Fig 19: Effect of multinutrient tablets on available nitrogen in soil at different stages

5.4.5 Available phosphorus

The available phosphorus in soil was significantly influenced due to the application of multinutrient tablets and the phosphors availability was found to be higher in all the tablet receiving treatment compared to control (Fig 20). This might

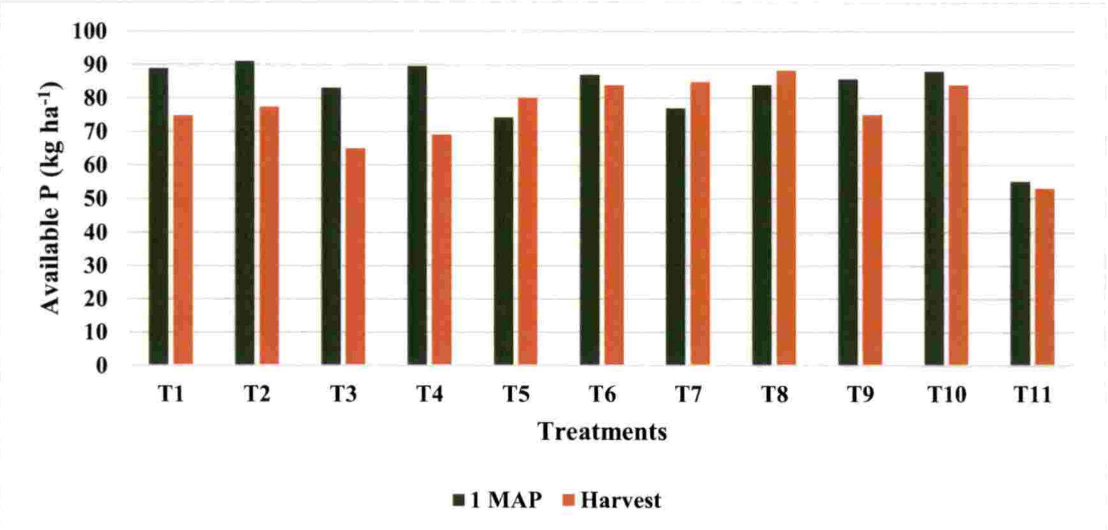

Fig 20: Effect of multinutrient tablets on available phosphorus in soil at different stages

be due to the placement of multinutrient tablets near the rhizosphere soil which ensured higher concentration of phosphorus in the immediate vicinity to diffuse faster to the roots from the tablets. These results are in accordance with the findings of Jagadheeswaran *et al.* (2007).

5.4.6 Available potassium

The potassium availability in soil was increased due to the application of multinutrient tablets (Fig. 21). This might be due to the reason that potassium fertilizers placed in the form of multinutrient tablets might have enhanced potassium availability in soil as reported by Jagadheeswaran *et al.* (2007). Similar results were reported by Xiang *et al.*, (2017) in cotton.

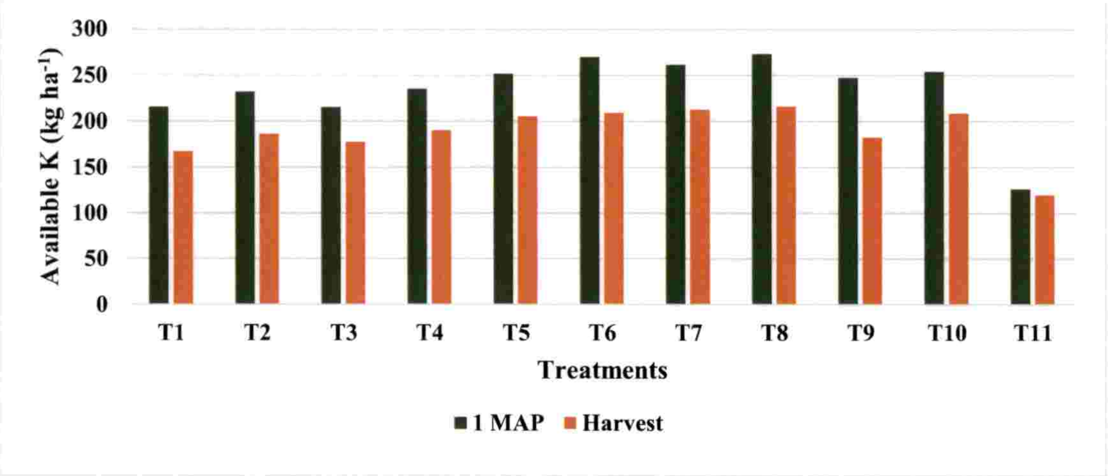

Fig 21: Effect of multinutrient tablets on available potassium in soil a different stages

5.4.7 Available calcium

Application of multinutriet tablets significantly increased available calcium in soil from deficient level to sufficient level (Fig 22). This might be due to the presence of $CaSO_4$ or phosphogypsum in multinutrient tablets which might have contributed to increased available calcium in soil. These results point towards a synergistic effect of B on Ca availability and a significant positive correlation exist between Ca and B ($p < 0.05$, $r = 0.653$). These results are on agreement with the findings of Tariq and Mott (2006) and Ramana, (2014).

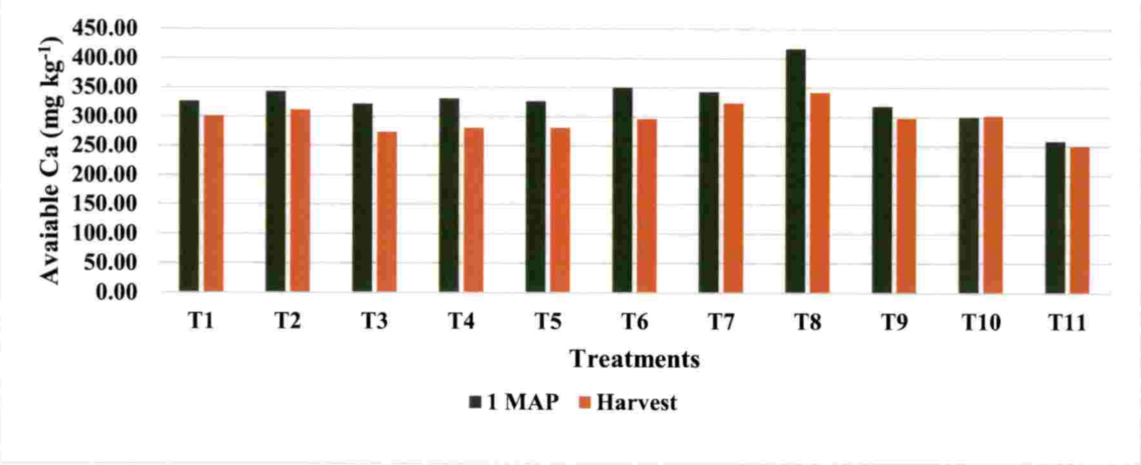

Fig 22: Effect of multinutrient tablets on available calcium in soil at different stages

5.4.8 Available magnesium

The effect of treatments on soil available Mg at one month after planting and at harvest is given in figure 23. The treatment T_6 recorded the highest available Mg in soil at both stages. This might be due to the presence of $MgSO_4$ in multinutrient tablets which might have contributed to sufficient magnesium content in soil. Similar results were reported by Hardter *et al.* (2003) and Parvathy (2018).

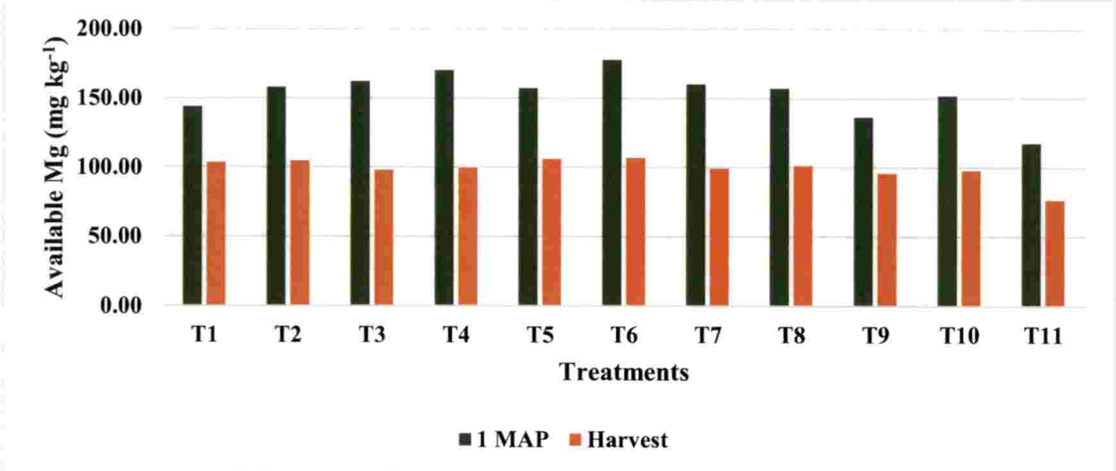

Fig 23: Effect of multinutrient tablets on available magnesium in soil at different stages

5.4.9 Available sulphur

The data with respect to available S in soil are given in fig 24. It was observed that T_6 was significantly superior to all other treatments with regard to sulphur availability in soil at sufficient levels. This might be due to the release of sulphate from the sulphate form of fertilizers present in multinutrient tablets.. These findings are in line with the findings of Parvathy (2018). Available S in Soil was found to be positively correlated with Mg in soil ($p < 0.05$, $r = 0.638$).

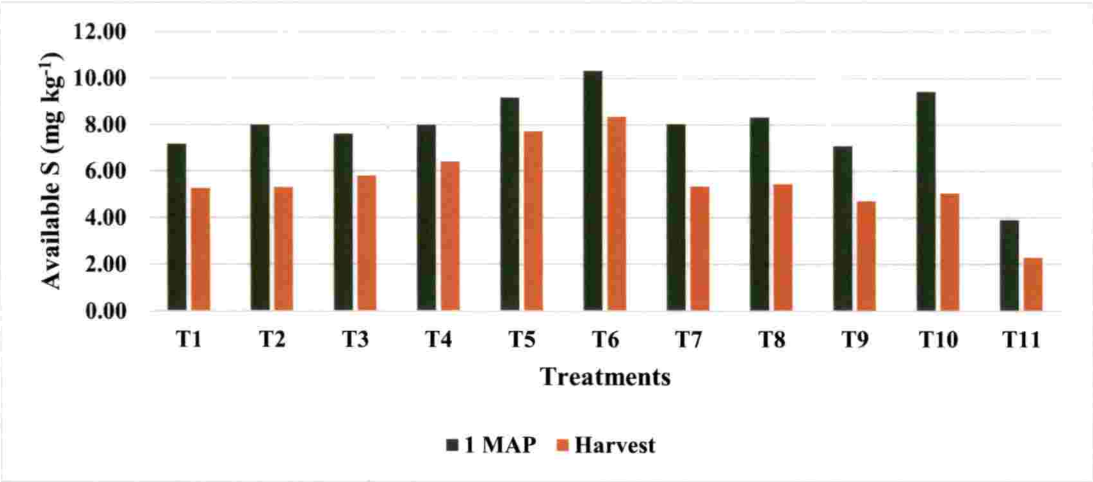

Fig 24: Effect of multinutrient tablets on available sulphur in soil at different stages

5.4.10 Available boron

The different treatment significantly influenced the available boron in soil (fig. 25). The treatment (T_2) receiving 100 % of recommended dose of fertilizer as tablet 2 recorded the highest value at 1 MAP and at harvest the highest value was recorded by treatment T_8. Application of boron in the form of boric acid or borax might be the reason for increased B availability and maximum release of boron from the tablets was also evident from the incubation study. These findings are in line with those reported by Ramana (2014) and Parvathy (2018).

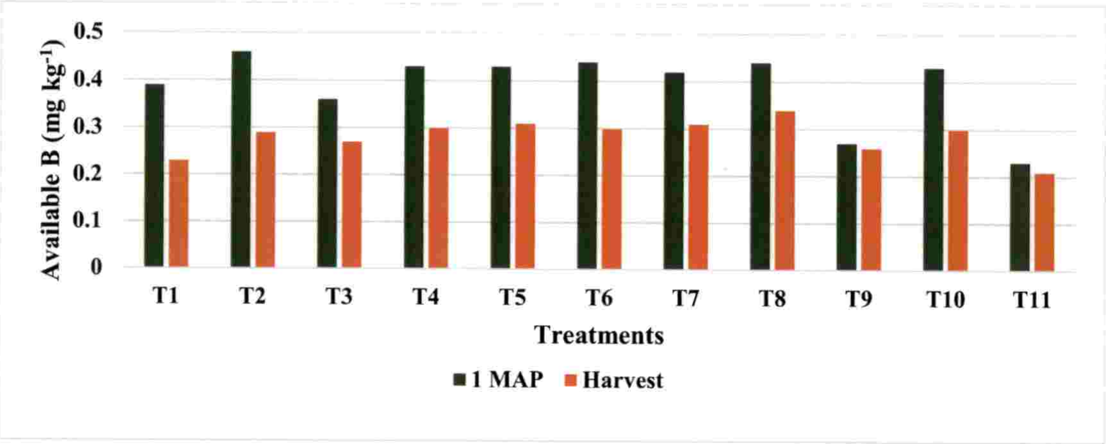

Fig 25: Effect of multinutrient tablets on available boron in soil at different stages

5.4.11 Available zinc

The available Zn content in soil was significantly increased by different treatments (Fig 26). The treatment T_8 receiving 100 % recommended dose of fertilizers as tablet 4 recorded the highest available Zn. This might be due to the presence of $ZnSO_4$ in multinutrient tablets that increased the availability of Zn.these findings are in line with the findings of Tariq and Mott (2006) and Parvathy (2018). A positive correlation exist between Zn and B ($p < 0.01$, $r = 0.888$).

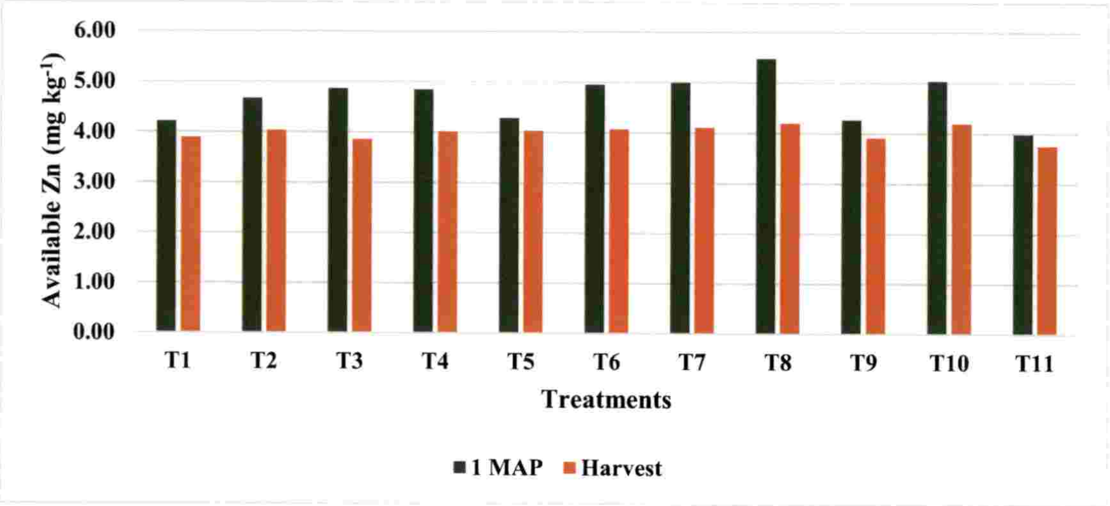

Fig 26: Effect of multinutrient tablets on available zinc in soil at different stages

5.5 EFFECT OF MULTINUTRIENT TABLETS ON CONTENT AND UPTAKE OF NUTRIENTS IN PLANT

5.5.1 Nitrogen content and uptake

The different treatments showed a significant increase in the content and uptake of N in shoot and fruit (fig. 27, fig. 28). The treatment T7 receiving 75 % of recommended dose of fertilizers as tablet 4 recorded the highest N content in shoot and fruit. The highest N uptake in shoot and fruit was also found in T7. The total uptake was also found to be the highest for T7 treatment (4.10 g $plant^{-1}$).

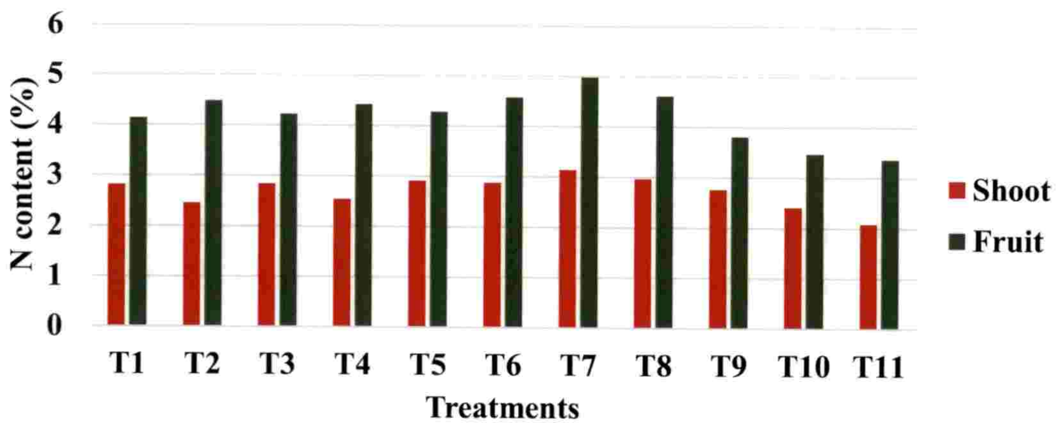

Fig 27: Effect of multinutrient tablets on N content in tomato

This might be due to application of tablet form of fertilizers which contain neem coated urea that makes continuous availability of nitrogen for uptake by plants. Similar results were reported by Jagadheeswaran *et al.* (2007). These results are also in line with those reported by Kiran *et al.* (2010) in rice and Ortas (2013) in pepper and tomato. Tian *et al.* (2016) reported that the N accumulation in rapeseed increased relatively constantly with the increased application of controlled release fertilizer throughout the growth period and caused obvious delays in leaf senescence and also reported a significant relationship between N accumulation in plant and yield.

A positive correlation exist between uptake of nitrogen by plant and available nitrogen in soil ($p < 0.05$, $r = 0.653$).

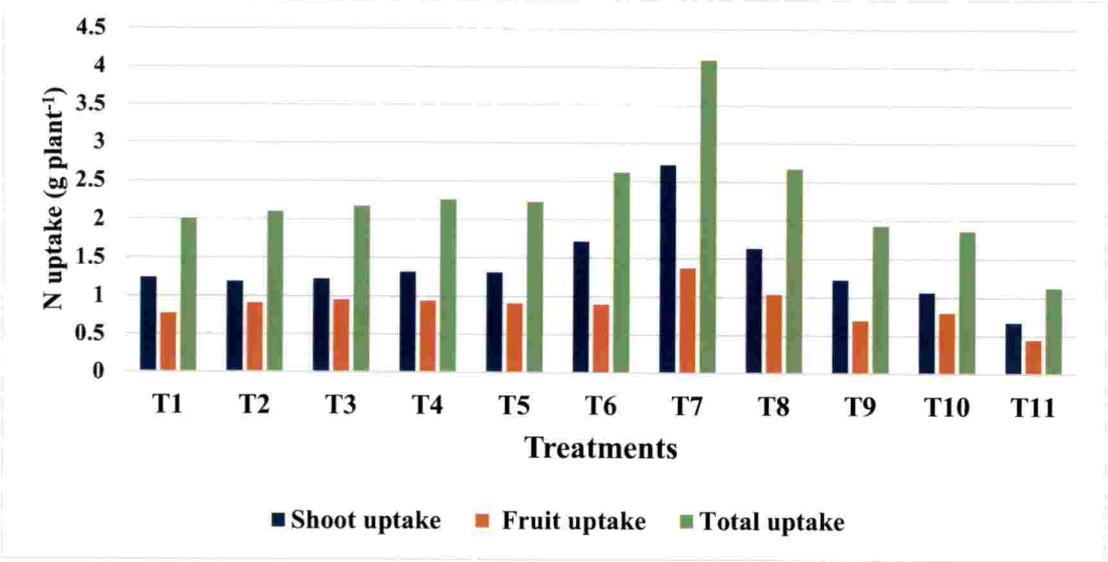

Fig 28: Effect of multinutrient tablets on N uptake of tomato

5.5.2 Phosphorus content and uptake

Significant difference was observed between the different treatments with respect to phosphorus content and uptake (Fig 29, 30). The treatment T_7 recorded the highest P content in shoot and fruit. With respect to phosphorus uptake also T_7 recorded the highest value.

Increase in P uptake is due to the translocation of P from root to shoot and fruit. Placement of tablets near the rhizosphere soil ensured higher concentration of phosphorus in the immediate vicinity of roots and the higher concentration gradient set up for P from tablets promotes the diffusion faster from tablets to roots as reported by Jagadheeswaran *et al.* (2007). Similar findings were reported by El- Ghramy *et al.* (2016) in maize and Tian *et al.* (2016) in rapeseed.

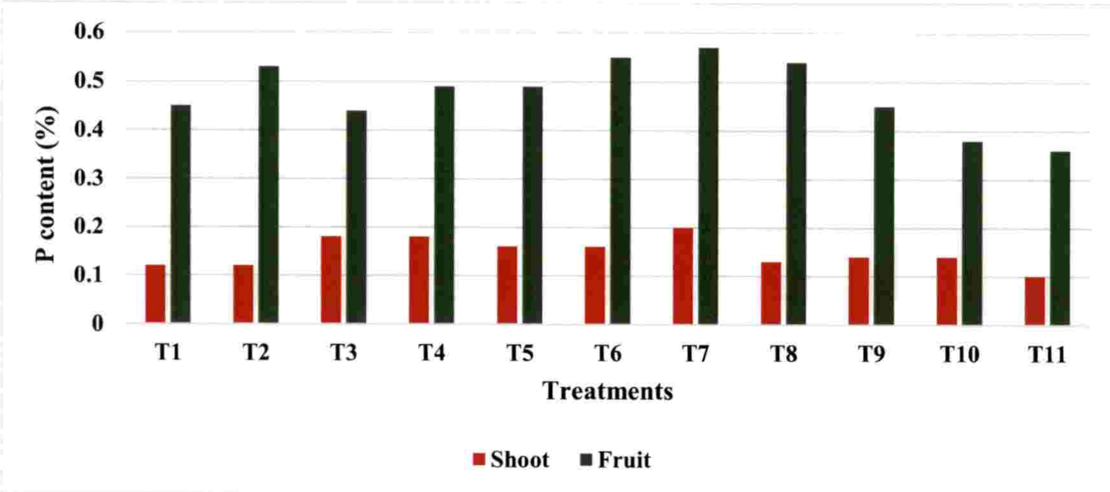

Fig 29: Effect of multinutrient tablets on P content in tomato

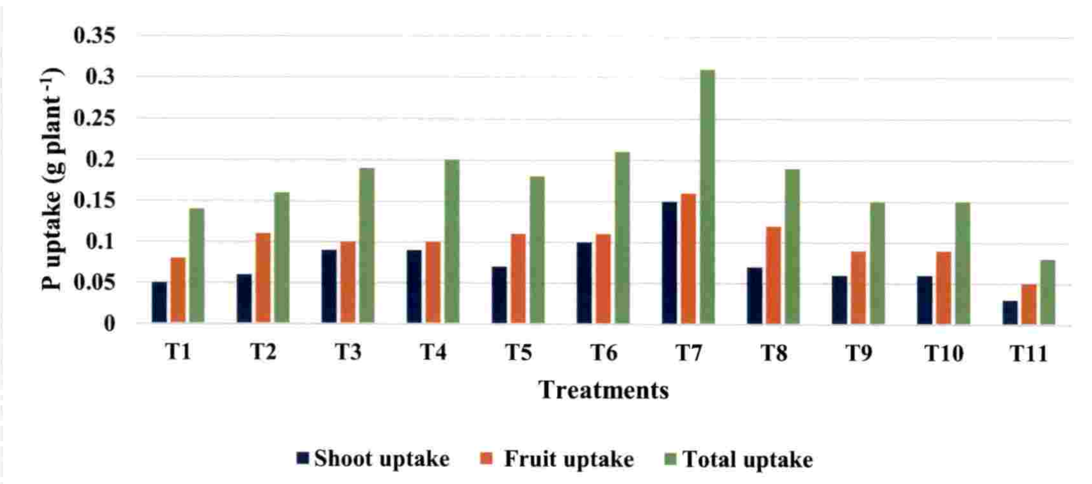

Fig 30: Effect of multinutrient tablets on P uptake in tomato

5.5.3 Potassium content and uptake

The highest K content in shoot and fruit was observed in T_7 (Fig 31). The uptake of potassium in shoot and fruit and also total uptake was found to be the highest in T_7 which was significantly superior to all other treatments (Fig 32). This might be due to the significant translocation of K from root to shoot and fruits with advancement of growth.

Potassium placed in the form of tablets enhanced potassium availability in soil which in turn significantly increased uptake in plant along with the slow and steady release of potassium from the tablets might be the reason for more potassium content and uptake in crop (Jagadheeswaran *et al.*, 2007). Similar findings are reported by El-Ghramy *et al*. (2016) in maize and Tian *et al*. (2016) in rapeseed.

A significant positive correlation exist between K uptake by plants and K availability in soil ($p < 0.01$, $r = 0.738$).

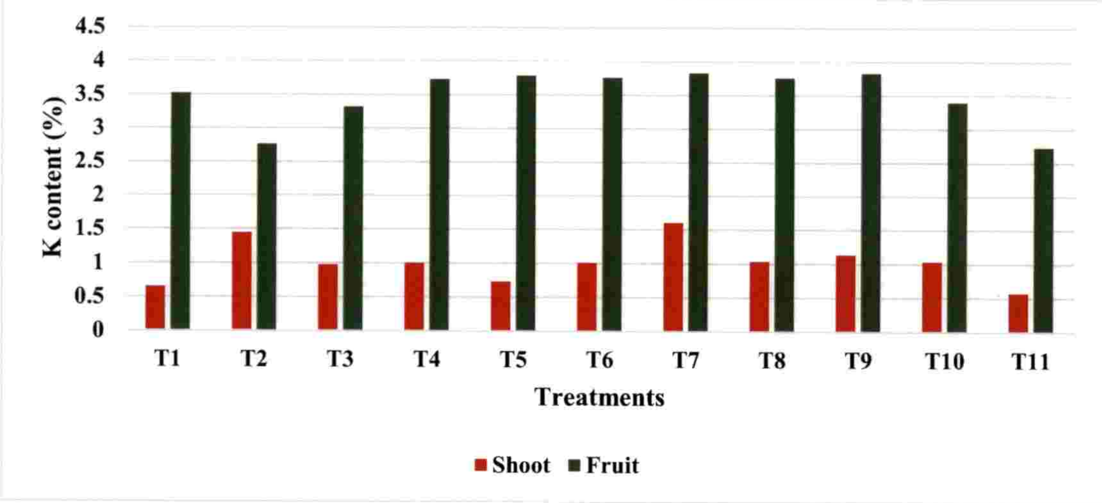

Fig 31: Effect of multinutrient tablets on K content in tomato

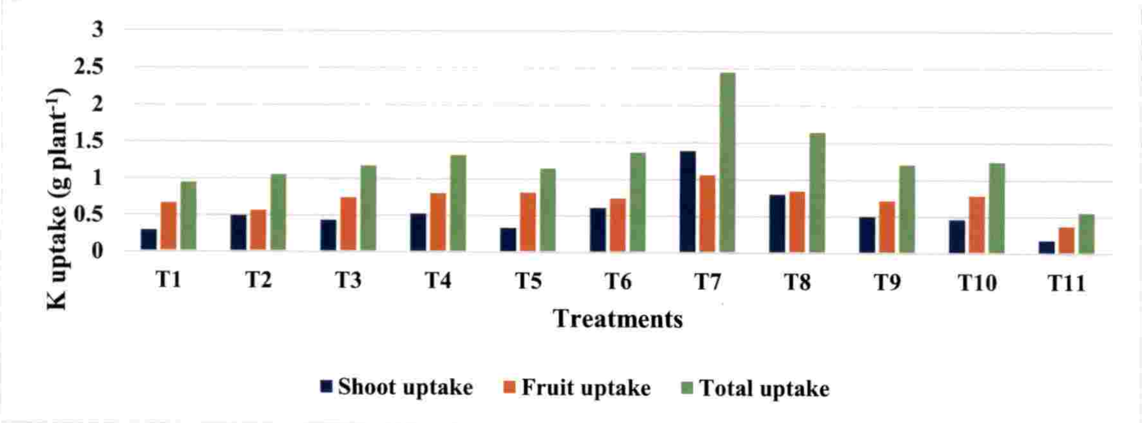

Fig 32: Effect of multinutrient tablets on K uptake in tomato

5.5.4 Calcium content and uptake

The concentration of Ca in shoot and fruit increased significantly with the application of multinutrient tablets (fig. 33, 34). The highest Ca content in shoot and fruit was recorded by treatment T_7 which received 75 % recommended dose of fertilizers as tablet 4. With respect to uptake in shoot and fruit, the highest total uptake was also recorded in T_7. This might be due to the release of calcium from the tablets and B tends to keep calcium in soluble form within the plant as there exist Ca- B interaction as reported by Ramon *et al.* (1990). Boron has a close relationship with calcium and it increases the Ca content in plants as they are similar in function (Golakiya and Patel, 1988). Similar results were also reported by Parvathy (2018) in cabbage.

A positive correlation exists between calcium uptake in plant and calcium availability in soil ($p < 0.05$, $r = 0.686$).

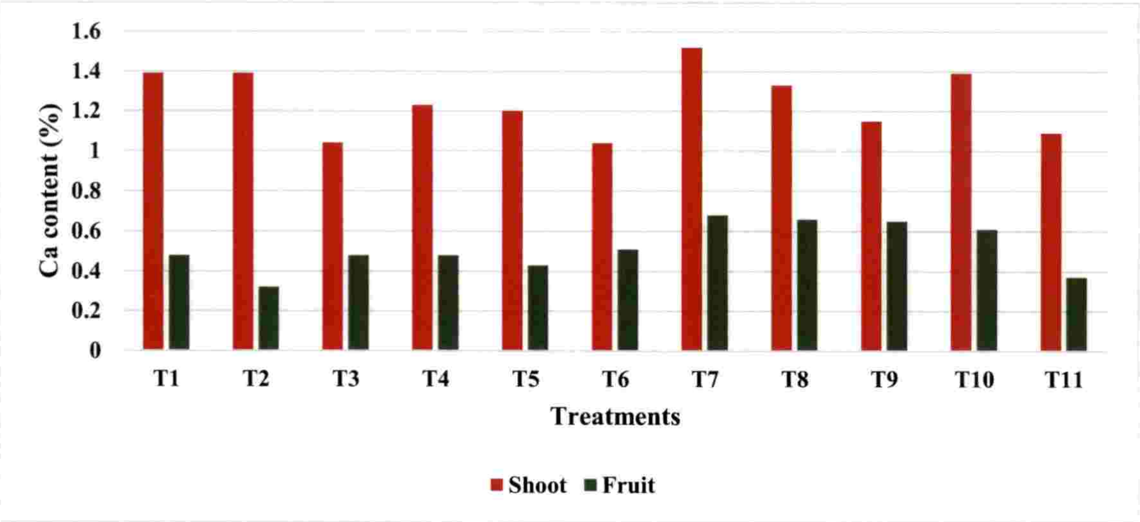

Fig 33: Effect of multinutrient tablets on Ca content in tomato

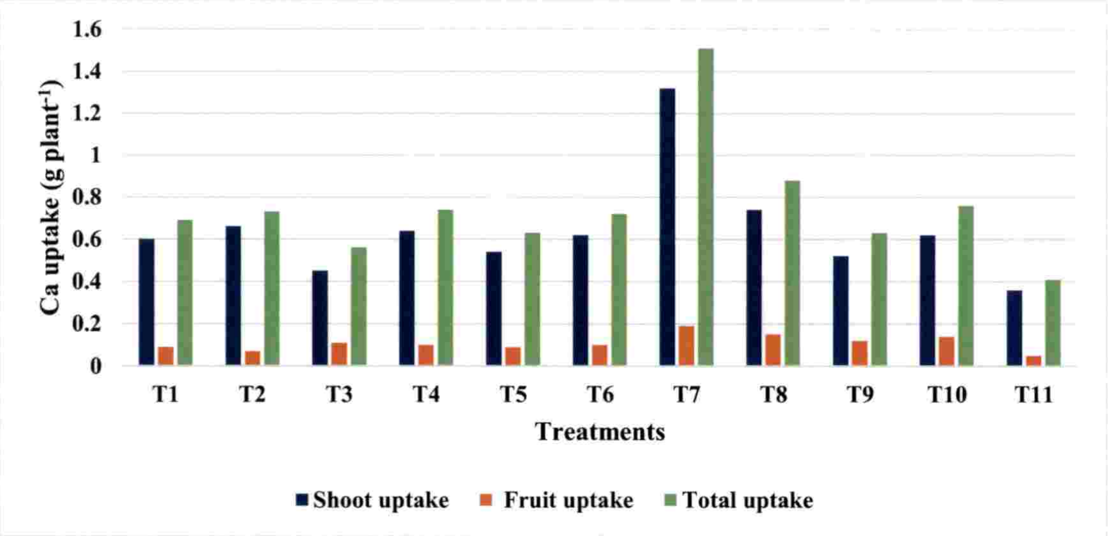

Fig 34: Effect of multinutrient tablets on Ca uptake in tomato

5.5.5 Magnesium content and uptake

The magnesium content and uptake in shoot and fruit in tomato were significantly influenced by treatments (fig 35, 36). The Mg content and uptake were found to be higher in T_7 receiving 75 % recommended dose of fertilizers as tablet 4 in both shoot and fruit. The highest uptake in shoot, fruit and the highest uptake was the highest in T_7 treatment.

This might be due to the maximum availability of nutrients from the tablets and also by the influence of other nutrients present in tablets. Mg content in pepper leaves was increased by the application of Mg and B (Ramana, 2014). Similar results were reported by Emil, (2013) in yard long bean and Parvathy (2018) in cabbage.

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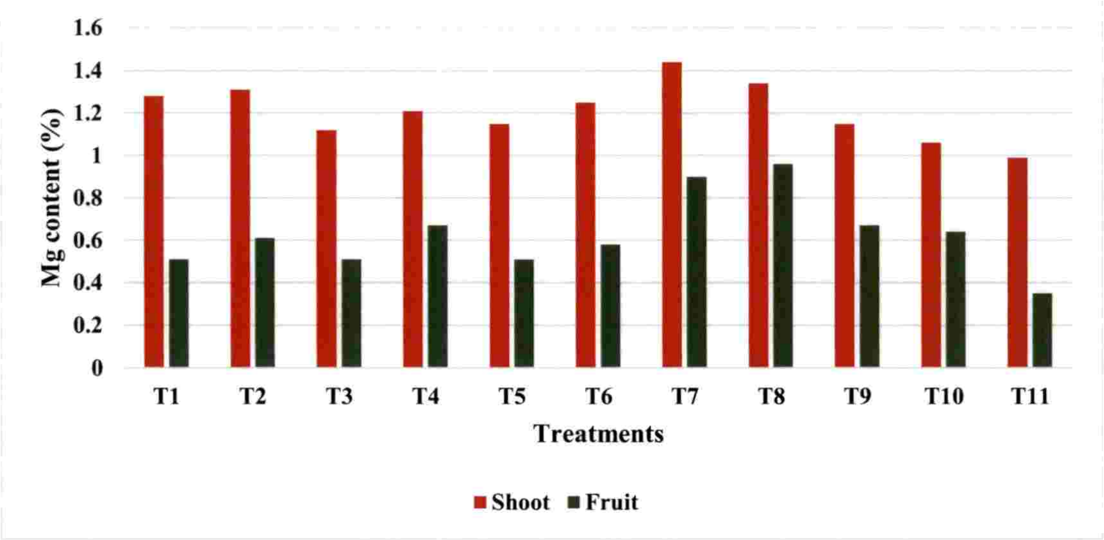

Fig 35: Effect of multinutrient tablets on Mg content in tomato

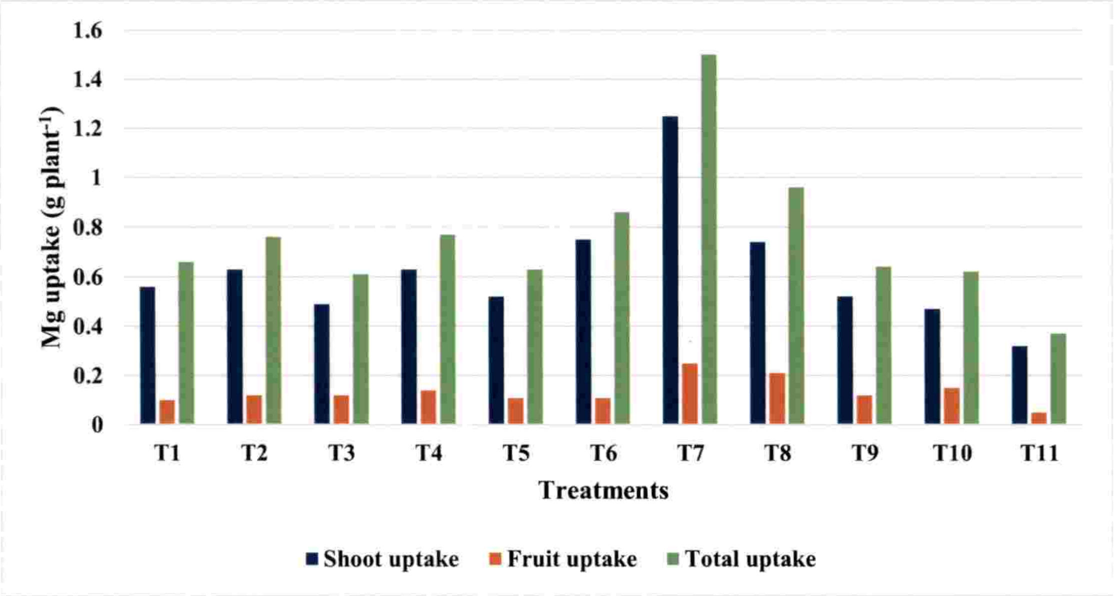

Fig 36: Effect of multinutrient tablets on Mg uptake in tomato

5.5.6 Sulphur content and uptake

The application of multinutrient tablets showed significant increase in S content and uptake (fig.37, 38). The highest B content in shoot and fruit were obtained in treatment T_7. With respect to shoot, fruit and total uptake also treatment T_7 receiving 75 % of recommended dose of fertilizers as tablet 4 recorded the highest value.

The sulphate available to the plant due to the application of sulphate form of fertilizers might have increased the S content in plant. Similar result was reported by Lopez (2010) in mustard, where the S content increased due to the application of $MgSO_4$.Sulphur uptake was found to be positively correlated with all the nutrients.

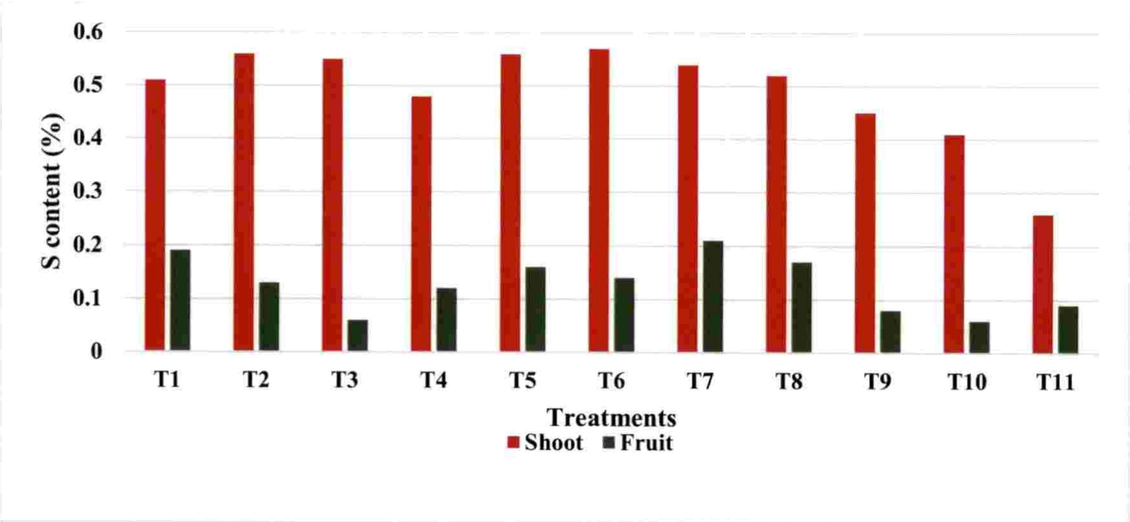

Fig 37: Effect of multinutrient tablets on S content in tomato

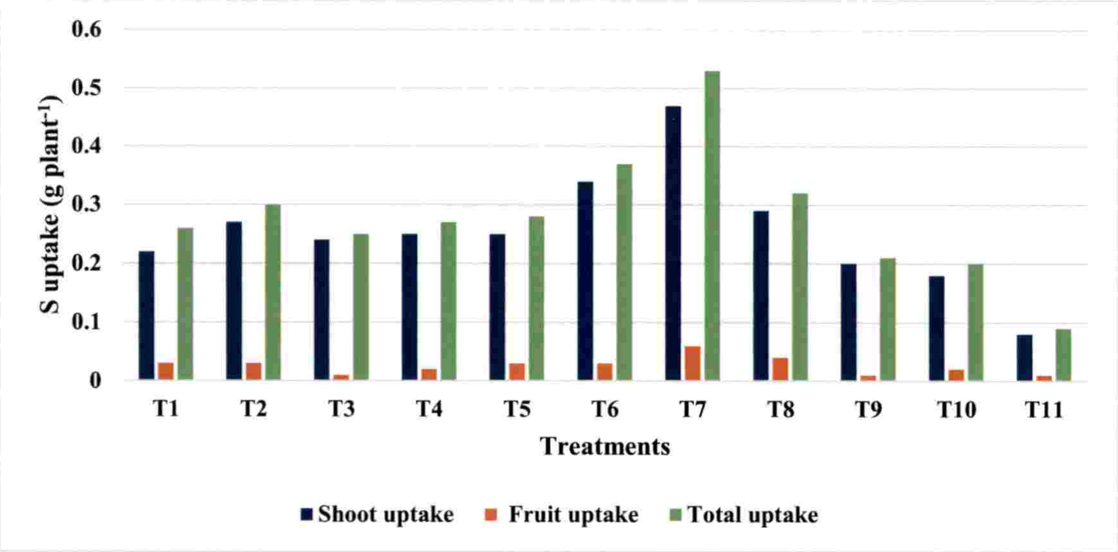

Fig 38: Effect of multinutrient tablets on S uptake in tomato

5.5.7 Boron content and uptake

The influence of the different treatments on boron content and uptake was significant (fig 39, 40). The treatment T_7 recorded the highest concentration of B in shoot and in fruit. The highest B uptake in shoot, fruit and total uptake were recorded in T_7.

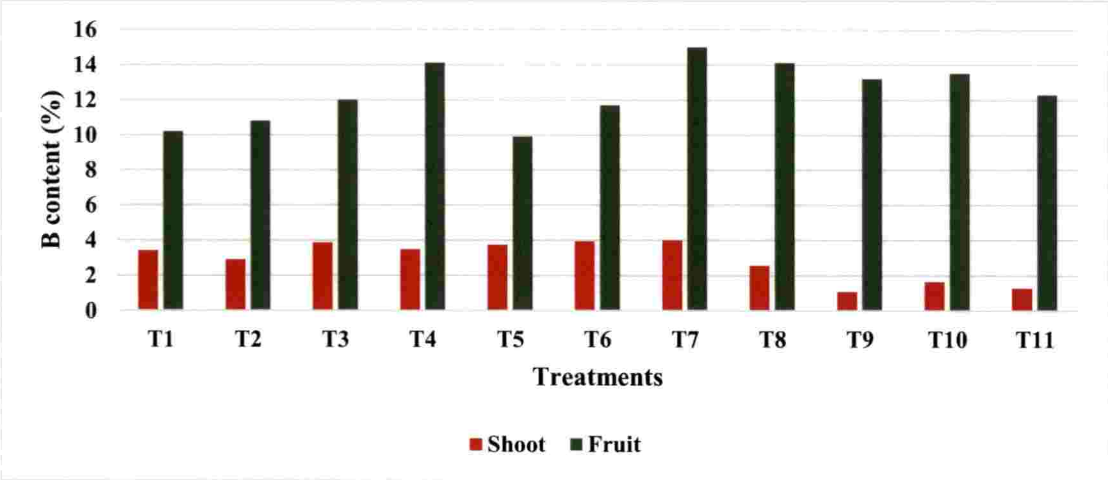

Fig 39: Effect of multinutrient tablets on B content in tomato

This significant increase might be due to the application of boron as borax. Tariq and Mott (2006) reported that the B content in leaves has increased linearly with the increase in B concentration. Similar results were reported by Parvathy (2018) in cabbage. B uptake by crop was found to be positively correlated with boron availability in soil ($p < 0.05$, $r = 0.678$).

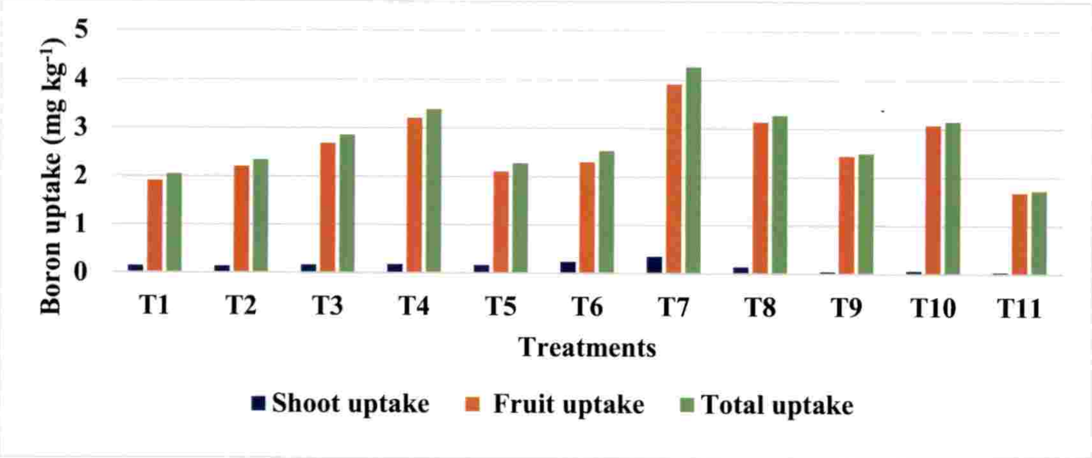

Fig 40: Effect of multiutrient tablets on B uptake in tomato

5.5.8 Zinc content and uptake

The effect of various treatments on Zn content and uptake in tomato shoot and fruit was found to be significant (fig. 41, 42). The highest value of Zn content in shoot and fruit was recorded in T_7.

With respect to uptake also T_7 recorded the highest uptake in shoot, fruit and total uptake which was found to be significantly superior to all other treatments.

The increase in zinc uptake in plant may be due to application of multinutrient tablets which contained $ZnSO_4$, which might have increased Zn availability in soil. Hence high concentration of Zn in soil solution enhanced the translocation of Zn from root to shoot (Tariq and Mott, 2006).

Zn uptake was found to be positively correlated with zinc availability ($p < 0.05$, $r = 0.693$)

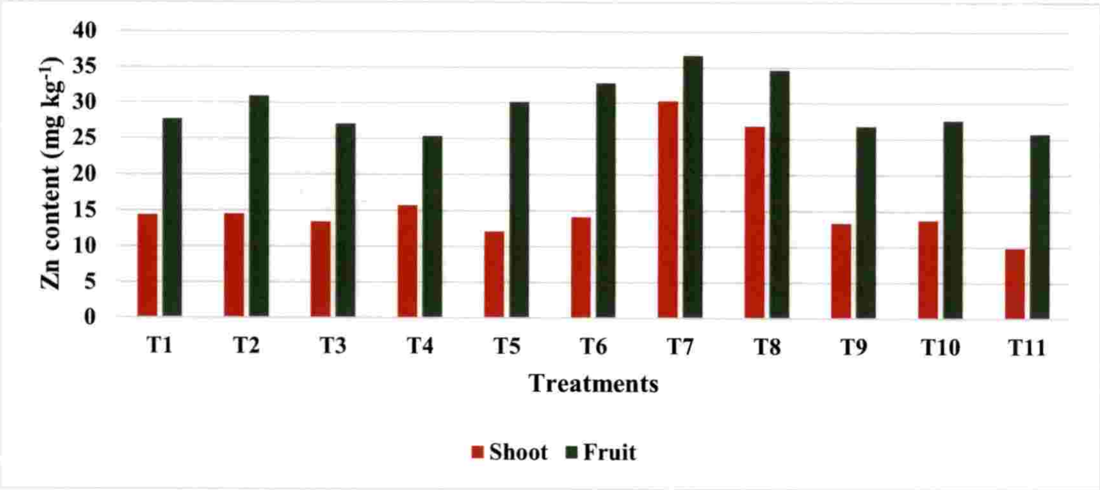

Fig 41: Effect of multinutrient tablets on Zn content in tomato

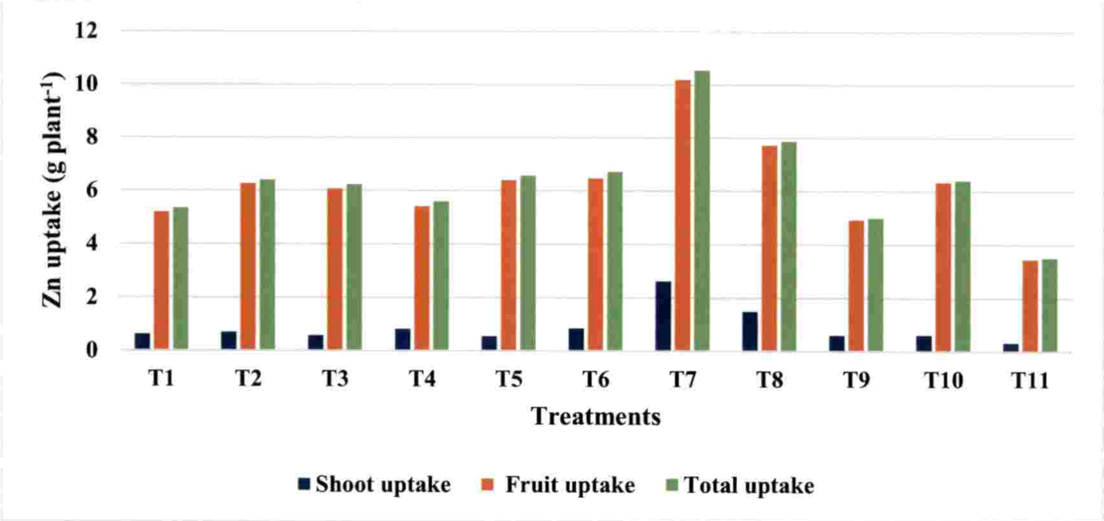

Fig 42: Effect of multinutrient tablets on Zn uptake in tomato

5.6 EFFECT OF MULTINUTRIENT TABLETS ON QUALITY OF TOMATO

The effect of multinutrient tablets on quality of tomato are given in figure 43. A significant influence was noticed in case of lycopene content of tomato fruit. The highest lycopene content was noticed in treatment T_7 with a mean value of 16.73 μg g^{-1}. It was found to be significantly superior to all other treatments.

This might be due to the application of slow release fertilizers in tablet form that might have increased the lycopene content than treatments with conventional fertilizers as reported by Taoukis and Assimakopoulos (2010). Similar results were reported by Li *et al.* (2017). Quality parameters were found to be significantly influenced by the application of coated fertilizers (Osman and El-Rahman, 2009) in guava, Gao *et al.* (2015) in potato and Bhanuvally *et al.* (2017) in sugarcane.

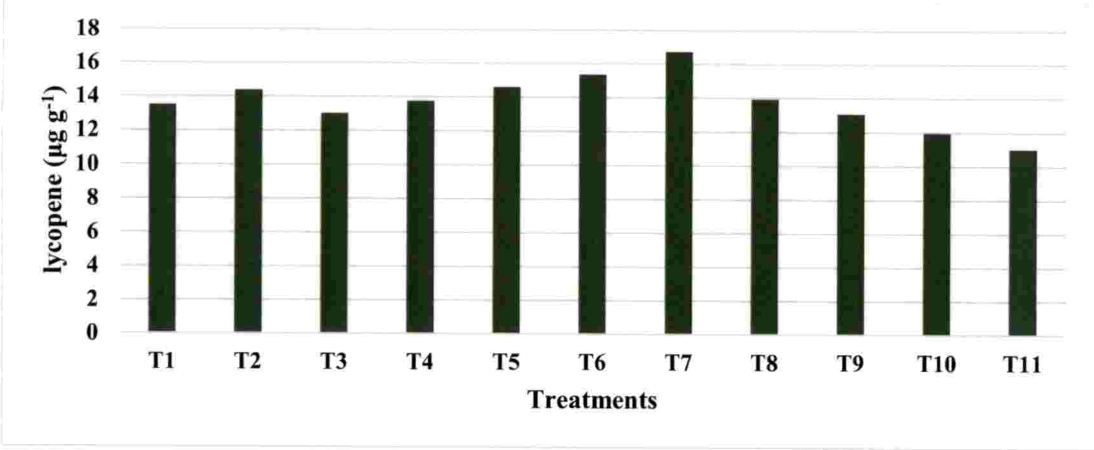

Fig 43: Effect of multinutrient tablets on lycopene content in tomato

5.7 EFFECT OF TREATMENTS ON NUTRIENT USE EFFICIENCY

The nutrient use efficiency of major nutrients are given in fig 44, 45. The treatment T_7 receiving 75% of recommended dose of fertilizers as tablet 4 recorded the highest agronomic efficiency for nitrogen (58.77 g g^{-1}), phosphorus (55.10 g g^{-1}) and potassium (79.35 g g^{-1}). With respect to apparent nutrient recovery of major nutrients the highest recovery percentage was recorded by T_7 for N (96.87 %), P (90.53 %) and K (94.95 %).The partial factor productivity from the applied nutrients revealed that treatment T_7 was found to be superior (27.71 g g^{-1}). Application of nutrients in tablet form might have enhanced the nutrient use efficiencies *viz.,* agronomic efficiency, apparent recovery and partial factor productivity as reported by Jagadheeswaran *et al.*

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(2005) in turmeric. Slow release of nutrients coupled with reduced loss have evidently enhanced nutrient availability in soil, nutrient uptake in plant and there by increased nutrient use efficiency. Placement of multinutrient tablets near the rhizosphere soil ensured higher availability of nutrients in soil solution in the immediate vicinity of roots which helped in the increased uptake of nutrients. Slow and steady release of nutrients from tablets near rhizosphere matched the crop uptake sparing not as much as nutrients for losses resulting in enhanced NUE. Shoji and Kanno (1992) reported an increase in fertilizer efficiency and the recovery of nitrogen when treated with coated fertilizers. Significant influence on partial factor productivity was reported by the use of attapulgite coated fertilizers (Guan *et al*., 2013). Similar results were reported by Tian *et al*. (2016) where controlled release NPK fertilizer improved fertilizer use efficiency as well as partial factor productivity. These findings are in line with Du *et al*. (2006) and Gao *et al*. (2015). Jadon *et al*. (2018) reported the increase in agronomic efficiency, recovery efficiency and partial factor productivity in maize by the application of coated fertilizers.

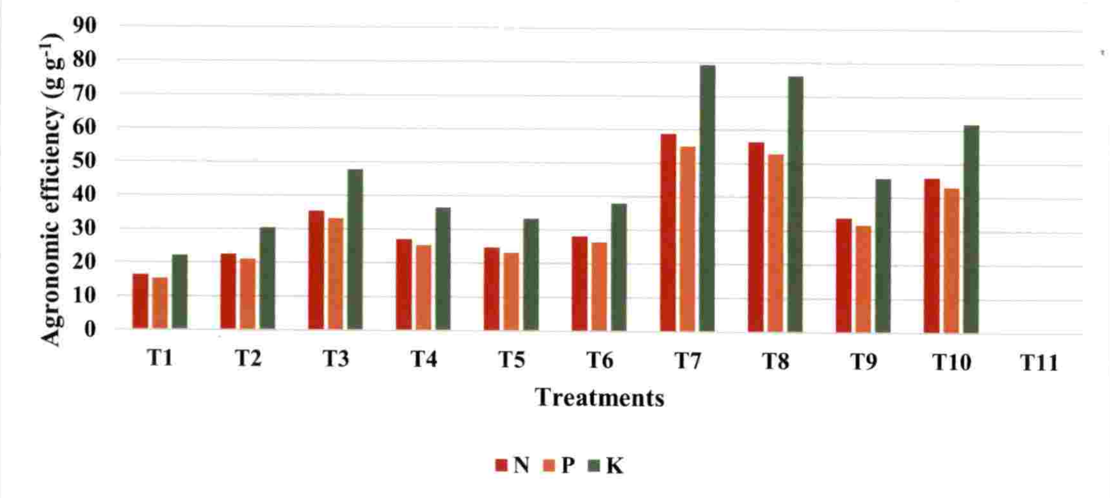

Fig 44: Effect of multinutrient tablets on agronomic efficiency in tomato

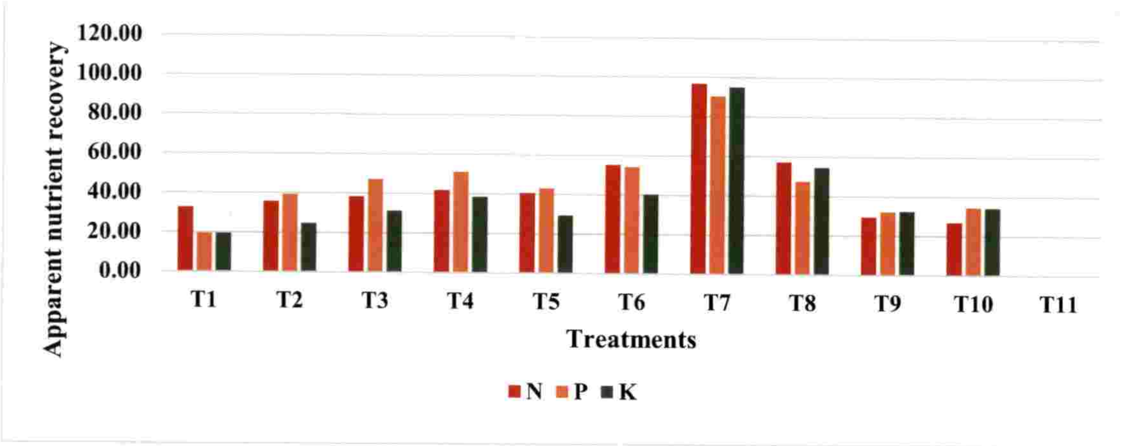

Fig 45: Effect of multinutrient tablets on apparent nutrient recovery in tomato

5.8 EFFECT OF MULTINUTRIENT TABLETS ON B:C RATIO

Net returns was increased by the application of multinutrient tablets (Fig 46). The treatment T_7 receiving 75 % of recommended dose of fertilizers as tablet 4 obtained the highest B:C ratio (1.17). Significant influence of neem oil coated urea on B:C ratio was reported by Gupta *et al.* (2016). These results are in line with Bhanuvally *et al.* (2017) in sugarcane where the net return as well as B:C ratio was significantly higher in treatment applied with neem coated urea.

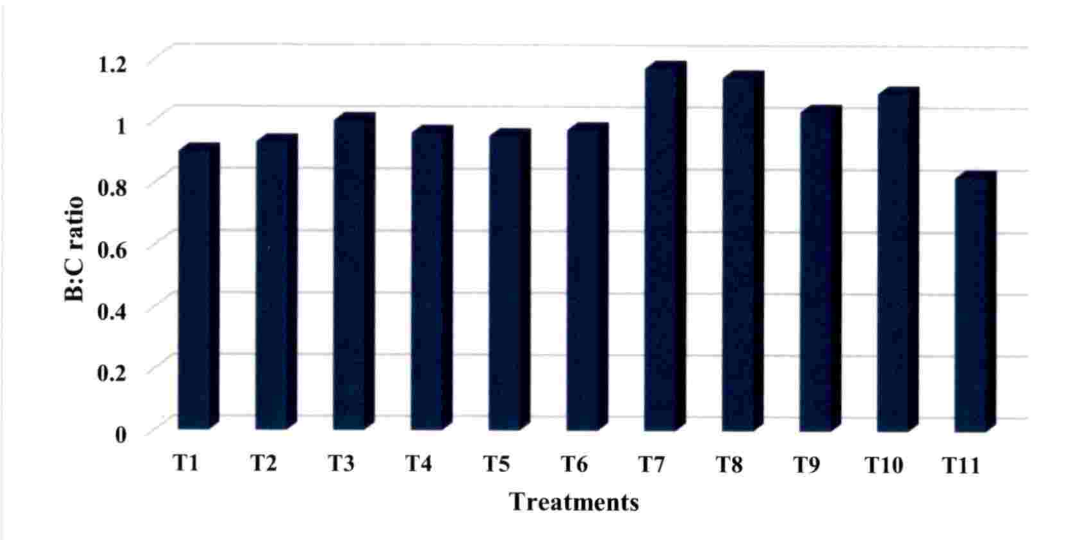

Fig 46: Effect of multinutrient tablets on benefit cost ratio

SUMMARY

6. SUMMARY

Slow release fertilizers in the form of tablets are effective compared to conventional fertilizers due to their gradual pattern of nutrient release which better meets plant needs, minimizes leaching and therefore increases fertilizer use efficiency. Hence the present study was conducted with the objective to develop multi nutrient fertilizer tablet containing major, secondary and micronutrients and to evaluate its effect on nutrient use efficiency, yield and quality of tomato.

Multinutrient fertilizer tablets were developed using three combination of compatible fertilizer materials, three binding agents and clay as filler material. Compatibility, stability, disintegration time, pH, EC, moisture content and nutrient content of multinutrient tablets were analyzed.

An incubation study was conducted for a period of three months to determine the nutrient release pattern of tablets and soil samples were analyzed for pH, EC and available major, secondary and micronutrients.

A pot culture experiment was conducted to evaluate the effect of the selected multinutrient tablets on yield and quality of tomato. The treatments include T_1 to T_8 consisted of two levels (75% and 100 %) of recommended dose of fertilizers applied as the selected 4 tablets, T_9 was soil test based POP recommendation, T_{10} was T_9 + secondary and micronutrient mixture and T_{11} was absolute control. The growth and yield parameters of tomato were observed and the nutrient availability in soil, the content and uptake of nutrients by plants and quality parameters of tomato were analyzed.

The conclusion drawn from the results are summarized in this chapter.

Compatibility study of multinutrient fertilizer blends revealed that all the tablets developed were non hygroscopic except T_8 and T_9 but caking was formed in T_2 and T_6. The multinutrient tablets T_3, T_4, T_5, T_7, T_8 and T_9 were stable, disintegration time ranged from 10 to 12 hours, moisture content ranged from 6.46 to 9.24% and EC ranged between 9.75 and 29.1 dS m^{-1}. The pH of tablets T_1, T_2 and T_3 were slightly alkaline while T_4, T_5, T_6, T_7, T_8 and T_9 were slightly acidic.

The multinutrient tablets contained 7.69 to 8.69 % nitrogen, 4.43 to 4.82 % phosphorus, 2.1 to 3.2 % potassium, 5.81 to 6.45 % calcium, 0.65 to 0.68 % magnesium, 2.37 to 3.27 % sulphur, 0.21 to 0.22 % boron and 0.21 to 0.25 % zinc.

The results of incubation study revealed that the pH of soil remained acidic throughout the incubation period and the EC of the soil was found to be increasing however, the values were within the permissible limit. The available nitrogen, phosphorus and potassium in soil were found to be increasing gradually with time during incubation. But maximum release of N and P were obtained on up 60^{th} day and K on 90^{th} day of incubation.

The release of secondary nutrients like Ca, Mg, S and micronutrients like B and Zn were also found to be increasing gradually from 15^{th} to 90^{th} day of incubation.

The results revealed that the tablets T_3, T_4, T_5 and T_7 were found to be the best with respect to the release of nutrients N, P, K, Ca, Mg, S, Zn and B throughout the incubation period and were selected for evaluation in the pot culture experiment.

The results of pot culture experiment revealed that application of 75 % recommended dose of fertilizers as tablet 4 containing neem coated urea, factomphos, muriate of potash, magnesium oxide, phosphogypsum, zinc sulphate, borax and binding agent methyl cellulose (T_7) recorded the maximum plant height (63 cm), number of branches per plant (6.67) and number of fruits per plant (16). Fruit weight was maximum in T_7 (33.77 g) which was on par with T_8 (32.27 g). Fruit yield was the highest in T_7 (502.02 g $plant^{-1}$) which was on par with T_8 (495.66 g $plant^{-1}$). Early flowering and fruiting were observed in T_9. Lycopene content was also found to be the highest in T_7 (16.73 μg g^{-1}).

The pH of experimental soil was found to be slightly acidic in all the treatments and was decreased from 1 MAP to harvest. The EC of soil was also decreased from 1 MAP to harvest and which was found to be within normal safe level. The available nutrients in soil *viz.,* N, P, K, Ca, B and Zn were found to be increased by the application of 100 % of recommended dose of fertilizers as tablet 4 (T_8), whereas available Mg and S were found to be the maximum in treatment T_6 receiving 100 % of recommended dose of fertilizers as tablet 3.

The content and uptake of major, secondary and micronutrients were found to be the highest in treatment T_7 receiving 75 % of recommended dose of fertilizers as tablet 4.

The use efficiency of major nutrients were also found to be the highest in treatment T_7 receiving 75% of recommended dose of fertilizers as tablet 4. The agronomic efficiency for nitrogen, phosphorus and potassium were 58.77 g g^{-1}, 55.10 g g^{-1} and 79.35 g g^{-1} respectively. With respect to apparent nutrient recovery the highest recovery percentage was recorded by T_7 for N (96.87 %), P (90.53 %) and K (94.95 %).The partial factor productivity from the applied nutrients was found to be the superior (27.71 g g^{-1}) in T_7. The highest B:C ratio of 1.17 was recorded by T_7.

From the results it can be concluded that multinutrient tablets containing macro, secondary and micro nutrients can be prepared using compatible fertilizer materials and binding agents. The multinutrient tablets T_3, T_4, T_5 and T_7 were found to be superior with respect to stability, disintegration time, nutrient content and release of nutrients. Application of multinutrient tablet containing neem coated urea, factomphos, muriate of potash, magnesium oxide, phosphogypsum, zinc sulphate, borax and binding agent methyl cellulose (T_7) at 75 % of recommended dose of fertilizers was able to significantly increase the yield, uptake of nutrients, nutrient use efficiency and quality of tomato.

Future line of study

- Coating and packing of multi nutrient tablets to increase stability during storage and transport.
- Standardization of method and time of application.
- Development of multinutrient tablets for other vegetable crops.
- Effect on rhizosphere microflora.

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APPENDICES

APPENDIX- 1

Weather parameters during pot culture experiment

Sl. No.	Week	Avg. RF (mm)	Max temp (°C)	Min temp (°C)	Evaporation (mm)	Max RH (%)	Min RH (%)
1	Oct 8-14	19.2	30.7	24.3	1.4	93.1	80.1
2	15-21	12.9	32	24.5	2.5	91.4	77.3
3	22-28	1.6	31.4	24.2	2.8	93.7	76.4
4	29-4	10.2	31.8	24.3	3.1	93.4	77.1
5	Nov 5-11	8.5	31.1	24.3	2.1	93.6	78.7
6	12-18	7.3	31.7	23.8	2.5	92.1	73.3
7	19-25	7.4	31.6	24.1	2.8	93	74
8	26-2	0	31.9	23.7	2.9	93.3	72.4
9	Dec 3-9	2.5	31.9	23.7	2.5	92.9	73.9
10	10-16	3.7	32.2	23.8	3.1	94.3	73.9
11	17-23	0.3	32	22.9	3.3	92.4	71.9
12	24-31	0.9	31.9	23.5	3.3	92.7	71.7
13	Jan 1-7	0	31.97	19.6	3.6	92	66.6
14	8-14	0	31.57	20.7	3.83	92	68.5
15	15-21	0	32.2	20.85	3.64	90.86	68.14

APPENDIX- 2

CORRELATION STUDIES

(Correlation between available nutrients in soil with yield of tomato)

	Available N	Available P	Available K	Available Ca	Available Mg	Available S	Available B	Available Zn	Yield
Available N	1								
Available P	0.788**	1							
Available K	0.941**	0.884**	1						
Available Ca	0.732*	0.844**	0.709*	1					
Available Mg	0.748**	0.641*	0.720*	0.559	1				
Available S	0.380	0.309	0.497	-0.048	0.638*	1			
Available B	0.873**	0.763**	0.940**	0.653*	0.629*	0.469	1		
Available Zn	0.858**	0.902**	0.921**	0.768**	0.574	0.278	0.888**	1	
Yield	0.823**	0.710*	0.814**	0.760**	0.385	0.002	0.764**	0.770**	1
**. Correlation is significant at the 0.01 level									
*. Correlation is significant at the 0.05 level									

APPENDIX-3

CORRELATION STUDIES

Correlation between available nutrients in soil with quality parameters of tomato

	Available N	Available P	Available K	Available Ca	Available Mg	Available S	Available B	Available Zn	TSS	Lycopene	Ascorbic acid
Available N	1										
Available P	0.788**										
Available K	0.941**	0.884**	1								
Available Ca	0.732*	0.844**	0.709*	1							
Available Mg	0.748**	0.641*	0.720*	0.559	1						
Available S	0.380	0.309	0.497	-0.048	0.638*	1					
Available B	0.873**	0.763**	0.940**	0.653	0.629*	0.469	1				
Available Zn	0.858**	0.902**	0.921**	0.768**	0.574	0.278	0.888**	1			
TSS	0.524	0.315	0.571	0.293	0.667*	0.612*	0.648 *	0.418	1		
Lycopene	0.610*	0.598	0.658*	0.551	0.689*	0.533	0.595	0.470	0.701*	1	
Ascorbic acid	0.205	0.013	0.189	0.124	0.036	0.312	0.326	0.051	0.363	0.487	1
**. Correlation is significant at the 0.01 level											
*. Correlation is significant at the 0.05 level											

APPENDIX-4

CORRELATION STUDIES

Correlation between total of nutrients with yield of tomato

	N uptake	P uptake	K uptake	Ca uptake	Mg uptake	S uptake	B uptake	Zn uptake	Yield
N uptake	1								
P uptake	0.971**	1							
K uptake	0.964**	0.939**	1						
Ca uptake	0.932**	0.866**	0.947**	1					
Mg uptake	0.977**	0.921**	0.961**	0.969**	1				
S uptake	0.974 **	0.944**	0.893**	0.882**	0.950**	1			
B uptake	0.810 **	0.843**	0.911**	0.840**	0.819**	0.703*	1		
Zn uptake	0.953**	0.911**	0.943**	0.920**	0.934**	0.922**	0.816**	1	
Yield	0.733 *	0.716*	0.856**	0.740**	0.727*	0.634*	0.864**	0.824**	1

**. Correlation is significant at the 0.01 level

*. Correlation is significant at the 0.05 level

APPENDIX-5

CORRELATION STUDIES

Correlation between total uptake of nutrients with quality parameters of tomato

	N uptake	P uptake	K uptake	Ca uptake	Mg uptake	S uptake	B uptake	Zn uptake	TSS	Lycopene	Ascorbic acid
N uptake	1										
P uptake	0.971**	1									
K uptake	0.964**	0.939**	1								
Ca uptake	0.932**	0.866**	0.947**	1							
Mg uptake	0.977**	0.921**	0.961**	0.969**	1						
S uptake	0.974**	0.944**	0.893**	0.882**	0.950**	1					
B uptake	0.810**	0.843**	0.911**	0.840**	0.819**	0.703	1				
Zn uptake	0.953**	0.911**	0.943**	0.920**	0.934**	0.922**	0.816**	1			
TSS	0.620*	0.706*	0.500	0.417	0.529	0.695*	0.478	0.644*	1		
Lycopene	0.893**	0.876**	0.771**	0.752**	0.850**	0.958**	0.533	0.812**	0.701*	1	
Ascorbic acid	0.497	0.530	0.465	0.331	0.503	0.471	0.420	0.312	0.363	0.487	1
**. Correlation is significant at the 0.01 level											
*. Correlation is significant at the 0.05 level											

APPENDIX-6

CORRELATION STUDIES

Correlation between total uptake of nutrients with available nutrients in soil

	N uptake	P uptake	K uptake	Ca uptake	Mg uptake	S uptake	B uptake	Zn uptake	Available N	Available P	Available K	Available Ca	Available Mg	Available S	Available B	Available Zn
N uptake	1															
P uptake	0.971**	1														
K uptake	0.964**	0.939**	1													
Ca uptake	0.932**	0.866**	0.947**	1												
Mg uptake	0.977**	0.921**	0.961**	0.969**	1											
S uptake	0.974**	0.944**	0.893**	0.882**	0.950**	1										
B uptake	0.810**	0.843**	0.911**	0.840**	0.819**	0.703*	1									
Zn uptake	0.953**	0.911**	0.943**	0.920**	0.934**	0.922**	0.816**	1								
Available N	0.653*	0.691*	0.720*	0.589	0.628*	0.655*	0.714*	0.697*	1							
Available P	0.613*	0.522	0.641*	0.618*	0.626*	0.639*	0.471	0.717*	0.788**	1						
Available K	0.694*	0.709*	0.738**	0.614*	0.651*	0.695*	0.675*	0.778**	0.941**	0.884**	1					
Available Ca	0.639*	0.515	0.677*	0.686**	0.705*	0.646*	0.552	0.718*	0.732*	0.844**	0.709*	1				
Available Mg	0.484	0.510	0.382	0.319	0.405	0.606*	0.253	0.496	0.748**	0.641*	0.720*	0.559	1			
Available S	0.272	0.375	0.139	-0.007	0.136	0.380	0.020	0.214	0.380	0.309	0.497	-0.048	0.638*	1		
Available B	0.630*	0.662*	0.681*	0.539	0.600	0.623*	0.678*	0.731*	0.873**	0.763**	0.940**	0.653*	0.629*	0.469	1	
Available Zn	0.553	0.527	0.637*	0.592	0.578	0.552	0.639*	0.693*	0.858**	0.902**	0.921**	0.768**	0.574	0.278	0.888**	1

**. Correlation is significant at the 0.01 level

*. Correlation is significant at the 0.05 level

DEVELOPMENT OF MULTI NUTRIENT FERTILIZER TABLET AND ITS EVALUATION IN TOMATO

by

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ABSTRACT

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ABSTRACT

The study entitled "Development of multinutrient fertilizer tablet and its evaluation in tomato"was conducted from 2017 to 2019 in the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani. The objectives of the study were to develop multi nutrient fertilizer tablet containing major, secondary and micronutrients and to evaluate its effect on nutrient use efficiency, yield and quality of tomato. The study consisted of three parts namely development of multinutrient fertilizer tablets, an incubation study to assess the nutrient release pattern of multi nutrient tablets and a pot culture experiment to evaluate the multi nutrient tablets in tomato.

Multinutrient fertilizer tablets were developed using three fertilizer combinations and three binding agents which constitute the 9 treatments and are replicated thrice in CRD. The treatments were T_1- urea, dicalcium phosphate, potassium sulphate, calcium sulphate, magnesium oxide, zinc EDTA, boric acid and binding agent methyl cellulose, T_2- fertilizer materials as in T_1 and binding agent gelatin, T_3 – fertilizer materials as in T_1 and binding agent polyvinyl pyrrolidone, T_4 – urea, diammonium phosphate, muriate of potash, calcium sulphate, magnesium sulphate, zinc EDTA, borax and binding agent methyl cellulose, T_5 – fertilizer materials as in T_4 and binding agent gelatin, T_6 – fertilizer materials as in T_4 and binding agent polyvinyl pyrrolidone, T_7 – neem coated urea, factomphos, muriate of potash, magnesium oxide, phosphogypsum, zinc sulphate, borax and binding agent methyl cellulose, T_8 – fertilizer materials as in T_7 and binding agent gelatin and T_9 – fertilizer materials as in T_7 and binding agent polyvinyl pyrrolidone.

Compatibility test of multinutrient fertilizer blends revealed that tablets T_3, T_4, T_5 and T_7 were non hygroscopic and no caking or colour change were observed. Whereas T_8 and T_9 were hygroscopic. Caking was observed in tablet T_2 and T_6 and colour change was noticed in tablets T_6, T_8 and T_9. Analysis of physical and chemical properties of tablets revealed that tablets T_3, T_4, T_5, T_7, T_8 and T_9 were stable, disintegration time ranged from 10 to 12 hours, moisture

content ranged from 6.46 to 9.24% and EC ranged between 9.75 and 29.1 dS m^{-1}. The pH of tablets T_1, T_2 and T_3 were slightly alkaline while T_4, T_5, T_6, T_7, T_8 and T_9 were slightly acidic. The nutrient content in tablets ranged from 7.69 to 8.69 % nitrogen, 4.43 to 4.82 % phosphorus, 2.1 to 3.2 % potassium, 5.81 to 6.45 % calcium, 0.65 to 0.68 % magnesium, 2.37 to 3.27 % sulphur, 0.21 to 0.22 % boron and 0.21 to 0.25 % zinc.

An incubation study was conducted for a period of three months to determine the nutrient release pattern of tablets in CRD with 9 treatments and 3 replications. Soil samples were drawn at 15 days interval and analyzed for major, secondary and micronutrients. The results revealed that the tablets T_3, T_4, T_5 and T_7 were found to be the best with respect to the release of nutrients N, P, K, Ca, Mg, S, Zn and B throughout the incubation period and were selected for evaluation in the pot culture experiment.

A pot culture experiment was conducted to evaluate the effect of the selected multinutrient tablets on yield and quality of tomato variety vellayani vijay in a completely randomized design with 11 treatments and 3 replications. The treatments T_1 to T_8 consisted of two levels (75% and 100 %) of recommended dose of fertilizers applied as the seleced 4 tablets, T_9 was soil test based POP recommendation, T_{10} was T_9 + secondary and micronutrient mixture and T_{11} was absolute control.

The results revealed that the treatment T_7 which received 75 % recommended dose of fertilizers as tablet 4 containing neem coated urea, factomphos, muriate of potash, magnesium oxide, phosphogypsum, zinc sulphate, borax and binding agent methyl cellulose recorded the maximum plant height (63 cm), number of branches per plant (6.67) and number of fruits per plant (16). Fruit weight was maximum in T_7 (33.77 g) which was on par with T_8 (32.27 g). Fruit yield was the highest in T_7 (502.02 g $plant^{-1}$) which was on par with T_8 (495.66 g $plant^{-1}$). Early flowering and fruiting were observed in T_9. Lycopene content was also found to be the highest in T_7 (16.73 μg g^{-1}) whereas no significant difference was observed with respect to TSS and ascorbic acid.

The analysis of post harvest soil revealed that electrical conductivity and available nutrients were significantly influenced by different treatments whereas pH and organic carbon content were found to be nonsignificant. The available nitrogen (321.96 kg ha^{-1}), phosphorus (88.18 kg ha^{-1}), potassium (216.53 kg ha^{-1}), calcium (342.56 mg kg^{-1}), zinc (0.34 mg kg^{-1}) and boron (4.21 mg kg^{-1}) were the highest in T_8 and was found to be on par with T_7. With respect to magnesium (107 mg kg^{-1}) and sulphur (8.35 mg kg^{-1}) T_6 recorded the highest value.

The content and uptake of nutrients in plant and fruit were found to be significantly influenced by different treatments. The treatment T_7 recorded the highest content and uptake of N, P, K, Ca, Mg, S, B and Zn. The highest NUE of nitrogen (58.77 g g^{-1}), phosphorus (55.10 g g^{-1}) and potassium (79.35 g g^{-1}) was observed in treatment T_7 followed by T_8.

It can be concluded that multinutrient tablets containing macro, secondary and micro nutrients can be prepared using compatible fertilizer materials and binding agents. The multinutrient tablets T_3, T_4, T_5 and T_7 were found to be superior with respect to stability, disintegration time and release of nutrients. Application of multinutrient tablet containing neem coated urea, factomphos, muriate of potash, magnesium oxide, phosphogypsum, zinc sulphate, borax and binding agent methyl cellulose (T_7) at 75 % of recommended dose of fertilizers was able to significantly increase the yield, uptake of nutrients, nutrient use efficiency and quality of tomato.