EVALUATION OF CALCIUM NUTRITION IN OKRA

(*Abelmoschus esculentus* (L.) Moench)

GIFFY THOMAS

(2017-11-145)

Thesis submitted in partial fulfilment of the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture

Kerala Agricultural University, Thrissur

Department of Agronomy

COLLEGE OF AGRICULTURE

PADANNAKKAD, KASARGOD- 671 314

2019

DECLARATION

I hereby declare that this thesis entitled '**Evaluation of calcium nutrition in okra (*Abelmoschus esculentus* (L.) Moench)**' is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Padannakkad
09-10-2019

Giffy Thomas
2017-11-145

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CERTIFICATE

Certified that this thesis entitled '**Evaluation of calcium nutrition in okra (*Abelmoschus esculentus* (L.) Moench)**' is a record of research work done independently by **Ms. Giffy Thomas (2017-11-145)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

9/10/2019

Padannakkad,

09-10-2019

Dr. VANDANA VENUGOPAL

(Chairperson, Advisory Committee)
Professor and Head i/c,
Rice Research Station,
Moncombu, Alappuzha

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CERTIFICATE

We, the undersigned members of the advisory committee of Ms. Giffy Thomas., a candidate for the degree of **Master of Science in Agriculture** with major in Agronomy, agree that the thesis entitled **"Evaluation of calcium nutrition in okra (*Abelmoschus esculentus* (L.) Moench)"** may be submitted by **Ms. Giffy Thomas**, in partial fulfilment of the requirement for the degree.

9/10/2019

Dr. Vandana Venugopal

(Chairman, Advisory Committee)
Professor and Head i/c
Rice Research Station
Moncombu

9/10/19

Dr. Bridgit. T. K

(Member, Advisory Committee)
Professor and Head
Department of Agronomy
College of Agriculture,
Padannakkad

9/10/2019

Dr. Geetha K.

(Member, Advisory Committee)
Professor
Department of Agronomy
Regional Agricultural Research Station
Kumarakom

9/10/19

Dr. Binitha. N. K

(Member, Advisory Committee)
Assistant Professor
Department of Soil Science and
Agricultural Chemistry
College of Agriculture,
Padannakkad

ACKNOWLEDGEMENT

"Humble yourselves, therefore, under God's mighty hand, that he may lift up you in due time. Cast all your anxiety on him because he cares for you" (1 Peter 5:6-7). I bow my head before the ***Almighty God*** *for blessing me the strength, support, good health and well-being for the completion of this work.*

My words are inadequate to express my deepest sense of gratitude and heartfelt thanks to ***Dr. Vandana Venugopal,*** *Chairman of my Advisory Committee, Professor and Head, Rice Research Station, Moncombu, Alappuzha for her valuable guidance, sustained encouragement, critical observations and constructive suggestions. It was a privilege and luck for me to be associated with her. I feel immense pleasure in expressing my thankfulness for her motherly affection, unfailing patience throughout my research work for preparation of technical programme, seminar presentations and thesis. Her support and patience during my struggling periods can't be expressed in words. Her constant encouragement and criticisms helped me to improve a lot. I got inspired from her honesty and perfection in every action.*

I also thank ***Dr. Bridgit. T. K,*** *member of my Advisory Committee, Professor and Head, Department of Agronomy, College of Agriculture, Padannakkad for her valuable suggestions and immense support during the course period, field work and thesis preparation.*

I take this opportunity to express sincere thanks to my other advisory committee members consisting ***of Dr. Geetha K.,*** *Professor, Department of Agronomy, RARS, Kumarakom and* ***Dr. Binitha. N. K,*** *Assistant Professor, Department of Soil Science and Agricultural chemistry, College of Agriculture, Padannakkad for their constant help, valuable suggestions during the investigation, sensible criticism in animating and ameliorating the manuscript and valuable counsel during the period of study and I owe them a lot for this small venture of mine.*

I am thankful to **Dr. Suresh. P. R**, Associate Dean, College of Agriculture for providing me all facilities from the University during the whole course of study.

I express my sincere thanks to my teachers, **Dr. Jinsy. V. S, Dr. N. Manikandan, Dr. Gayathri Karthikeyan. P, Dr. Devi. V. S, Dr. K. M. Sreekumar, Dr. K. Prathapan, Dr. P. K. Mini, Dr. Sujatha N., Dr. Ramesha B., Dr. Sangeetha. K. G, Dr. A. Rajagopalan, Dr. N. Raji Vasudevan, Dr. Vanaja. T, Dr. Allan Thomas, Dr. Geetha Radhakrishnan and Dr. Pratheesh P Gopinath** for their valuable guidance during the course of study.

I express my gratitude to **Dr. V. P. Ajithakumari**, Assistant Librarian, College of Agriculture, Padannakkad for providing me the library facilities for writing this thesis. I specially thank **Mrs. Ramya. V** and **Mr. Sukil kumar. C,** Research Assistants, Department of Soil Science & Agricultural Chemistry for helping me in my research work. I express my gratitude to all administrative, non-teaching staff of College of Agriculture, Padannakkad and RARS, Pilicode who was involved during the conduct of the research programme. I am thankful to **Kerala Agricultural University** for financial support in the form of fellowship during the tenure of the M. Sc. Agriculture programme.

My diction doesn't seem too rich enough to provide suitable words to articulate my sincere and heartfelt gratitude to my dearest friend **Mr. Adarsh S.** for his immense support and valuable suggestions during my field work and thesis preparation. I also thank my other PG batchmates **Chethan, Anu, Roshni, Radhika, Gladis, Jaseera, Amrita, Reshma, Fathimath, Akhil, Vinayak, Amalendu, Sajay, Shibin, Wayoolang,** my seniors, **Chanchala, Shiva Kumar, Vineetha, Amrutha, Eurekha, Ashwini, Laya, Sreelaja, Shana, Manju, Ajeesh, Mubarack,** and my juniors **Deepa, Sugina, Fousiya, Lintu, Haritha, Shuhaila, Veena, Jeevitha, Karishama, Nimya and Anu Prasad** who has given sound and fruitful advice, timely help and also a constant encouragement throughout my venture of this study for which I am greatly indebted to them. I thank my **UG**

batchmates *Jasmin, Sandra and Aswathy for their love and care. I also thank* ***Mr. Jithin Joji*** *for the help rendered during my thesis submission.*

This thesis would be incomplete if I do not reckon the sacrifices, love, affection and support of my mother ***Sheela Thomas****, elder sisters* ***Steffy, Liffy and Tiffy****, elder brother* ***Anto,*** *niece* ***Hannava*** *and nephew* ***Jokuttan.*** *It is immense pleasure to express my sincere gratitude and heartfelt respect to my grandparent* ***Thangham.***

Any omission in this acknowledgement does not mean lack of gratitude.

Giffy Thomas

Dedicated to

AMMA

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LIST OF ABBREVIATIONS AND SYMBOLS

%	-	Per cent
@	-	At the rate of
ANOVA	-	Analysis of variance
BCR	-	Benefit-cost ratio
B	-	Boron
cm	-	Centimeter
Ca	-	Calcium
CAN	-	Calcium ammonium nitrate
$CaCl_2$	-	Calcium chloride
$Ca(NO_3)_2$	-	Calcium nitrate
$CaCO_3$	-	Calcium carbonate
CPCRI	-	Central Plantation Crops Research Institute
DAS	-	Days after sowing
$dS\ m^{-1}$	-	Deci siemens per metre
EC	-	Electrical conductivity
et al	-	And others
Fig.	-	Figure
FYM	-	Farmyard manure
g	-	Gram
$g\ kg^{-1}$		Gram per kilogram
ha	-	Hectare
hrs.	-	Hours
H_2SO_4	-	Sulphuric acid
K	-	Potassium
K_2O	-	Potassium oxide
KAU	-	Kerala Agricultural University
kg	-	Kilogram
$kg\ cm^{-2}$	-	Kilogram per square centimetre
$kg\ ha^{-1}$	-	Kilogram per hectare
$kg\ plant^{-1}$	-	Kilogram per plant
L.	-	Linnaeus

lakh ha^{-1}	-	Lakh per hectare
LR	-	Lime requirement
m	-	Metre
M	-	Molar
meq L^{-1}	-	Milliequivalents per litre
mg	-	Milligram
ml	-	Millilitre
mM	-	Millimolar
mg kg^{-1}	-	Milligram per kilogram
Mg	-	Magnesium
mg $100g^{-1}$	-	Milligram per hundred gram
N	-	Nitrogen
NAA	-	Naphthalene acetic acid
NaOH	-	Sodium hydroxide
NS	-	Not significant
°C	-	Degree Celsius
°E	-	Degree East
°N	-	Degree North
P	-	Phosphorus
POD	-	Point of deliquescence
POP	-	Package of Practices
P_2O_5	-	Phosphorous pentoxide
ppm	-	Parts per million
q ha^{-1}		Quintal per hectare
RARS	-	Regional Agricultural Research Station
RDF	-	Recommended dose of fertilizers
RDN	-	Recommended dose of nutrients
Rs.	-	Rupees
SE(m)	-	Standard error of means
var.	-	Variety
T	-	Tonnes
t ha^{-1}	-	Tonnes per hectare
YVM	-	Yellow vein mosaic
Zn	-	Zinc

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Introduction

1. INTRODUCTION

Okra *(Abelmoschus esculentus* (L.) Moench), popularly known by the names "Lady's finger" and "Bhindi" belongs to the family Malvaceae, is an important vegetable grown throughout the country as summer crop. Okra is consumed as a fresh vegetable and also used in culinary preparations. It is also added for the thickening of gravies and soups. Okra provides carbohydrates, fat, protein, minerals and vitamins that are essential in human nutrition. The okra fruits are rich in vitamin A (0.1 mg), thiamine (0.07 mg), riboflavin (0.1 mg), nicotinic acid (0.6 mg), vitamin C (13 mg), protein (1.9 g), carbohydrates (6.4 g), fat (0.2 g) and fibre (1.2 g). It also contains iron (0.35 mg), calcium (90 mg), phosphorus (56 mg), potassium (103 mg), sodium (6.9 mg), sulphur (30 mg) and magnesium (53 mg) per 100 g of raw okra fruits. The nutritive value of okra is found to be higher than many other vegetables like tomato, brinjal (Gopalan *et al.,* 2007). India is the largest producer of okra in the world where the total area and production comes to about 5.09 lakh ha and 60.95 lakh t respectively (GOI, 2017). Kerala is one of the important okra growing states covering 0.03 lakh ha of area with a production of 0.3 lakh t and productivity of 9.74 t ha^{-1} during 2016-2017.

Calcium, a secondary nutrient is essential for the plant metabolism. This element is required for the growth of meristematic tissues and functioning of root tips (Prasad *et al.*, 2014). It has a fundamental role in the integrity and stability of cell. Calcium present as calcium pectate in the middle lamella is found essential for strengthening of cell wall and plant tissues and thereby provides mechanical support. The calcium pectate proportion in the cell wall thus determines the sensitivity of tissue to bacterial and fungal infections (Marschner, 2012) and responsible for the fruit ripening (Ferguson, 1984). This portion preserves the fruits from deterioration by regulating the respiration rate and minimizes the evolution of ethylene from tender fruits thereby conserving moisture content and retaining freshness of fruit (Balasubramanian *et al.*, 2010). Even a relatively small rise in the concentration of calcium in fruits can be effective in preventing or reducing storage losses and thereby

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increases economic returns. Calcium in water-soluble form extracted from egg shells has been proven as efficient and effective in Korean natural farming technique (Chang *et al.*, 2013). Water-soluble supplements of calcium available in the market are expensive. Therefore, the experiment envisages developing and characterizing a water soluble organic calcium source for foliar spray with locally available inputs.

Calcium in soil also regulates availability of other nutrients and thereby yields. Therefore, calcium nutrition is important. Calcium deficiency may occur in soil with less base saturation and increased levels of acidic deposition (McLaughlin and Wimmer, 1999). The lime stone and dolomite are commonly used liming material in acidic soils. Calcium mobility in the plant takes places through the xylem rather than phloem, together with water. Uptake and transport of calcium are passive and upward movement is with transpiration stream (Epstein, 1972). Therefore, uptake of calcium is related to the transpiration rate directly. Calcium deficiencies are caused either due to less availability of calcium or due to water stress which results in low rates of transpiration. Calcium cannot be mobilized from older tissues and redistributed via phloem. This forces the tissues to lean upon the immediate supply of calcium in the xylem (Valero and Serrano, 2010). The transpiration rate is low in young leaves, enclosed tissues and fruit (White and Broadley, 2003). Therefore, it is essential to ensure the constant supply of calcium required for continuous plant growth. The low transpiration rate of fruits in combination with mobility of calcium in the phloem causes serious problem enhancing the distribution of the element to the fruit via calcium application to the root system (Bangerth, 1979). Therefore calcium sprays in aerial parts of plant is recommended and applied in many fruit production zones of the world (Lurie and Crisosto, 2005), either as routine application to lessen or prevent the emergence of calcium deficiencies in localized areas or to enhance the quality of commodities in the market (Liebisch *et al.*, 2009). Foliar feeding results in quick uptake and translocation of nutrients to different plant parts and allows rapid correction of nutrient deficiencies and thereby increases the production and marketability of the produce (Fageria *et al.*, 2009).

Hence the present study on “Evaluation of calcium nutrition in okra *(Abelmoschus esculentus* (L.) Moench)” was conducted using okra as test crop. The following were the objectives:

1. To develop and characterize an organic calcium source for foliar spray
2. To identify the best source and method of calcium nutrition by assessing its impact on growth, productivity, profitability and quality of okra

Review of literature

2. REVIEW OF LITERATURE

Okra *(Abelmoschus esculentus* (L.) Moench), an important summer vegetable, meet the demand of vegetables in the country when other vegetables are found scarce in market. Okra is cultivated year round in Kerala. It grows well in summer whereas in winter they are found retarded and late in maturity. Calcium, a macro nutrient plays vital role in cell elongation, cell division and thereby yields in the vegetables. The present study entitled "Evaluation of calcium nutrition in okra *(Abelmoschus esculentus* (L.) Moench)." was done to identify the best source and method of calcium nutrition and thereby assessing its impact on growth, productivity, profitability and quality of okra.

A literature study was conducted for the experiment and supporting reviews are presented below under different titles.

2.1 IMPORTANCE OF CALCIUM NUTRITION IN VEGETABLES

Calcium have vital role in growth and development of the crop. Beeson (1941) reported that leaves of tomato, legumes. contain several per cent of calcium on a dry weight basis. The calcium content in plants is highly variable and ranges from 0.1 per cent to 10 per cent of total dry weight.

Maynard *et al.* (1981) observed that older foliage of cauliflower contain higher amount of calcium than younger leaves implying calcium immobility in plants. Marme and Dieter (1983) reported the role of calcium in cell division and cell enlargement. The frequent appearance of calcium deficiency in calcium rich soils is due to poor repartioning of the nutrient within the plant (Poovaiah, 1986).

Calcium present as calcium pectate is essential for maintenance of structural integrity of membranes and cell walls. The major portion of calcium in plants is found in the apoplast, associated with cell wall and the plasma membrane (Poovaiah, 1988).

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Calcium deficiency in chilli caused drying up of shoots tips and chlorosis of younger leaves (Roychoudhury *et al.*, 1990).

Maynard and Hochmuth (1996) found that phloem immobile nutrients such as calcium should be applied in small quantities at frequent intervals for correcting calcium deficiencies in vegetables.

The calcium content in leaves and fruit of tomato plants were about 0.67 per cent and 0.056 per cent respectively indicating leaves contain more calcium than fruits (Adams and Holder, 1992).

The membrane integrity and cell wall structure of cucumber fruits is improved when treated with calcium chloride during storage (Kwon *et al.*, 1999).

The low supply of calcium adversely affected the nodulation, growth and nitrogen fixation capacity of rhizobium with the roots of legumes (Pan, 2000).

High calcium levels improved growth of rhizobium, adsorption to roots and nodule number in the pea (El-hamdaoui *et al.*, 2003).

Hao and Papadopoulos (2003) revealed that increased calcium concentration of about 300 ppm reduced the incidences of blossom end rot and fruit rosetting in tomato fruits.

Taylor and Locasio (2004) reported that low soluble calcium concentrations were one of the causes for increased incidences of blossom end rot in tomato.

Gao *et al.* (2006) observed that in grafted eggplant seedlings calcium increased chilling resistance.

2.2 DEVELOPMENT AND CHARACTERIZATION OF ORGANIC CALCIUM SOURCE FOR FOLIAR SPRAY

Taylor (1970) observed that egg shells of chicken were composed of calcite mostly in the form of columnar crystals having 0.04 cm thick.

Agnew (1981) reported that egg shells stored in wooden cabinets of Queensland Museum got corroded and identified the presence of water soluble calcium acetate on the surface of the eggshell by infra-red spectroscopy.

Mitchell (2005) reported that finely grounded eggshell contain calcium in soluble form than hand crushed egg shells where plant uptake was found less due to the presence of calcium in non-soluble form.

Optimal pH values of spray solutions for the uptake of mineral nutrients were within the range of 3.0-5.5 (Kannan, 1980).

Chang *et al.* (2013) demonstrated an experiment for the preparation of water soluble calcium (WCA) using house hold items such as egg shells (oyster or calm shells) with brown rice vinegar as solvent.

Dhanalakshami (2017) reported that the fresh preparation of egg extract had a pH varied from 2.89 to 4.88 and EC of 0.06 dS m^{-1}. The N, P, K, Ca and Mg content in egg extract varied from 0.57 to 0.68 per cent, 0.011 to 0.014 per cent, 0.23 to 0.30 per cent, 1139 to 1367 ppm and 117 to 126 ppm respectively.

Xiu-rong (2019) conducted a study on making calcium acetate from egg shells by the addition of eggshells burned at 1000°C for one hour to the acetic acid having concentration ranged from 15 to 17 M.

2.3 EFFECT OF CALCIUM SOURCE AND METHOD OF APPLICATION

2.3.1 Growth characters

Decreased mitotic activity due to calcium deficiency resulted reduction in plant height of tulip (Nelson and Niedziela, 1998).

Aghofack-Nguemezi and Tatchago (2010) observed that there was no significant effect of calcium fertilizers on plant height of tomato.

Oluwatoyinbo *et al.* (2005) studied the response of okra to lime and phosphorus fertilization in an acid soil and demonstrated that lime application @ 500 kg ha^{-1} increased plant height compared to control.

Lime application had significantly resulted in increased plant height of okra plants grown in acidic soils (Oluwatoyinbo *et al.*, 2009).

The foliar $Ca(NO_3)_2$ application increased plant height on cucumber (Al-Hamzavi, 2010).

Ayyub *et al.* (2012) declared that foliar application of 0.5 M calcium chloride increased number of leaves per plant in tomato.

Rab and Haq (2012) reported that the maximum plant height (86.60 cm) in tomato was observed with foliar application of 0.6 per cent calcium chloride.

In an experiment with different levels of calcium (0, 3, and 6 per cent) as foliar spray on tomato at Agriculture Extension and Model Farm Service, Pakistan, it was found that six per cent concentration increased plant height. (Ilyas *et al.*, 2014).

The calcium foliar application @ 0.25 per cent on tomato plants increased and improved vegetative growth (Husein *et al.*, 2015)

The application of lime @ 450 kg ha^{-1} significantly improved plant height and number of leaves by 18.04 and 34.00 per cent respectively than control in broccoli (Kumari, 2017).

Abd-El-Hamied and Abd El-Hady (2018) revealed that maximum plant height was noticed with foliar application of 0.3 per cent calcium in tomato.

Ashraf *et al.* (2018) observed that foliar treatment of calcium @ 0.3 per cent significantly increased growth parameters such as plant height and number of leaves in tomato.

Haleema *et al.* (2018) revealed that calcium foliar application @ 0.6 per cent increased plant height and number of leaves in tomato.

2.3.2 Yield attributes

2.3.2.1 Days to 50 per cent flowering

Aghofack-Nguemezi and Tatchago (2010) studied the effect of fertilizers containing calcium on the growth and development of tomato and found that calcium nitrate application @ 800 kg ha^{-1} prolonged 50 per cent flowering in tomato.

Shobo *et al.* (2016) studied the effect of foliar application of Megagreen®, an activated calcite containing 95 per cent $CaCO_3$ on the growth and yield performance of tomato and revealed that Megagreen® application @ 1 kg ha^{-1} resulted earliness for flowering.

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2.3.2.2 Number of fruits per plant

Maximum number of fruits (95.33) per tomato plant was found in plants foliar treated with 0.5 M calcium chloride (Ayyub *et al*., 2012).

Foliar application of 0.6 per cent $CaCl_2$ produced highest number of fruits per plant (96.37) in tomato (Rab and Haq, 2012).

Ilyas *et al*. (2014) reported that foliar application of calcium @ 6 per cent had significantly increased number of fruits in tomato. Similar observations were made by Ashraf *et al*. (2018) in tomato where foliar application of calcium chloride @ 0.2 per cent recorded maximum number of fruits (32.73).

Haleema *et al*. (2018) observed that calcium foliar application @ 0.6 per cent significantly increased number of fruits in tomato.

2.3.2.3 Girth of fruit

Ghoname *et al*. (2007) observed that foliar application of calcium chloride had not significantly influenced neck and bulb diameter of onion .

In tomato foliar application of calcium chloride at 0.25 and 0.50 per cent increased width of the fruit (Budak and Erdal, 2016).

According to Abd-El-Hamied and Abd El-Hady (2018) foliar application of calcium at 0.3 per cent resulted in highest fruit diameter in tomato.

Youssef *et al*. (2017) reported that head diameter of lettuce was significantly increased by foliar application with calcium chloride.

2.3.2.4 Length of fruit

Susheela *et al.* (2006) reported that lime application @ 4 t ha^{-1} significantly increased pod length of garden pea compared to control.

Budak and Erdal (2016) conducted a greenhouse study to determine the effect of foliar calcium application on yield and mineral nutrition of tomato cultivars and reported that calcium chloride sprays given in three growing periods at flowering, fruit set and pre-harvest significantly increased fruit length.

2.3.2.5 Weight of fruit

Foliar application of $CaCl_2$ (0.6 per cent Ca) in tomato plants resulted in the maximum fruit weight (Rab and Haq, 2012).

Foliar application of calcium nitrate at a higher concentration (15 mM) was superior in improving growth and mean fruit weight than at lower concentrations (0 and 10 mM) in cucumber plants (Shafeek *et al.*, 2013).

In a study to know the response of tomato (*Lycopersicon esculentum* L.) cv 'Rio Grand' at different levels of calcium as foliar spray, Ilyas *et al.* (2014) observed that foliar application at a concentration of 6 per cent resulted in highest fruit weight (78.01 g).

The foliar application of calcium chloride increased tomato fruit weight when spraying was done in three growing season at flowering stage, fruit set and preharvest (Budak and Erdal, 2016).

The application of lime @ 450 kg ha^{-1} gave maximum fresh weight (674.32 g) in F1 hybrid Green Magic variety of broccoli (Kumari, 2017).

Foliar application of calcium at a concentration of 0.2 per cent produced maximum fruit weight in tomato (Ashraf *et al.*, 2018).

2.3.2.6 Fruit yield

Budak and Erdal (2016) observed that foliar application of calcium chloride at 0.25 and 0.5 per cent increased fruit yield per plant in tomato.

The fruit yield of tomato per plant was highest with calcium foliar application at a concentration of 0.2 per cent (Ashraf *et al.*, 2018).

Asiegbu and Uzo (1983) reported that lime application increased fruit yield of tomato.

In a 2-year study it was reported that cabbage responded well to liming and yield was increased by 46 per cent when lime was applied at 15.7 t ha^{-1} (Smith *et al.*, 1986).

Kotur (1998) revealed that lime application increased the yield of okra to about 3.4 t ha^{-1} when a field experiment was done on lime application in three cropping sequeneces.

Soil application of calcium nitrate increased the yield of vegetables by 9.1 to 24.1 per cent while foliar application @ 0.25- 0.5 per cent increased the yield of vegetables by 4.2-27.7 per cent (Bao *et al.*, 2000).

Calcium nitrate application in green gram as foliar spray had significant effect on yield when sprayed at 0.406 per cent (Sarkar and Pal, 2006).

The cabbage yield differed significantly with lime application and varied between 39.9 to 62 t ha^{-1}. The application of lime increased cabbage yield by 21 to 31 per cent over control. After harvest of the cabbage, okra was grown in residual lime and boron. The yield of succeeding crop okra increased by 5-10 per cent under residual lime (Jena *et al.*, 2009).

Oluwatoyinbo *et al.* (2009) studied the effect of lime application on okra (*Abelmoschus esculentus* (L) Moench) grown on an acidic soil and reported that lime application resulted in highest yield of about 4.4 t ha^{-1}.

Preharvest spray of $CaCl_2$ enhanced the yield of okra from 8.12 t ha^{-1} (control) to 10.5 t ha^{-1} giving an yield advantage of 1.5-2 t ha^{-1} (Balasubramanian *et al.*, 2010).

On conducting an experiment to study the effect of calcium on tomato growth, Kazemi (2014) found that foliar application of $CaCl_2$ at a concentration of 15 mM resulted in the maximum yield (25.36 t ha^{-1}).

Calcium foliar application at 6 per cent had resulted in significant increase in the yield (21.1 t ha^{-1}) of tomato (Ilyas *et al.*, 2014).

Calcium foliar application @ 0.25 per cent was done on tomato plants after two, four, six and eight weeks of transplanting and it was observed that the treatment had significantly increased fruit yield (Husein *et al.*, 2015).

Lime application @ 450 kg ha^{-1} recorded 56.09 per cent higher yield (16.16 t ha^{-1}) over the control (5.93 t ha^{-1}) in F1 hybrid Green Magic variety of broccoli (Kumari, 2017).

According to Abd-El-Hamied and Abd El-Hady (2018) highest tomato yield were recorded for foliar application of calcium at 0.3 per cent.

2.3.3 Soil nutrient status

Kumar and Halder (1996) studied the effect of dolomite application in acid soil and demonstrated that application of dolomite increased exchangeable calcium and decreased boron content in soil compared to control where no application was done.

The lime application of acid soils in the tropics @ 250 kg ha^{-1} resulted in the release of nutrients such as P, K, Ca and Mg (Oluwatoyinbo *et al.*, 2009).

Kisanrao (2005) conducted an experiment to study the effect of application of lime, Zn and B on soil properties, growth, yield and quality of soyabean-cowpea sequence in lateritic soil and reported that available N, exchangeable Ca and Mg content in the soil improved with lime application compared to control where no lime was applied.

Ewulo (2012) reported that lime application increased N, P, K, Ca and Mg content in the soil where okra was grown.

2.3.4 Plant analysis

2.3.4.1 Dry matter production

The tomato plants having calcium deficiency accumulated less dry matter. Dry matter yield was optimal from plants grown in the solution containing only 0.2 meq L^{-1} of calcium and decreased at higher levels of substrate calcium (Hall, 1977).

The dry matter accumulation of tomato plant was increased by lime application (Asiegbu and Uzo, 1983).

Calcium chloride foliar application prior to NPK application in muskmelon and other cucurbits increased dry weight by 47 per cent (Giskin and Nerson, 1984).

In cucumber and melon, irrigation water which was supplemented with calcium nitrate increased dry matter content (Kaya *et al.*, 2002).

Al-Hamzavi (2010) reported that foliar $Ca(NO_3)_2$ applications increased shoot dry weight on cucumber.

Mumivand *et al.* (2010) reported that plant fresh and dry weights of summer savory (*Satureja hortensis* L. cv. Saturn) were increased by $CaCO_3$ up to 5 t ha^{-1}.

2.3.4.2 Nutrient content in the plant and fruit

Asiegbu and Uzo (1983) observed that liming resulted in increased concentration of Ca and Mg in the leaf than fruit whereas P concentration in the fruit was higher than in the leaf.

Gupta and Sanderson (1993) reported that calcium fertilization in the soil was ineffective in increasing calcium content in leaf.

Application of calcium nitrate in soil increased the content of Ca and Mg in Chinese cabbage, salad leaf crops, celery, and cabbage and improved the quality of vegetables (Bao *et al.*, 2000).

Calcium and nitrogen content in cucumber and melon plants increased when calcium nitrate were given as foliar spray (Kaya *et al.*, 2002).

Dong *et al.* (2004) demonstrated that potassium, magnesium, phosphorus and boron content in the fruit reduced with application of calcium. Spraying calcium solution on the leaves during anthesis and young fruits increased calcium content.

Dordas *et al.* (2007) observed that leaf concentration of calcium increased when the nutrient was given as foliar spray and foliar application have direct effect on nutrient concentration of leaf and on growth parameters than soil application.

Jena *et al.* (2009) demonstrated that nitrogen and calcium content of cabbage increased by 3-10 and 31 per cent with lime application respectively.

Oluwatoyinbo *et al.* (2009) observed that leaf calcium and plant potassium content increased with lime application in okra grown on acidic soil.

In cucumber (*Cucumis sativus* L. cv. AL-Hytham) foliar application of calcium nitrate increased nutrients such as nitrogen, phosphorus, potassium and calcium content of leaf (Al-Hamzavi, 2010).

Mumivand *et al.* (2010) reported that $CaCO_3$ application positively affected the leaf calcium content of summer savory but leaf N content were negatively affected.

Calcium content of the cucumber fruits increased with the application of preharvest foliar sprays of $CaCl_2$ @ 1 per cent (Sumathi *et al.*, 2011).

Increased absorption of calcium was reported in tomato plants and fruits, which were foliar sprayed with NAA in combination with $CaCl_2$ (Abbasi *et al.*, 2013).

Highest phosphorus in fruits were obtained by foliar application of 10 mM of $CaNO_3$ on cucumber (Shafeek *et al.*, 2013).

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Foliar $Ca(NO_3)_2$ application increased leaf N, P, K and Ca content by an average of 7.5, 16.7, 7.2 and 20 per cent, respectively in first harvest and 11.6, 20.8, 10.2 and 26.9 per cent, respectively in second harvest compared with the control in tarragon plants (Heidari *et al.*, 2014).

Buczkowsa *et al.* (2015) observed that foliar application of calcium nitrate @ one per cent increased K, Zn, and Cu content of sweet pepper fruits.

According to Tejashvini and Thippeshappa (2017) foliar application of different sources of calcium significantly increased nutrient content of fruits and leaves of tomato over the control.

Abd-El-Hamied and Abd El-Hady (2018) studied the effect foliar treatments of calcium at a concentration of 0, 0.3 and 0.6 per cent on tomato plants. It was observed that foliar application at 0.3 per cent calcium recorded the highest results of N and P contents in leaves.

2.3.4.3 Nutrient uptake

Foliar spray of one per cent $CaCl_2$ increased plant growth and yield by improving mineral uptake of tomato plants (Abbasi *et al.*, 2013).

Tejashvini and Thippeshappa (2017) conducted an experiment to study the response of foliar nutrition of different sources (calcium chloride, calcium nitrate and calcium ammonium nitrate) and levels of calcium on nutrient uptake of tomato and revealed that nutrient uptake by the fruits and leaves significantly increased over the control. However, compared to other calcium sources foliar application of 0.5 per cent calcium ammonium nitrate recorded higher nutrient uptake of N, K, Ca and Mg by the tomato fruit.

According to Abd-El-Hamied and Abd El-Hady (2018) foliar application of calcium at 0.3 per cent obtained highest N and P uptake by fruits of tomato.

2.3.5 Quality aspects of fruits

2.3.5.1 Shelf life

Foliar application of calcium chloride at a concentration of 0.2 per cent significantly increased pectin content and firmness of the tomato fruits (Subbiah and Perumal, 1990)

Subbiah (1994) demonstrated that foliar application of 0.5 per cent calcium chloride resulted in increased firmness index of tomato fruits.

Dong *et al.* (2004) reported that calcium foliar application on the leaves during anthesis and on the young fruits improved the quality of tomato.

The foliar application of 0.5 per cent $CaCl_2$ increased shelf life for ten days in okra (Balasubramanian *et al.*, 2012).

Tomato fruits from calcium treated plants maintained their quality for longer period (Abbasi *et al.*, 2013).

Foliar application of $CaCl_2$ (15 mM) resulted in the maximum fruit firmness (3.91 kg cm^2) and increased shelf life of tomato fruits (Kazemi, 2014).

Islam *et al.* (2016) studied the effect of foliar spraying of calcium on the 'Unicorn' cherry tomato. Calcium treated tomato fruits at harvest time and after storage showed improved cell wall compactness, less respiration rate, least fresh weight loss and best shelf life.

2.3.5.2 Ascorbic acid content

The young okra pods were found to be a good source of ascorbic acid and as the pods matured the ascorbic acid content decreased (Hollinger and Colvin, 1945).

Application of calcium nitrate in soil increased vitamin C content in Chinese cabbage (Bao *et al.*, 2000).

The ascorbic acid content was increased in tomato fruits with calcium application (Dong *et al.*, 2004).

In a field experiment in the lateritic soils of Bhubaneswar to study the effect of lime and boron on cabbage, it was found that ascorbic acid content only slightly increased by one per cent at 0.1 LR after which it declined by 4-13 per cent with higher dose of lime (Jena *et al.*, 2009).

The ascorbic acid content of cucumber was improved with application of 100 per cent water soluble fertilizers plus calcium chloride combination (Sumathi *et al.*, 2011).

Foliar application of $CaCl_2$ (15 mM) resulted in the maximum vitamin C content (25.14 mg 100 g^{-1}) in tomato (Kazemi, 2014).

The ascorbic acid content was improved in calcium treated tomato fruits (16.11 mg $100g^{-1}$) than in the control (Islam *et al.*, 2016).

2.3.5.3 Crude protein

Kisanrao (2005) reported that lime application had resulted in the increased crude protein content in soybean grain.

The experiment at Bhubaneswar on cabbage revealed that mean protein content was 13.9 per cent with no liming which increased significantly by 3 and 10 per cent with application of lime @ 0.1 and 0.3 LR, respectively (Jena *et al.*, 2009).

2.3.5.4 Crude fibre

A field experiment was conducted to study the effect of application of lime on soil properties, growth, yield and quality of Soybean – Cowpea sequence in lateritic soil and found that lime application resulted in decreased crude fibre and soluble carbohydrate content (Kisanrao, 2005).

2.3.6 Pest and disease incidence

According to Woltz *et al.* (1992) calcium administration through leaves resulted in the reduced incidences of crown rot of tomato.

Fertilization of bean plants grown with 1 and 3 mM $CaCl_2$ or $Ca(NO_3)_2$ reduced severity of grey mould as compared with control plants (Elad and Volpin, 1993).

The reduced incidences of bacterial wilt were found in tomato seedlings with increased calcium concentration in nutrient solutions (Yamazaki and Hoshina, 1995).

The incidence of heart rot of Chinese cabbage and that of tomato navel rot disease decreased after application of calcium nitrate (Bao *et al.*, 2000).

Foliar application of $CaCl_2$ at a concentration of 15 mM resulted in the lowest blossom end rot incidence of about 5 per cent in tomato (Kazemi, 2014). Similar observations were done by Rab and Haq (2012) with 0.6 per cent $CaCl_2$ as foliar application.

Ustun *et al.* (2009) reported that treating irrigation water with calcium at a concentration of 120 ppm decreased the severity of tomato pith necrosis.

The blossom end rot incidences in tomato fruits were lowered with increased absorption of calcium (Abbasi *et al.*, 2013).

Ilyas *et al.* (2014) also observed that incidences of blossom end rot were lowest in tomato plants when foliar application of calcium was done at a concentration of 6 per cent compared to 0 and 3 per cent.

2.3.7 Economics

Nazrul and Shaheb (2016) observed that dolomite lime application @ 2 t ha^{-1} increased yields in cabbage and cauliflower and resulted in maximum economic returns.

Muhammad *et al.* (2019) revealed that foliar application of 9 per cent calcium chloride on tomato plants at 30 days after transplanting resulted in highest B:C ratio of 2.3 compared to control (1.8).

Materials and methods

3. MATERIALS AND METHODS

The present study entitled "Evaluation of calcium nutrition in okra (*Abelmoschus esculentus* (L.) Moench)." was carried out at the College of Agriculture, Padannakkad and Regional Agricultural Research Station (RARS), Pilicode during the period extending from June 2018 to December 2018. The work was done as two experiments with the objective to develop and characterize an organic calcium source for foliar spray and to identify the best source and method of calcium nutrition by assessing its impact on growth, productivity, profitability and quality of okra. The experimental site, season and weather conditions, materials used and methods adopted for study are detailed below.

3.1 EXPERIMENT I

STANDARDIZATION OF ORGANIC SOURCE OF CALCIUM FOR FOLIAR SPRAY AND ITS CHARACTERIZATION

A lab study was conducted to determine and characterize an organic calcium source from locally available inputs using coconut water vinegar as solvent. The coconut water vinegar was purchased from CPCRI, Kasaragod. The experiment was laid out with three inputs as treatments replicated five times in CRD.

Treatments

T_1 – Egg shell

T_2 – Bone pieces

T_3 – Powdered lime shell

3.1.1 Experimental site

The experiment has been undertaken in the lab of Department of Agronomy at College of Agriculture, Padannakkad.

3.1.2 Time of experiment

The experiment was conducted during June 2018 to October 2018.

3.1.3 Methods of preparation of foliar spray

In Korean natural farming technique, water soluble form of calcium extracted from egg shell is widely used. It has been proven as effective and efficient method where brown rice vinegar is used as solvent. This technique was employed in the experiment where water soluble calcium is extracted from three sources of calcium such as egg shells, bone pieces and powdered lime shell using coconut vinegar as solvent. The different steps followed during the experiment are explained below.

Firstly, internal membranes in egg shell were removed and then the eggshell and lime shell were cleaned, powdered to small pieces and roasted in a frying pan to a light tan colour. The roasted shells were added slowly to a glass container containing natural coconut water vinegar at a ratio of 1:10 by weight. The fragments of shell floated up and down within the vinegar, releasing carbon dioxide bubbles, while the calcium dissolved into the solution. The mouth of the jar was covered with cloth and secured with rubber bands to get it freed of maggots. The jar was placed in a cool, dark location for a period of 10 days. Since bubbles were not present after 10 days more roasted shells were not added and allowed to stand for 1 to 2 days as per the standard procedure available with brown rice vinegar as solvent (Chang *et al.*, 2013). The resultant solution were strained to remove shells and stored in a clean glass jar at room temperature away from falling of direct sunlight. In the case of bone pieces, vertebrate bones collected were boiled to get rid of fat and meat. Then they were pounded to pieces and roasted in the same way as for shells except that they were treated with coconut water vinegar at a ratio of 1:5 by weight. All other steps remaining the same. The solutions were stored in clean glass containers away from falling of direct sunlight and the analysis was done.

3.2 EXPERIMENT II – EXPERIMENTAL SITE

3.2.1 Location

The field experiment was conducted at Regional Agricultural Research Station (RARS), Pilicode. Geographically, the experimental field is located at 12°12'086''N to 12°12'097" N latitude and 75°09'879" E to 75°09'898''E longitude and an altitude of 19 m above mean sea level.

3.2.2 Soil

Soil samples were collected from 15 cm depth from the experimental site before the experiment was undertaken and analysis were done for bulk density, particle density, pH, EC, organic carbon and nutrients such as N, P, K, Ca, Mg, Zn and B. The physico chemical characteristics of the soil of experimental site and standard procedures followed for the analysis are presented in Table 1. The soil was found to be strongly acidic in pH (4.56) with high organic carbon content of about 0.95 per cent. The available N (200.70 kg ha^{-1}), P (26.97 kg ha^{-1}) and K (198.24 kg ha^{-1}) content of initial soil sample of the experimental site was found to be low, high and medium respectively. The calcium, magnesium and boron content of soil sample were found to be low having 120, 72 and 0.365 ppm respectively. The zinc content of soil obtained higher value of about 3.44 ppm.

3.2.3 Season and weather condition

The experiment was conducted during September 2018 to December 2018. A warm humid tropical climate prevailed over the experimental site. The data on various weather parameters (maximum temperature, minimum temperature, relative humidity, rainfall and sunshine hours) during crop period were collected from the agromet observatory of RARS, Pilicode and depicted graphically in Fig. 1 and summarized in Appendix I.

The maximum and minimum temperature varied from 30.5 to 33 °C and 17.7 to 24.5 °C respectively. The relative humidity during the crop period was in the range of 73 to 84 per cent. The rainfall received during the crop period extending from September 2018 to December 2018 was 246.3 mm.

3.3 CROP AND VARIETY

Okra var. Arka Anamika was used for the field experiment. The characters of the variety include tall and well branched plants with green stem having purple shade. The pods were long and green in colour having five to six ridges. This variety exhibits yellow vein mosaic resistance and hence selected in the experiment as the area is prone to YVM. Seeds were obtained from Indian Institute of Horticultural Research, Hesaraghatta, Bangalore where it has been developed and released.

3.4 METHODS

The experiment was laid out in randomized block design with 9 treatments and 3 replications. The experimental area was divided into 27 plots having 3.6 m length and 1.5 m breadth accommodating 18 plants per plot. The spacing adopted for the sowing was 60 cm between rows and 45 cm within the row. The layout of the experiment is presented in Fig. 2.

3.4.1 Treatments

T_1 - POP (KAU 2016)

T_2 - Organic POP (KAU 2017)

T_3 - T_1 + Lime as soil application (600 kg ha^{-1})

T_4 - T_1 + Dolomite as soil application (550 kg ha^{-1})

T_5 - T_1 + Calcium nitrate foliar spray (1%)

T_6 - T_1 + Calcium chloride foliar spray (0.5%)

T_7 - T_1 + Calcium acetate foliar spray (0.5%)

T_8 - T_1 + foliar spray of solution prepared from eggshell (Best treatment from the first experiment

T_9 - T_1 + Coconut vinegar

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The experiment was conducted in soil with low calcium content having a concentration of 120 ppm. The nutrient management practices for okra were followed as per Package of Practices Recommendations 'Crops' (KAU, 2016) for all plots except for those having T_2. In the plots having T_2, manure and fertilizer application were done as per Organic Package of Practices Recommendations (KAU, 2017). Lime and Dolomite were applied as per ad hoc recommendation given in POP based on soil test values of pH as basal at the time of land preparation for plots having T_3 and T_4 respectively. Foliar sprays of calcium nitrate, calcium chloride, calcium acetate, water soluble calcium and coconut water vinegar were provided from bud stage at fortnightly intervals (30, 45, 60 and 75 DAS).

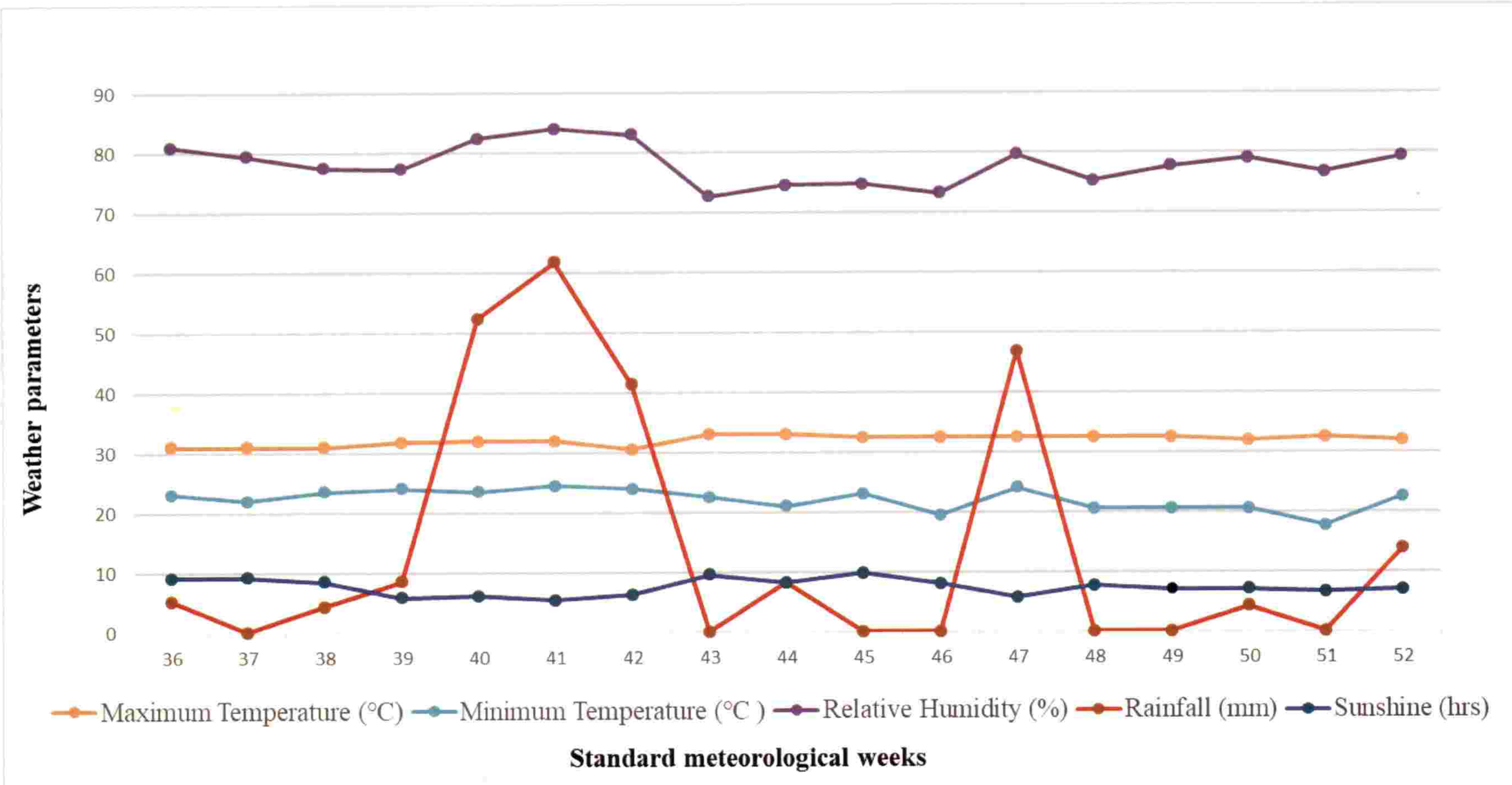

Fig. 1. Weather parameters during the crop season in standard weeks

3.5 CUTIVATION PRACTICES OF MAIN CROP

3.5.1 Field preparation and planting

The experimental field was cleared from weeds two weeks before sowing. It was followed by ploughing using a power tiller. The weeds were uprooted and removed. The field was brought to a fine tilth after removing stubbles and breaking clods. The raised beds were prepared with 3.6 m length, 1.5 m width and 30 cm height with 30 cm spacing between beds.

The sowing was done after lime and dolomite application on respective plots followed by FYM application on all plots. Healthy seeds soaked in water for about 6 hrs. were sown at a spacing of 60 cm between rows and 45 cm within the row. The seeds were dibbled at the rate of 2 seeds per hill. The dibbling was followed by irrigation. Gap filling was done one week after sowing. After establishment, seedlings were thinned out to one per hill. The seed rate adopted was 8.5 kg ha^{-1}.

3.5.2 Application of organic and inorganic fertilizers

Lime and dolomite were applied as per ad hoc recommendation given in POP based on soil test values of pH. The soil was found to be strongly acidic having a pH of about 4.56 and low in calcium content. The lime was applied in the plots having treatment T_2 and T_3 @ 500 and 600 kg ha^{-1} respectively after bed preparation. The dolomite was applied in the plots having T_4 @ 550 kg ha^{-1}. After one week of lime and dolomite application, FYM application and incorporation was done on all plots uniformly @ 20 t ha^{-1}. Fertilizers like urea, rajphos and muriate of potash were applied on all plots except for T_2 as per Package of Practices Recommendations 'Crops' (KAU, 2016) @ 110:35:70 kg ha^{-1} N: P_2O_5: K_2O. For plots having T_2, 190.4 kg rock phosphate and 173 kg sulphate of potash along with *P. fluorescens* @ 2 kg ha^{-1} were given as basal dose at 3 leaf stage and vermicompost application was done @ 1 t ha^{-1} after one month of sowing as per Organic Package of Practices Recommendations (KAU, 2017). Foliar sprays of calcium nitrate, calcium chloride, calcium acetate, water soluble calcium extracted from eggshell and coconut vinegar were provided from bud stage at fortnightly intervals (30, 45, 60 and 75 DAS). The calcium concentration in one per cent calcium nitrate is 1600 ppm whereas the water soluble calcium extracted from egg shell contains 12480 ppm. Hence the developed source of water soluble calcium extracted from egg shell was diluted to 5 times with water before spray. Coconut water vinegar was also sprayed at the same dilution. The pH of the coconut water vinegar is 3.1.

3.5.3 Maintenance of the crop

Hand weeding and earthing up were carried out at 15 DAS. Second and third weeding was done at 30 and 60 DAS. Irrigation was given daily till 30 DAS and later it was extended to once in two days.

3.5.4 Plant protection measures

Timely plant protection measures were taken up as per Package of Practices Recommendations Crops and (Organic) Crops of KAU 2016 and 2017 respectively. The major pests noticed during the crop period were leaf roller and fruit and shoot borer. Flubendiamide was sprayed at 0.3 % uniformly except for plots having treatment T_2. *Beauveria bassiana* @ 10 g per litre was sprayed for the plots following organic practices.

3.5.5 Harvesting

The fruits were picked in morning hours on alternate days when they were still tender. Picking of fruits was started from 43 days after sowing. The length, diameter, weight, yield per plant, yield per plot were recorded immediately after harvest.

N

R_1T_2	R_1T_4	R_1T_7	R_1T_1	R_1T_5	R_1T_9	R_1T_3	R_3T_6	R_3T_3
R_1T_6	R_1T_8	R_2T_5	R_2T_9	R_2T_8	R_2T_2	R_2T_4	R_3T_5	R_3T_1
R_2T_1	R_2T_6	R_2T_7	R_2T_3	R_3T_4	R_3T_7	R_3T_8	R_3T_9	R_3T_2

Fig. 2. Layout of the experimental field

Plate 1. Field preparation

Plate 2. Field layout

Plate 3. Three leaf stage

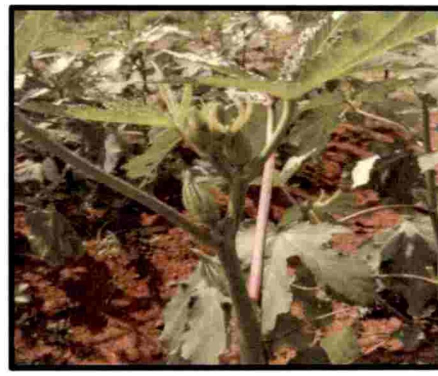

Plate 4. Bud stage

Plate 5. Flowering

Plate 6. Fruit set

Plate 7. Fruit formation

Plate 8. Foliar application of calcium fertilizers

Plate 9. Harvesting

Plate 10. General view of the field at 30 DAS

Plate 11. General view of the field at 60 DAS

3.6 OBSERVATIONS

3.6.1 Experiment I

3.6.1.1 Colour

Visual evaluation of change in the colour of solution was done after filtering on 10th day, 30th and 60th day of preparation.

3.6.1.2 pH

The pH of the solutions was estimated using Beckman glass electrode method (Jackson, 1958) where sample solution and distilled water were taken in the ratio of 1:2.5.

3.6.1.3 Electrical Conductivity

Electrical conductivity of the filtered solutions was estimated using Conductometric method (Jackson, 1958) where the solution and distilled water were taken in the ratio of 1:2.5.

3.6.1.4 Nutrient content

The water soluble calcium extracted from different calcium sources using coconut water vinegar as solvent were analysed to find out the macronutrients such as N, P, K, Ca and Mg at 10, 30 and 60 days after preparation using standard analytical methods furnished in Table 2.

3.6.1.5 Shelf life

The shelf life of the solutions was determined by the odour released from the preparations and presence of maggots in the solution.

Table 1. Physico- chemical properties of soil

Particulars	Content	Method used
Physical properties		
Bulk density (g cm^{-3})	1.33	Undisturbed core sample (Black *et al.*, 1965)
Particle density (g cm^{-3})	2.34	Pycnometer (Black *et al.*, 1965)
Mechanical composition		Robinson international pipette method (Piper, 1966)
Sand (%)	78.35	
Silt (%)	16.8	
Clay (%)	4.85	
Textural class	Loamy sand	
Chemical properties		
pH	4.56	1:2.5 soil water suspension- pH meter (Jackson, 1958)
EC (dS m^{-1})	0.15	Conductivity meter (Jackson, 1958)
Organic carbon (%)	0.957	Walkley and Black method (Jackson, 1958)
Available N (kg ha^{-1})	200.70	Alkaline permanganate method (Subbiah and Asijah, 1956)
Available P (kg ha^{-1})	26.97	Ascorbic acid reduced molybdo phosphoric blue colour method (Watnabe and Olsen, 1965)
Available K (kg ha^{-1})	198.24	Neutral normal ammonium acetate extractant flame photometry (Jackson, 1958)
Available Ca (mg kg^{-1})	120	Atomic absorption spectroscopy (Jackson, 1958)
Available Mg (mg kg^{-1})	72	Atomic absorption spectroscopy (Jackson, 1958)
Available Zn (mg kg^{-1})	3.44	Atomic absorption spectroscopy (Emmel *et al.*, 1977)
Available B (mg kg^{-1})	0.365	Photoelectric colorimetry method (Bingham, 1982)

Table 2. Analytical method used for the chemical characterization of water- soluble calcium

Sl. No.	Estimated characters	Method used	References
1	Total N (%)	Microkjeldahl method	Jackson, 1958
2	Total P (%)	Vanadomolybdo phosphoric yellow colour method	Bray and Kurtz, 1945
3	Total K (%)	Flame photometer method	Jackson, 1958
4	Total Ca (mg kg^{-1})	Atomic Absorption Spectroscopy	Jackson, 1958
5	Total Mg (mg kg^{-1})	Atomic Absorption Spectroscopy	Jackson, 1958

3.6.2 Experiment II

3.6.2.1 Growth characters

The growth parameters recorded were plant height and number of leaves. The observations were taken from five randomly selected plants from each plot which were tagged.

3.6.2.1.1 Plant height

The height of plants was recorded at 30, 60 and 90 DAS. The plant height was measured from ground level to tip of the plant using meter scale and the mean value was computed and expressed in cm.

3.6.2.1.2 *Number of leaves*

Fully opened and photosynthetically active leaves were counted at 30, 60 and 90 DAS on tagged plants and the mean number of leaves per plant was calculated.

3.6.2.2 Yield attribute

3.6.2.2.1 Days to 50 per cent flowering

The number of days taken for fifty per cent of the plant population to flower from the date of sowing was observed as 50 per cent flowering in each plot.

3.6.2.2.2 Number of fruits per plant

The number of fruits harvested in all the plucking from five tagged plants was counted and the average was calculated. Total number of fruits per plant was obtained by the addition of number of fruits thus calculated from each harvest.

3.6.2.2.3 Length of fruit (cm)

In each harvest, the fruit length of five fruits was measured from each treatment, from the base to the tip of the fruit and expressed in cm.

3.6.2.2.4 Girth of fruit (cm)

In each harvest, after recording the length, the girth of the same fruit was measured and expressed in cm.

3.6.2.2.5 Fruit weight (g)

The same fruits after recording length and girth were weighed with the help of electronic balance and mean was computed and expressed in grams.

3.6.2.2.6 ***Fruit yield per plant (kg)***

Total weight of fruits recorded from five selected plants from each plot at each harvest was taken and mean was computed. The fruit yield per plant was computed by addition of mean value thus obtained from each harvest.

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3.6.2.2.7 Total fruit yield per hectare (kg ha^{-1})

Total yield was obtained by addition of yield after harvest from each plot and expressed in kg ha^{-1}.

3.6.2.3 Soil analysis

Soil was collected before the experiment and after the harvest of the crop from the field.

3.6.2.3.1 Soil analysis before the experiment

Soil samples taken from the field before the experiment was analysed and ensured that experiment was done in the soil having low calcium content. Soil samples were drawn from different places of the field which was then mixed, reduced to required quantity and air dried. The air dried soil samples were ground and passed through sieve and was then stored for the analysis of pH, EC, organic carbon and various nutrients like N, P, K, Ca, Mg, Zn and B.

3.6.2.3.2 Soil analysis after the experiment

The soil samples were collected from each plot after the experiment. It was then dried under shade, pounded, sieved and stored. They were analysed for organic carbon and available nutrients like N, P, K, Ca, Mg, Zn and B as per standard procedures furnished in Table 3.

3.6.2.4 Plant analysis

3.6.2.4.1 Dry matter production (kg ha^{-1})

The whole plants were uprooted and fresh weight was recorded from each plot. The uprooted plants were shade dried and was then oven dried at a temperature of 60 °C. The weight of biomass produced was recorded and expressed in kg ha^{-1} basis. Similarly harvested fruits were shade dried and oven dried at 60 °C. The dry matter production of the fruit was also expressed in kg ha^{-1} after recording the fresh weight and dry weight.

3.6.2.4.2 Nutrient content of plant and fruit

Plant samples were collected from the field after the crop was uprooted. Fruits were also collected after the harvest. Plant and fruit samples were shade dried under open condition for some days and was then oven dried at a temperature of 60 °C. Then it was grinded and powdered and analysed for nutrients such as N, P, K, Ca, Mg, Zn and B content using standard procedures as given in the Table 4.

3.6.2.4.3 Nutrient uptake (kg ha^{-1})

The uptake of nutrients such as N, P, K, Ca, Mg, Zn and B by plants and fruits were calculated. It is calculated by multiplying dry matter production and nutrient concentration in the plant and fruit respectively. Both plant and fruit nutrient uptake is expressed in kg ha^{-1}.

3.6.2.5 Quality aspects of fruits

3.6.2.5.1 Shelf life (days)

Five fruits of okra from each plot were harvested and kept in ambient conditions for checking the shelf life of fruits. When the fruits started shrivelling, observations were taken.

3.6.2.5.2 Ascorbic acid content (mg $100g^{-1}$)

Ascorbic acid content of okra was determined using 2, 6- dichlorophenol dye. The ascorbic acid from okra fruits was extracted by blending with 4% oxalic acid and then made up to 100 ml and centrifuged. From that 10 ml supernatant was pipetted into a conical flask and 10 ml of 4 % oxalic acid was added. Then it was titrated with standard dye to a pink end point which last for only few minutes

(Sadasivam and Manickam, 1996). The vitamin C content was calculated using the formula shown below and expressed as mg 100 g $^{-1}$.

$$\text{Ascorbic acid content} = \frac{\text{Titre value} * 0.5 * 100 * 100}{\text{Working standard titre value} * 5 * \text{weight of sample}}$$

3.6.2.5.3 Crude protein (%)

Crude protein was calculated by multiplying the nitrogen content (%) in fruit with Simpson factor 6.25 (Simpson *et al.*, 1965) and expressed in per cent.

3.6.2.5.4 Crude fibre (%)

Two g of dried fruit sample was boiled with 200 ml H_2SO_4 for 30 min, washed and filtered through muslin cloth. It was then boiled with 200 ml NaOH for another 30 minutes, washed and filtered. The sample was dried out, weighed and ignited in muffle furnace at 600 °C. Loss in weight was considered as crude fiber content and expressed in per cent (A.O.A.C, 1975).

3.6.2.6 Economic analysis

3.6.2.6.1 Net returns

The cost of cultivation is computed using price of each input such as seed, fertilizer etc. in rupees at the time of experiment. The cost of cultivation is calculated for one ha. Gross returns per hectare were calculated using the market price of okra. While calculating gross returns marketable yield is considered instead of total yield. The net returns were calculated by subtracting cost of cultivation from gross returns.

3.6.2.6.2 Benefit-cost ratio (BCR)

Benefit-cost ratio is the ratio of gross returns and cost of cultivation. It was calculated using the following formula

$$\text{BCR} = \frac{\text{Gross returns}}{\text{cost of cultivation}}$$

3.6.2.7 Statistical analysis

The data obtained from the experiment was analysed statistically by following the techniques of Analysis of Variance (ANOVA) for Completely Randomised Design and Randomized Block Design (Panse and Sukhatme, 1995). It was then used for comparison and interpretation of result.

Table 3. Methods followed for soil analysis

Sl. No	Parameter	Method	Reference
1	Ph	pH meter	Jackson (1958)
2	EC	Conductivity	Jackson (1958)
3	Organic carbon	Wet digestion method	Walkley and Black (1934)
4	Available N	Alkaline permanganate method	Subbiah and Asija (1956)
5	Available P	Bray extraction and photoelectric colorimetry	Jackson (1958)
6	Available K	Ammonium acetate method	Pratt (1965)
7	Available Ca	Atomic absorption spectroscopy	Jackson (1958)
8	Available Mg	Atomic absorption spectroscopy	Jackson (1958)
9	Available B	Photoelectric colorimetry	Bingham (1982)
10	Available Zn	Atomic absorption spectroscopy	Emmel *et al.* (1977)

Table 4. Methods followed for plant analysis

l.No	Parameter	Method	Reference
1	Total N	Modified kjeldhal digestion method	Jackson (1958)
2	Total P	Vanadomolybdate yellow colour method	Piper (1966)
3	Total K	Flame photometry	Jackson (1958)
4	Total Ca	Atomic absorption spectroscopy	Issac and Kerber (1971)
5	Total Mg	Atomic absorption spectroscopy	Issac and Kerber (1971)
6	Total Zn	Atomic absorption spectroscopy	Emmel *et al.*, (1977)
7	Total B	Azomethine- H colorimetric method	Bingham (1982)

Results

4. RESULTS

The results of the study on 'Evaluation of calcium nutrition in okra *(Abelmoschus esculentus* (L.) Moench)' are presented below after statistical analysis.

4.1 EXPERIMENT I

STANDARDISATION OF ORGANIC SOURCE OF CALCIUM FOR FOLIAR SPRAY AND ITS CHARACTERIZATION

4.1.1 Colour

Initially, colour of coconut water vinegar purchased from CPCRI, Kasaragod was light brown (Plate. 15). Later changed to dark brown after filtering on the tenth day of addition of calcium sources. The colour development was observed from tenth day up to 2 months of preparation and was shown in the Table 5, 6, 7 and Plate. 20.

4.1.2 Chemical characters after ten days of preparation

The pH, EC, N, P, K, Ca and Mg content of water soluble calcium filtered on 10th day of preparation was statistically analysed and given in the Table 5.

The pH of the solutions was acidic in nature and ranged from 3.76 - 4.59. The pH differed significantly between the treatments. The lowest pH was recorded with T_2 which was found more acidic than other solutions.

There was significant difference in EC with treatments. The range of EC was 0.06-0.13 dS m^{-1}. The highest EC was observed in the solution extracted from powdered lime shell and lowest for the solution prepared from bone pieces.

The nitrogen and magnesium content of the solutions didn't differ significantly with the treatments whereas phosphorus content varied. The highest phosphorus content was observed from solution extracted using bone pieces.

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The potassium content in the solution was found significantly influenced by the treatments. The potassium content was obtained highest in the solution extracted using powdered lime shell and it was on par with that of bone pieces.

The calcium content in the solutions were analysed and found that treatments were significantly influenced. The highest calcium content was recorded in solution prepared from powdered lime shell (16440 ppm).

4.1.3 Chemical characters after 30 days of preparation

The data of chemical analysis after 30 days of preparation are given in the Table 6.

The pH of the solutions remained acidic in nature and ranged from 4.22-4.29. They did not vary with the treatments.

The EC of the solution varied significantly with treatments and highest EC was recorded from the solutions extracted from powdered lime shell.

The nitrogen and potassium content of the solution showed no significant difference with the treatments. The phosphorus and magnesium content of the solution differed significantly and highest value for phosphorus content was recorded in bone pieces. The solutions extracted from egg shell recorded highest magnesium which was on par with powdered lime shell.

The calcium content in solution was significantly influenced by the treatments with highest value recorded for powdered lime shell (13640 ppm) and was on par with egg shells (13440 ppm).

4.1.4. Chemical characters after 60 days of preparation

The data pertaining to pH, EC, N, P, K, Ca and Mg content of organic calcium after 60 days of preparation was furnished in Table 7.

The pH of solution differed significantly with the treatments. The solutions extracted from egg shell and powdered lime shell were acidic and that of bone pieces was increased to almost neutral.

The EC of the solution showed variation among the treatments. The highest value was recorded for powdered lime shell.

The nitrogen and phosphorus content of solutions didn't differ significantly. Solution containing eggshell showed a decreasing trend in N and P with increasing days of storage.

The potassium content of solution was significantly influenced by treatment and highest value was recorded for bone pieces. The calcium content was significantly superior in the solution extracted from powdered lime shell (14880 ppm). The calcium content increased with increasing storage life from 10 to 30 days of preparation in case of eggshell solution, thereafter decreased. The significant influence of treatments on magnesium content was observed with highest concentration in the solutions extracted from egg shells and was on par with powdered lime shell.

4.1.5 Shelf life

The maggots was observed in the solutions extracted from lime shell and bone pieces two days after filtering whereas in solutions prepared from egg shells maggots was developed 15 days after filtering.

The solution extracted from bone pieces gave rotten smell 10 days after filtering. Whereas no rotten smell was released in the solution extracted from egg shell and lime shell. Hence it is recommended to use the fresh solution extracted after filtering from egg shells within 15 days.

Table 5. Colour and chemical characters after ten days of preparation

Treatments	Colour	pH	EC (dS m^{-1})	N (%)	P (%)	K (%)	Ca (mg kg^{-1})	Mg (mg kg^{-1})
T_1 – Eggshell	Brown	4.19	0.11	0.69	0.05	0.09	12480	1668
T_2 – Bone pieces	Brown	3.76	0.06	0.56	0.13	0.19	3660	1056
T_3 – Powdered lime shell	Brown	4.59	0.13	0.54	0.04	0.20	16440	1080
SE(m)±		0.040	0.001	0.048	0.017	0.013	184.932	185.580
CD (0.05)		0.120	0.004	NS	0.054	0.041	576.145	NS

Table 6. Colour and chemical characters after 30 days of preparation

Treatments	Colour	pH	EC (dS m^{-1})	N (%)	P (%)	K (%)	Ca (mg kg^{-1})	Mg (mg kg^{-1})
T_1 – Eggshell	Brown	4.22	0.10	0.53	0.04	0.29	13440	1552.00
T_2 – Bone pieces	Brown	4.16	0.05	0.54	0.12	0.30	3240	690.00
T_3 – Powdered lime shell	Brown	4.29	0.11	0.49	0.03	0.24	13640	1140.00
SE(m)±		0.196	0.001	0.028	0.003	0.019	424.185	198.660
CD (0.05)		NS	0.004	NS	0.010	NS	1321.522	618.929

Table 7. Colour and chemical characters after 60 days of preparation

Treatments	Colour	pH	EC (dS m^{-1})	N (%)	P (%)	K (%)	Ca (mg kg^{-1})	Mg (mg kg^{-1})
T_1 – Eggshell	Brown	4.54	0.11	0.50	0.035	0.24	10160	1588.00
T_2 – Bone pieces	Brown	6.67	0.05	0.55	0.040	0.27	2504	907.20
T_3 – Powdered lime shell	Brown	4.51	0.13	0.51	0.031	0.16	14880	1292.00
SE(m)±		0.272	0.002	0.030	0.003	0.018	621.293	200.020
CD (0.05)		0.848	0.006	NS	NS	0.056	1935.598	650.748

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Plate 12. Removal of inner membrane of egg shell followed by crushing

Plate 13. Lime shell

Plate 14. Bone pieces after boiling in water and drying

Plate 15. Coconut water vinegar

Plate 16. Roasting of egg shells, lime shells and bone pieces

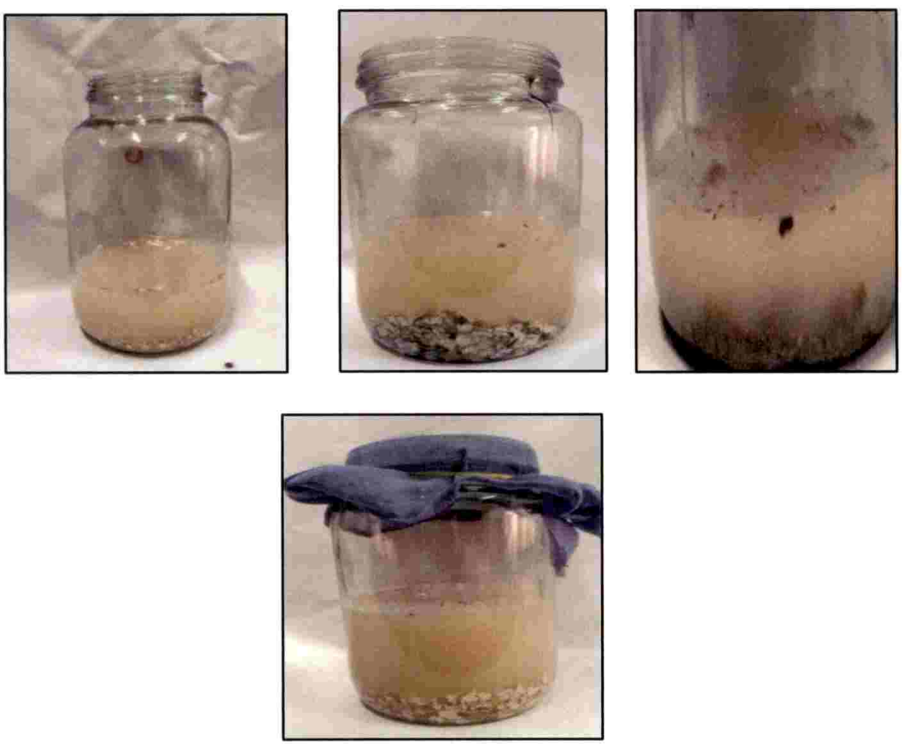

Plate 17. Addition of roasted eggshells, lime shells and bone pieces to coconut water vinegar followed by covering with cloth

Plate 18. Bubble formation on addition of calcium sources to coconut water vinegar

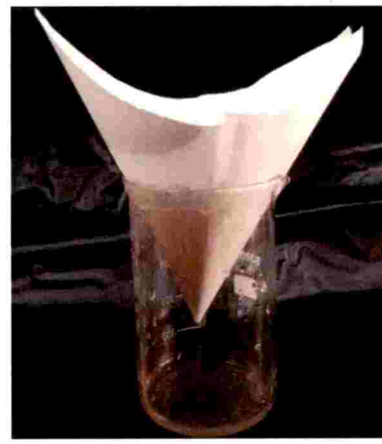

Plate 19. Filtering on tenth day of addition of calcium sources

Plate 20. Solutions stored after filtering

4.2 EXPERIMENT II – EVALUATION OF SOURCE AND METHOD OF CALCIUM APPLICATION IN OKRA

The field experiment was conducted at Regional Agricultural Research Station, Pilicode to identify best source and method of calcium nutrition and thereby assessing its impact on growth, productivity, profitability and quality of okra. The data recorded during the conduct of field experiment were subjected to statistical analysis and results are presented below.

4.2.1 Growth characters

The growth characters such as plant height and number of leaves were recorded at 30, 60 and 90 DAS.

4.2.1.1 Plant height

The plant height at 30, 60 and 90 DAS are presented in Table 8.

The plant height showed significant difference among treatments at different stages of growth at 30, 60 and 90 DAS. The plant height was recorded the lowest in T_2 followed by T_4 and T_1 at 60 DAS. At 90 DAS, lowest height was exhibited in T_2 followed by T_9 and T_1 respectively. However all the treatments involving inorganic fertilizers with calcium nutrition recorded significant increase in plant height at later stages of growth.

4.2.1.2 Number of leaves per plant

The number of leaves per plant as influenced by source and method of calcium nutrition at 30, 60 and 90 DAS are depicted in Table 9.

Significant variation on number of leaves per plant among the treatments was observed at 30, 60 and 90 DAS. At 60 and 90 DAS, number of leaves per plant was highest in T_5 and was on par with T_6. Foliar sprays of calcium nitrate and calcium chloride increased number of leaves at 60 and 90 days after sowing and were significantly superior to other treatments.

It was observed that at 30 and 60 DAS, treatment having highest plant height recorded maximum number of leaves indicating a linear relationship between the parameters. But this trend was not noticed in plants at 90 DAS.

Table 8. Effect of source and method of calcium application on plant height at 30, 60 and 90 DAS

Treatments	Plant height (cm)		
	30 DAS	60 DAS	90 DAS
T_1 - KAU POP 2016	22.40	114.33	153.53
T_2 – Organic POP	25.25	105.53	149.93
T_3 - T_1+ Lime as soil application	26.17	124.43	155.47
T_4 - T_1+ Dolomite as soil application	26.46	114.07	162.00
T_5 - T_1+ Calcium nitrate foliar spray (1 %)	21.71	132.07	158.17
T_6 -T_1+ Calcium chloride foliar spray (0.5%)	25.54	128.33	163.13
T_7 - T_1+ Calcium acetate foliar spray (0.5%)	20.80	123.87	155.07
T_8 - T_1+ Organic calcium from Exp.1	25.10	126.17	161.00
T_9 - T_1+ Coconut Vinegar	25.58	119.87	150.83
SE(m)±	0.893	4.171	1.663
CD (0.05)	2.675	12.490	4.981

Table 9. Effect of source and method of calcium application on number of leaves per plant at 30, 60 and 90 DAS

Treatments	Number of leaves per plant		
	30 DAS	60 DAS	90 DAS
T_1 - KAU POP 2016	10.47	25.7	20.00
T_2 – Organic POP	12.07	22.67	17.40
T_3 - T_1+ Lime as soil application	12.53	26.53	19.53
T_4 - T_1+ Dolomite as soil application	14.13	25.67	22.40
T_5 - T_1+ Calcium nitrate foliar spray (1 %)	10.27	35.27	25.13
T_6 - T_1+ Calcium chloride foliar spray (0.5%)	11.80	32.00	23.50
T_7 - T_1+ Calcium acetate foliar spray (0.5%)	9.60	28.87	19.33
T_8 - T_1+ Organic calcium from Exp.1	12.77	30.67	20.80
T_9 - T_1+ Coconut Vinegar	13.00	24.67	18.87
SE(m)±	0.267	1.107	0.631
CD (0.05)	0.801	3.313	1.908

4.2.2 Yield attributes

4.2.2.1. Days to 50 per cent flowering

The data on days taken to 50 per cent flowering as influenced by source and method of calcium application are given in Table 10.

The days taken to 50 per cent flowering showed no significant difference with the treatments.

4.2.2.2 Number of fruits per plant

The numbers of fruits per plant are furnished in Table 10 after statistical analysis.

The source and method of calcium application significantly influenced number of fruits per plant. The maximum number of fruits per plant (38.94) was recorded in T_5 and was on par with all treatments involving calcium nutrition. The low values were recorded in T_2, T_1 and T_9 respectively. All the calcium application treatments increased number of fruits and was significantly superior to other treatments having no calcium application.

4.2.2.3 Fruit characters

The effect of source and method of calcium application on fruit characters such as girth (cm), length (cm) and weight (g) of fruit are presented in Table 11.

The girth and weight of fruit were influenced significantly by treatments. The fruit girth was maximum in T_5 (5.97 cm) and was on par with T_6, T_4 and T_3. The highest fruit weight was exhibited by T_6 (25.16 g) and was statistically on par with T_5 (24.54 g) and T_7 (23.26 g). Foliar application of all inorganic forms of calcium increased fruit weight. Treatment did not produce any significant influence on the length of fruit.

4.2.2.4 Per plant (kg) and Total fruit yield (kg ha^{-1})

The per plant and total fruit yield as influenced by source and method of calcium application are presented in Table 12.

T_5 recorded maximum fruit yield (0.657 kg) per plant and it was on par with T_6 (0.652 kg), T_7 (0.642 kg), T_3 (0.634 kg), T_4 (0.626 kg) and T_8 (0.613 kg). The minimum fruit yield was recorded in T_2 followed by T_1 and T_9 respectively.

The results revealed that total fruit yield was significantly influenced by treatments. Highest total fruit yield was recorded in T_5 (24.93 t ha^{-1}) and lowest fruit yield was recorded in T_2 (18.17 t ha^{-1}) followed by T_1 and T_9 respectively. The treatment T_5 was on par T_6, T_7, T_4, T_8, and T_3. The per cent increase in the yield of these treatments over recommended dose of nutrients as per KAU Package of Practices Recommendations 'Crops' (2016) ranged from 12.38 per cent to 25.02 per cent. Treatments receiving calcium either as soil or foliar spray along with inorganic fertilizers produced highest fruit yield and total fruit yield.

Table 10. Effect of source and method of calcium application on days to 50 per cent flowering and number of fruits plant $^{-1}$

Treatments	Days to 50 per cent flowering	Number of fruits plant $^{-1}$
T_1 - KAU POP 2016	38.67	33.55
T_2 – Organic POP	37.67	31.11
T_3 - T_1+ Lime as soil application	37.67	37.43
T_4 - T_1+ Dolomite as soil application	37.67	36.72
T_5 - T_1+ Calcium nitrate foliar spray (1 %)	38.33	38.94
T_6 - T_1+ Calcium chloride foliar spray (0.5%)	38.00	38.46
T_7 - T_1+ Calcium acetate foliar spray (0.5%)	38.00	37.69
T_8 - T_1+ Organic calcium from Exp.1	38.33	35.96
T_9 - T_1+ Coconut Vinegar	38.00	34.65
SE(m)±	0.401	1.264
CD (0.05)	NS	3.789

Table 11. Effect of source and method of calcium application on fruit characters

Treatments	Fruit girth (cm)	Fruit length (cm)	Fruit weight (g)
T_1 - KAU POP 2016	5.36	18.29	21.38
T_2 – Organic POP	5.27	17.88	19.11
T_3 - T_1+ Lime as soil application	5.57	18.84	22.47
T_4 - T_1+ Dolomite as soil application	5.58	19.13	21.45
T_5 - T_1+ Calcium nitrate foliar spray (1 %)	5.97	20.05	24.54
T_6 - T_1+ Calcium chloride foliar spray (0.5%)	5.81	19.60	25.16
T_7 - T_1+ Calcium acetate foliar spray (0.5%)	5.44	18.55	23.26
T_8 - T_1+ Organic calcium from Exp.1	5.39	19.19	22.60
T_9 - T_1+ Coconut Vinegar	5.35	18.02	20.56
SE(m)±	0.135	0.609	0.783
CD (0.05)	0.410	NS	2.348

Table 12. Effect of source and method of calcium application on fruit yield per plant and total fruit yield

Treatments	Fruit yield per plant (kg)	Total fruit yield (t ha^{-1})
T_1 - KAU POP 2016	0.537	19.94
T_2 – Organic POP	0.519	18.17
T_3 - T_1+ Lime as soil application	0.634	22.41
T_4 - T_1+ Dolomite as soil application	0.626	23.85
T_5 - T_1+ Calcium nitrate foliar spray (1 %)	0.657	24.93
T_6 - T_1+ Calcium chloride foliar spray (0.5%)	0.652	24.88
T_7 - T_1+ Calcium acetate foliar spray (0.5%)	0.642	24.17
T_8 - T_1+ Organic calcium from Exp.1	0.613	22.48
T_9 - T_1+ Coconut Vinegar	0.562	20.14
SE(m)±	0.027	1.085
CD (0.05)	0.081	3.280

4.2.3 Soil nutrient status after the experiment

The available nutrient content of the soil recorded after the harvest of the crop are presented in Table 13 and 14.

Organic carbon, available form of nitrogen, magnesium, boron and zinc in soil did not differ with source and method of calcium application. However available soil phosphorus showed significant influence with treatment.

Significant difference in available potassium and calcium was observed with treatments. Soil application of lime and dolomite increased available calcium and potassium in soil. Treatment involving recommended dose of nutrients alone and with foliar application showed lower values for available potassium and calcium.

4.2.4 Plant analysis

4.2.4.1 Dry matter production (kg ha^{-1})

Dry matter produced by the fruit and plant expressed in kg ha^{-1} are given in Table 15.

The effect of treatments significantly influenced fruit dry matter. The dry matter production recorded higher value with T_6 (1648.99 kg ha^{-1}) which was on par with T_5 (1486.64 kg ha^{-1}). However dry matter produced recorded minimum value for T_2 *viz.*, organic POP (956 kg ha^{-1}) followed by T_1 and T_9 respectively.

The dry matter produced by the plant showed significant influence with treatments and maximum dry matter was accumulated at T_6 (2692.84 kg ha^{-1}). It was statistically on par with T_5 (2620.49 kg ha^{-1}). Foliar application of calcium chloride and calcium nitrate increased fruit and plant dry matter production significantly over other treatments.

Table 13. Effect of source and method of calcium application on soil organic carbon, available N, P and K after the harvest

Treatments	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1 - KAU POP 2016	1.55	217.43	62.47	231.66
T_2 – Organic POP	1.46	217.42	65.74	238.21
T_3 - T_1+ Lime as soil application	1.54	225.79	61.77	342.18
T_4 - T_1+ Dolomite as soil application	1.60	229.98	63.94	307.15
T_5 - T_1+ Calcium nitrate foliar spray (1 %)	1.33	192.34	47.41	214.02
T_6 - T_1+ Calcium chloride foliar spray (0.5%)	1.60	229.97	57.50	231.63
T_7 - T_1+ Calcium acetate foliar spray (0.5%)	1.48	20.9.09	62.51	225.23
T_8 - T_1+ Organic calcium from Exp.1	1.45	238.34	52.40	244.58
T_9 - T_1+ Coconut Vinegar	1.05	229.97	61.72	221.30
SE(m)±	0.162	14.400	2.286	13.152
CD (0.05)	NS	NS	6.914	39.770

Table 14. Effect of source and method of calcium application on soil available Ca, Mg, B and Zn after the harvest

Treatments	Available Ca (mg kg^{-1})	Available Mg (mg kg^{-1})	Available B (mg kg^{-1})	Available Zn (mg kg^{-1})
T_1 - KAU POP 2016	200.00	80.00	0.260	5.27
T_2 – Organic POP	250.00	82.00	0.250	5.23
T_3 - T_1+ Lime as soil application	286.33	66.67	0.254	4.28
T_4 - T_1+ Dolomite as soil application	283.33	85.83	0.248	4.69
T_5 - T_1+ Calcium nitrate foliar spray (1 %)	170.00	50.00	0.256	3.75
T_6 - T_1+ Calcium chloride foliar spray (0.5%)	213.33	69.60	0.247	6.15
T_7 - T_1+ Calcium acetate foliar spray (0.5%)	170.00	72.33	0.241	4.53
T_8 - T_1+ Organic calcium from Exp.1	220.00	76.33	0.233	4.21
T_9 - T_1+ Coconut Vinegar	176.670	62.000	0.253	4.510
SE(m)±	26.559	9.190	0.005	0.823
CD (0.05)	80.31	NS	NS	NS

Table 15. Effect of source and method of calcium nutrition on plant and fruit dry matter production

Treatments	Dry matter production (kg ha^{-1})	
	Plant	Fruit
T_1 - KAU POP 2016	2055.93	1223.79
T_2 – Organic POP	2009.97	956.02
T_3 - T_1+ Lime as soil application	2283.33	1328.10
T_4 - T_1+ Dolomite as soil application	2177.10	1367.46
T_5 - T_1+ Calcium nitrate foliar spray (1 %)	2620.49	1486.64
T_6 - T_1+ Calcium chloride foliar spray (0.5%)	2692.84	1648.99
T_7 - T_1+ Calcium acetate foliar spray (0.5%)	2189.51	1309.72
T_8 - T_1+ Organic calcium from Exp.1	2189.88	1226.05
T_9 - T_1+ Coconut Vinegar	1794.17	1224.05
SE(m)±	115.803	89.750
CD (0.05)	350.167	271.388

4.2.4.2 Nutrient content in plant

The available nutrient content of the plant at the harvest of the crop are presented in Table 16.

The nutrient content in the plant such as nitrogen, phosphorus, potassium, calcium, magnesium, zinc and boron showed significant influence with treatments.

The treatment T_5 (2.61 per cent) recorded maximum nitrogen content and was on par with T_7 (2.58 per cent), T_4 (2.46 per cent), T_1 (2.28 per cent) and T_6 (2.24 per cent). The highest phosphorus and calcium content was observed in T_5 and it was on par with T_6 and T_7. All the treatments receiving inorganic calcium foliar application significantly resulted in increased phosphorus and calcium content in the plant. The calcium content was found to be comparatively more in plant than fruit. T_9 recorded the lowest calcium content in plant.

The potassium (3.91 per cent) and magnesium content (1.21 per cent) in the plant was highest in T_5 and was superior to all other treatments.

The highest values for zinc (71.14 ppm) and boron (28.31 ppm) was observed in T_6. The zinc content in T_6 was on par with T_2 and T_5.

4.2.4.3 Nutrient content in fruit

The data regarding the nutrient content in the fruit are furnished in Table 17.

The results revealed that nutrient content in the okra fruit such as nitrogen, phosphorus, calcium, magnesium and zinc had influence from the treatments whereas potassium and boron content showed no variation.

The nitrogen content in the fruit was highest in T_5 (3.81 per cent) and was statistically on par with T_6, T_3, T_4, T_7 and T_8. All the calcium treatments increased nitrogen content of fruits significantly over other non-calcium treatments. The phosphorus (0.76 per cent) content was highest in T_5 and was on par with all treatments except T_9. The minimum values for nitrogen was in T_2.

The calcium content was highest in T_6 (1.33 per cent) which was on par with T_7 (1.23 per cent), T_8 (1.22 per cent) and T_5 (1.21 per cent). Foliar application of calcium increased fruit calcium content.

The highest value for magnesium content was in T_8 and was statistically on par with T_4 (1.13 per cent).

The zinc content was highest in T_6 and was on par with T_8, T_4, T_7 and T_5.

Table 16. Effect of source and method of calcium application on nutrient content in plant at harvest

Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Zn (mg kg^{-1})	B (mg kg^{-1})
T_1	2.28	0.35	1.77	2.31	0.72	59.13	20.11
T_2	1.83	0.30	2.70	1.83	0.73	69.27	19.51
T_3	1.90	0.33	2.21	2.04	0.75	53.70	17.87
T_4	2.46	0.29	2.55	2.14	0.77	61.70	20.93
T_5	2.61	0.43	3.91	2.77	1.21	68.60	21.35
T_6	2.24	0.38	2.91	2.75	0.99	71.14	28.31
T_7	2.58	0.38	3.27	2.57	0.88	63.62	24.65
T_8	1.83	0.34	2.79	2.25	0.87	58.40	18.81
T_9	1.79	0.33	2.20	1.47	0.83	51.67	20.65
SE(m)±	0.141	0.021	0.143	0.111	0.038	1.907	0.711
CD (0.05)	0.423	0.064	0.428	0.333	0.113	5.717	2.132

Table 17. Effect of source and method of calcium application on nutrient content in fruit at harvest

Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Zn (mg kg^{-1})	B (mg kg^{-1})
T_1	3.17	0.72	3.12	1.07	1.03	29.49	17.05
T_2	2.51	0.70	3.14	1.03	0.97	29.30	17.19
T_3	3.62	0.69	3.21	1.13	0.94	32.19	16.74
T_4	3.58	0.71	3.16	1.11	1.13	34.73	17.13
T_5	3.81	0.76	3.25	1.21	1.07	33.83	19.71
T_6	3.73	0.69	3.27	1.33	1.06	36.74	16.93
T_7	3.51	0.75	3.16	1.23	1.07	33.85	18.83
T_8	3.51	0.72	3.12	1.22	1.24	34.81	17.50
T_9	3.17	0.61	3.08	1.04	0.98	30.92	14.95
SE(m)±	0.206	0.028	0.207	0.052	0.041	1.058	1.720
CD (0.05)	0.618	0.084	NS	0.155	0.124	3.171	NS

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4.2.4.4 Nutrient uptake of plant

The nutrient uptake of the plant expressed in kg ha^{-1} is presented in Table 18.

The results revealed that plant uptake of nitrogen, phosphorus, potassium, calcium, magnesium, zinc and boron showed significant influence with treatments.

The nitrogen uptake by plant was obtained highest in T_5 (68.92 kg ha^{-1}) and was on par with T_6 and T_7. The plant uptake of phosphorus (11.13 kg ha^{-1}) was the highest in T_5 and was on par with T_6. The uptake of potassium by plant was significantly superior in T_5.

The calcium (73.54 kg ha^{-1}) and zinc (0.193 kg ha^{-1}) uptake of plant was highest in T_6 which was found on par with T_5. The lowest value for the calcium uptake was in T_9. Foliar application of calcium nitrate and calcium chloride significantly increased phosphorus, calcium and zinc uptake by plants over other treatments.

The magnesium (31.11 kg ha^{-1}) and boron (0.076 kg ha^{-1}) uptake by plant was significantly superior in T_5 and T_6 respectively.

4.2.4.5 Nutrient uptake of fruit

The data pertaining to the fruit uptake of nutrients are presented in Table 19.

Significant difference among the treatments was observed on fruit uptake of nitrogen, phosphorus, potassium, calcium, magnesium and zinc.

The fruit uptake of nitrogen was maximum in T_6 (61.52 kg ha^{-1}) and it was on par with T_5 (56.51 kg ha^{-1}) and T_4 (49.40 kg ha^{-1}). The fruit uptake of nitrogen was lowest in T_2.

The highest uptake of phosphorus by the fruits was obtained in T_5 and was statistically on par with T_6, T_7, T_4 and T_3. The fruit P uptake was significantly superior in all the treatments where calcium is applied in the soil or as foliar along with inorganic sources.

The potassium (53.94 kg ha^{-1}) uptake by the fruits was highest in T_6 and was on par with T_5. The calcium (21.94 kg ha^{-1}) uptake was significantly superior in T_6. The minimum value for calcium uptake by fruit was obtained in organic POP followed in T_9 and T_1 respectively.

T_6 recorded the highest values for magnesium uptake (17.57 kg ha^{-1}) and was statistically on par with T_5, T_4, T_8, T_7. The zinc uptake (0.061kg ha^{-1}) of fruit was obtained highest in T_6 and was statistically on par with T_5.

Treatments were statistically non-significant on boron uptake of the fruit.

4.2.5 Quality aspects of fruits

4.2.5.1 Shelf life (days)

The data obtained were statistically analysed and presented in the Table 20.

The results revealed that shelf life of the fruit was significantly influenced by treatments. The shelf life was highest in T_6 (7.33 days) and was on par with T_5, T_7 and T_8. All treatments with foliar application of calcium significantly increased shelf life of fruits. The per cent increase in the shelf life of foliar treated fruits over the soil application ranged from 17.63 per cent to 29.27 per cent.

4.2.5.2 Ascorbic acid content of okra fruit (mg $100g^{-1}$)

Data pertaining to the ascorbic acid content of okra fruit was statistically analysed and presented in Table 20.

Significant influence of treatments on ascorbic acid content of fruit was noticed. The ascorbic acid content was superior in T_5 (28.95 mg 100 g^{-1}) and it was found on par with T_6 (26.31 mg 100 g^{-1}) and T_8 (25.44 mg 100g $^{-1}$).

Table 18. Effect of source and method of calcium application on nutrient uptake of plant at harvest

Treatment	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Ca (kg ha^{-1})	Mg (kg ha^{-1})	Zn (kg ha^{-1})	B (kg ha^{-1})
T_1	46.57	7.17	36.28	47.25	14.72	0.122	0.041
T_2	36.78	6.03	54.28	36.96	14.65	0.139	0.039
T_3	43.52	7.49	50.60	46.58	17.17	0.123	0.041
T_4	53.29	6.37	55.97	47.01	16.97	0.135	0.046
T_5	68.92	11.13	95.30	72.59	31.11	0.180	0.056
T_6	60.67	10.32	77.89	73.54	26.69	0.193	0.076
T_7	56.65	8.22	71.49	56.45	19.27	0.139	0.054
T_8	40.00	7.40	61.11	48.97	19.01	0.128	0.041
T_9	32.15	5.86	39.66	26.31	14.96	0.093	0.037
SE(m)±	4.683	0.611	4.004	3.379	1.444	0.011	0.004
CD (0.05)	14.162	1.831	12.107	10.630	4.329	0.034	0.011

Table 19. Effect of source and method of calcium application on nutrient uptake of fruit at harvest

Treatment	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Ca (kg ha^{-1})	Mg (kg ha^{-1})	Zn (kg ha^{-1})	B (kg ha^{-1})
T_1	38.98	8.83	38.42	13.08	12.54	0.036	0.021
T_2	23.91	6.66	29.90	9.79	9.28	0.028	0.016
T_3	48.08	9.11	42.83	14.94	12.42	0.043	0.022
T_4	49.40	9.72	43.54	15.12	15.43	0.048	0.024
T_5	56.51	11.44	48.96	17.87	15.91	0.050	0.022
T_6	61.52	11.30	53.94	21.94	17.57	0.061	0.028
T_7	46.00	9.87	41.42	16.11	14.15	0.044	0.026
T_8	42.99	8.88	38.00	15.01	15.23	0.043	0.022
T_9	38.86	7.41	37.49	12.71	11.96	0.038	0.024
SE(m)±	4.275	0.841	3.430	1.211	1.251	0.004	0.004
CD (0.05)	12.815	2.521	10.284	3.631	3.751	0.011	NS

4.2.5.3 Crude protein content (per cent)

The crude protein content of okra fruit as influenced by source and method of calcium application are presented in Table 20.

The highest value of 23.80 per cent was recorded with T_5 while the lowest value was noticed with T_2. The treatment T_5 was on par with T_6, T_3, T_4, T_7 and T_8. All the treatments involving soil or foliar application of calcium were significantly superior in crude protein content.

4.2.5.4 Fibre content (per cent)

Data pertaining to fibre content of okra fruits are presented in Table 20.

The effect of treatment on fibre content of okra fruit remained not significant.

4.2.6 Pest and disease incidence

The major pests in the experimental area noticed during crop period were leaf roller and fruit and shoot borer. The attack was noticed at 43 and 48 DAS respectively. The number of larvae of leaf roller (*Sylepta derrogata*) noticed from each plot and per cent damage caused by fruit and shoot borer (*Earias vitella*) per plant were recorded and thereafter control measures were taken effectively. The data obtained were subjected to statistical analysis and presented in Table 21.

The results revealed that lowest number of leaf roller larvae was in T_5 Treatments *viz.*, T_7 (0.67), T_8 (0.67), T_6 (1.00) and T_9 (1.00) was on par with T_5.

The mean per cent of damage caused by *Earias vitella* was calculated and it was observed that lowest per cent of damage was on T_6 and it was on par with T_5, T_7, T_8 and T_3.

Table 20. Effect of source and method of calcium application on quality aspects of fruit

Treatments	Shelf life (days)	Ascorbic acid content (mg 100g^{-1})	Crude protein content (%)	Fibre content (%)
T_1 - KAU POP 2016	5.33	21.05	19.83	5.688
T_2 – Organic POP	5.33	20.72	15.68	5.398
T_3 - T_1+ Lime as soil application	5.67	23.68	22.63	5.127
T_4 - T_1+ Dolomite as soil application	5.67	18.42	22.40	5.842
T_5 - T_1+ Calcium nitrate foliar spray (1 %)	7.00	28.95	23.80	5.660
T_6 - T_1+ Calcium chloride foliar spray (0.5%)	7.33	26.31	23.33	6.493
T_7 - T_1+ Calcium acetate foliar spray (0.5%)	7.00	23.68	21.93	5.100
T_8 - T_1+ Organic calcium from Exp.1	6.67	25.44	21.93	6.067
T_9 - T_1+ Coconut Vinegar	5.33	23.68	19.83	5.487
SE(m)±	0.412	1.459	1.289	0.552
CD (0.05)	1.235	4.375	3.865	NS

4.2.7 Economic analysis

Net returns (Rs.) and BCR as influenced by source and method of calcium application are presented in Table 22.

Net returns and BCR had significant influence with the treatments. The highest net returns (Rs. 3.38 lakh ha^{-1}) and BCR (3.29) was obtained in T_6 and was on par with T_5, T_4, T_7 and T_3. The lowest net returns and BCR was with T_2 followed by T_9. All the inorganic calcium foliar application and soil application of lime and dolomite were significantly superior to other treatments in BC ratio and net returns.

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Table 21. Effect of source and method of calcium application on pest and disease incidence

Treatments	No. of larvae per plot (*Sylepta derrogata*)	Mean per cent of damage per plant (*Earias vitella*)
T_1 - KAU POP 2016	3.33 (2.06)	14.41 (3.84)
T_2 - Organic POP	8.67 (3.07)	26.56 (5.25)
T_3 - T_1+ Lime as soil application	6.00 (2.65)	13.02 (3.731)
T_4 -T_1+ Dolomite as soil application	3.67 (2.16)	17.07 (4.22)
T_5 -T_1+ Calcium nitrate foliar spray (1 %)	0.00 (1.00)	9.45 (3.23)
T_6 -T_1+ Calcium chloride foliar spray (0.5%)	1.00 (1.38)	7.60 (2.92)
T_7 - T_1+ Calcium acetate foliar spray (0.5%)	0.67 (1.24)	9.62 (3.18)
T_8 - T_1+ Organic calcium from Exp.1	0.67 (1.28)	12.15 (3.59)
T_9 - T_1+ Coconut Vinegar	1.00 (1.38)	16.64 (4.20)
SE(m)±	0.189	0.296
CD (0.05)	0.572	0.895

Figures in parenthesis denotes $\sqrt{x+1}$ transformed values.

Table 22. Effect of source and method of calcium application on economics

Treatments	Net Returns (Rs. lakh ha^{-1})	B:C ratio
T_1 - KAU POP 2016	2.50	2.81
T_2 – Organic POP	1.56	1.78
T_3 - T_1+ Lime as soil application	2.90	2.97
T_4 - T_1+ Dolomite as soil application	3.20	3.20
T_5 - T_1+ Calcium nitrate foliar spray (1 %)	3.35	3.21
T_6 - T_1+ Calcium chloride foliar spray (0.5%)	3.38	3.29
T_7 - T_1+ Calcium acetate foliar spray (0.5%)	3.19	3.09
T_8 - T_1+ Organic calcium from Exp.1	2.39	2.20
T_9 - T_1+ Coconut Vinegar	1.94	1.97
SE(m)±	0.212	0.137
CD (0.05)	0.640	0.414

Plate 21. Harvested fruits

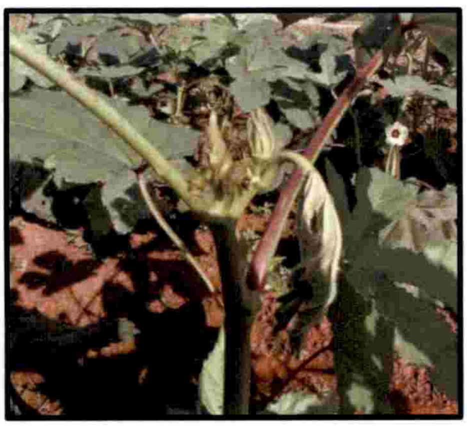

Plate 22. Fruit and shoot borer attack

Plate 23. Leaf roller larvae

Plate 24. Leaf scorching after foliar application of coconut water vinegar

Discussion

5. DISCUSSION

An investigation was designed to study the possibility of utilizing egg shell, lime shell and bone pieces extracted with coconut water vinegar as source of calcium for foliar spray to enhance productivity of okra. This study was also intended to assess the best source and method of calcium nutrition and thereby its impact on growth, productivity, profitability and quality of okra.

The results obtained on the experiment "Evaluation of calcium nutrition in okra *(Abelmoschus esculentus* (L.) Moench)" presented in the previous chapter are discussed below.

5.1 EXPERIMENT I: STANDARDISATION OF ORGANIC SOURCE OF CALCIUM FOR FOLIAR SPRAY AND ITS CHARACTERIZATION

The pH of the solutions differed significantly with the treatments. The solutions were acidic in nature at 10 days of preparation and ranged from 3.76 - 4.59. This was in line with the findings of Chang *et al.* (2008) and Dhanalakshami (2017). The acidic nature of the solution might be due to the acetic acid content in the coconut water vinegar. The lowest pH was recorded in the solutions extracted from bone pieces. The pH of the coconut water vinegar (3.1) has increased after the addition of the lime shells, bone pieces and egg shells. This indicates the role of calcium in decreasing the acidity. Kannan (1980) reported that spray solutions should have pH ranged from 3.0 to 5.5 for the uptake of nutrients. Blanpied (1979) found that maximum absorption of calcium occurred in apple leaves when pH of spray solution ranged from 3.3 to 5.2. The cuticle having isoelectric point of pH 3 will become negatively charged when solutions greater than this pH are sprayed resulting in the easy binding of carboxyl groups of cuticle with positively charged cations (Schonherr and Huber, 1977). After 30 days of preparation, all solutions remained acidic and pH ranged from 4.22- 4.29. They did not vary with the treatments. The solutions extracted from egg shell and powdered lime shell were acidic and that of bone pieces was increased to almost neutral at 60 days of preparation.

The EC of the solutions differed significantly at 10, 30 and 60 days of preparation and varied from 0.05-0.13 dS m^{-1}. The highest EC was in the solution prepared from powdered lime shell.

The nitrogen content in the solution showed no variation with the treatments at 10, 30 and 60 days after preparation.

The phosphorus content differed significantly with treatments at 10 and 30 days after preparation and the highest was recorded in the solution extracted from bone pieces. At 60 days of preparation, phosphorus content of the solution didn't differ significantly. The highest phosphorus content in the solution extracted from bone pieces may be due to dissolution of high amount phosphorus present in the bone pieces under the action of acid. The phosphorus content of bones is 18.66 per cent on dry weight basis (Al Ghuzaili *et al.*, 2019). Solution containing eggshell showed a decreasing trend in N and P with increasing days of storage.

At ten days after preparation, potassium content was the highest recorded in the solution extracted using powdered lime shell and was on par with bone pieces. The potassium content varied significantly at 60 days after preparation and highest value was recorded for bone pieces.

The calcium content in the solutions showed significant influence with treatments at 10, 30 and 60 days of preparation. When the calcium sources such as egg shells, bone pieces and lime shells are mixed with a weak acid such as coconut water vinegar, the chemical reaction converts calcium into an available form, creating carbondixoide escaping as gas and water as by products (Mitchell, 2005). It was highest in the solution extracted from powdered lime shell at 10 days after preparation. At 30 days after preparation, the highest value recorded for powdered lime shell (13640 ppm) which was on par with eggshells. At 60 days after preparation, calcium content (14880 ppm) was the highest in the solution prepared from powdered lime shell. This indicates that more number of calcium ions might have been dissociated in the powdered lime shell than egg shell and bone pieces under the action of acetic acid leading to the formation of calcium acetate. The calcium content in dried bones is 38.97 per cent (Al Ghuzaili *et al.*, 2019). Nys *et al.* (2004) reported that about 750-800 mg of elemental calcium is present in a medium sized egg shell. The calcium content increased with increasing storage life from 10 to 30 days of preparation in case of eggshell solution, thereafter decreased.

The magnesium content in the different sources didn't vary significantly at 10 days of preparation. The solutions extracted from egg shell recorded highest magnesium content at 30 and 60 days of preparation and was on par with powdered lime shell. This indicates dissolving of shells in the coconut water vinegar can provide magnesium. About 95 per cent of an eggshell is made up of calcium carbonate ($CaCO_3$) crystals and the remaining mass is made up of calcium phosphate and magnesium carbonate (Nelson *et al.*, 1966). This is in conformity with findings of Taylor (1970) and Shwetha *et al.* (2018).

The maggot development was observed in the solutions prepared from powdered lime shell and bone pieces after two days of filtering. The solution extracted from egg shell showed maggot formation only 15 days after filtering. The rotten smell was released from solutions prepared using bone pieces at 10 days after filtering. It may be due to fermentation resulting in the production of compounds responsible for foul smell. Hence it is recommended to use solutions prepared from egg shells within the 15 days. This all indicates the short life span of organic calcium sources. The calcium concentration in organic solutions prepared from lime shells and egg shells were comparable with other spray solutions of calcium fertilizers such as calcium nitrate, calcium chloride and calcium acetate upon dilution to five times (Appendix II).

The solution prepared from egg shell is suggested as a source of calcium for foliar spray in plants considering the calcium content, easy availability of egg shells for the farmers and comparatively longer period of storage than other calcium sources. It is having an added advantage of providing appreciable amount of magnesium along with calcium to the plants.

5.2 EXPERIMENT II: EVALUATION OF SOURCE AND METHOD OF CALCIUM APPLICATION IN OKRA

5.2.1 Growth characters

5.2.1.1 Plant height

The plant height was significantly influenced by various sources of calcium application at 30, 60 and 90 DAS. However all the treatments involving inorganic fertilizers with calcium nutrition recorded significant increase in plant height at later stages of growth. This was in line with the findings of Oluwatoyinbo *et al.* (2005), Oluwatoyinbo *et al.* (2009), Al-Hamzavi (2010), Uwah *et al.* (2010), Rab and Haq (2012), Shafeek *et al.* (2013), Badak *et al.* (2015), Ashraf *et al.* (2018) and Sidhu *et al.* (2018). Marschner (1995) reported that growth rate can be enhanced through calcium application which regulates the activities of IAA having role in cell division and metabolism. Motamedi *et al.* (2013), Mengel *et al.* (2001) and Kazemi (2013) also observed that calcium salts positively influences the vegetative growth.

The plant height was recorded the lowest in organic POP followed by dolomite application and KAU POP at 60 DAS respectively. At 90 DAS, organic POP followed by foliar spray of coconut water vinegar and KAU POP obtained lowest height. The lowest height in organic POP was attributed to the nutrients which are readily available for absorption by the plant in inorganic fertilizers compared to organics during critical stages of growth. Sanwal *et al.* (2007) reported that organic fertilizers have less nutrient content, solubility and nutrient release rates than inorganic fertilizers. The direct decomposition is not required as the nutrients in mineral fertilizers are relatively high, and the release of these nutrients is quick and can improve yield of crop significantly (Ojeniyi, 2002). The calcium uptake was lower in organic POP compared to treatments involving foliar nutrition of calcium thereby retarding cell division and plant height. The reduced plant height in foliar spray of coconut water vinegar and KAU POP is due to low amount of calcium supplied.

5.2.1.2 Number of leaves per plant

The number of leaves showed significant influence with the treatments at 30, 60 and 90 DAS. The plant foliar treated with calcium nitrate recorded highest number of leaves at 60 and 90 DAS and was on par with foliar spray of calcium chloride. Foliar sprays of calcium nitrate and calcium chloride increased number of leaves at 60 and 90 days after sowing and were significantly superior to other treatments. It may be due to more calcium uptake by the plant resulting in increased plant growth which is evident from Table 18. The increased calcium uptake through foliar application of calcium chloride and calcium nitrate than other treatments having foliar application may be due to its less POD value (Fernandez *et al.*, 2013). Similar results were reported by Kaya *et al.* (2002), Ayyub *et al.*, (2012), Shafeek *et al.* (2013) and Sidhu *et al.* (2018). These two treatments increased leaf area which led to increased photosynthesis creating a source sink relationship. These factors ultimately reflected in production.

It was observed that plant height and number of leaves showed linear relationship at 30 and 60 DAS *i.e.* treatment having highest plant height exhibited maximum number of leaves. But this trend was not observed in growth characters recorded at 90 DAS.

5.2.2 Yield attributes

The effect of source and method of calcium application showed significant influence on girth of fruit, weight of fruit, number of fruits per plant, fruit yield per plant and total fruit yield. The length of the fruit and days taken to 50 per cent flowering did not significantly vary with the treatments.

The maximum number of fruits per plant (38.94) was recorded in the foliar spray of calcium nitrate and was on par with treatments involving calcium nutrition. It is found that all treatments having calcium nutrition with KAU POP showed highest number of fruits which were significantly superior to other treatments. This may be due to enhanced absorption of nitrogen which was evident from Table 17. Similar findings are observed by Uwah *et al.* (2010) in

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okra, Rab and Haq (2012) in tomato, Kassa *et al.* (2014) in bean, Ashraf *et al.* (2018) in tomato, Dixit *et al.* (2018) in tomato and Souri and Dehnavard (2018) in tomato. The low values were recorded in Organic POP, KAU POP and foliar spray of coconut water vinegar respectively.

The fruit girth was highest with foliar spray of calcium nitrate and was on par with foliar spray of calcium chloride, dolomite and lime application in the soil. This result was in conformity with Budak and Erdal (2016) in tomato, Youssef *et al.* (2017) in lettuce, Dixit *et al.* (2018) in tomato and Chowdhury *et al.* (2019) in broccoli.

The highest fruit weight was exhibited by foliar spray of calcium chloride and was statistically on par with foliar spray of calcium nitrate and calcium acetate. Foliar applications of all inorganic forms of calcium increased fruit weight since calcium is available directly through foliar application and in readily forms. Fernandez *et al.* (2013) found that foliar feeding of nutrients was target-oriented and had quick response than soil fertilization since nutrients are directly available to plant tissues. Similar results were reported by Rab and Haq (2012) in tomato, Shafeek *et al.* (2013) in cucumber, Rajasekhar and Swaminathan (2015) in bitter gourd and Budak and Erdal (2016) in tomato. The increased fruit weight can be attributed to the increase in the fruit characters such as girth and length (Fig. 3 and 4). The increased fruit calcium content and its accumulation as calcium pectate might have resulted in highest individual fruit weight (Subbaih, 1994). This indicates the importance of calcium in increasing fruit weight (Toivonen and Bowen, 1999). Treatment did not produce any significant influence on the length of fruit.

The maximum fruit yield per plant and total fruit yield was obtained in foliar spray of calcium nitrate and was on par with all treatments having calcium nutrition. Treatments receiving calcium either as soil or foliar spray along with inorganic fertilizers produced highest fruit yield and total fruit yield. This indicated importance of calcium nutrition in increasing total yield. Calcium might have influenced endogenous growth regulators (Bangerth, 1979) and resulted in

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thickening of pericarp walls due to enhanced cytokinin activity (Leopold and Kriedeman, 1975). Similar results were reported by Asiegbu and Uzo (1983), Smith *et al.* (1986), Kotur (1998), Sarkar and Pal (2006), Balasubramanian *et al.* (2010), Budak and Erdal (2016) , Ashraf *et al.* (2018) and Dixit *et al.* (2018). The fruit yield per plant is reflected by fruit weight and fruit number as indicated in the graph (Fig. 3 and 4). The total fruit yield per hectare is decided by the number of fruits per plant and plants per hectare. The increased fruit yield per plant might have contributed to the higher fruit yield per hectare. The results were in line with findings of Kuchay *et al.* (2018) in apple and Rajasekhar and Swaminathan (2015) in bitter gourd. This emphasises the importance of calcium in okra cultivation. The number of fruits per plant, fruit yield per plant and total fruit yield was found lowest in organic practices followed by KAU POP and foliar spray of coconut water vinegar respectively. The low yield in organic cultivation is due to the exclusion of chemical fertilizers and increased damage caused by the pests. This is in conformity with the findings of Kawaski and Fujimoto (2009) and de Ponte *et al.* (2012). The lesser number of fruits per plant, fruit yield per plant and total fruit yield with KAU POP and foliar spray of coconut water vinegar may be due to lack of calcium nutrition.

5.2.3 Soil nutrient status after the experiment

The source and method of calcium application didn't have any significant effect on organic carbon content. It indicate that lime and dolomite application on the soil have no influence on the organic carbon content. However the content was increased generally in all treatments after the experiment than the initial value (0.95 per cent) which may be due to the addition of farm yard manures and decomposition of fallen leaves. The results are in accordance with Kisanrao (2005) and Prasad and Singh (1980).

The available nitrogen content in the soil didn't differ with treatments but nitrogen content was increased from initial value (200.70 kg ha^{-1}) after the experiment. This may be due to the addition of nitrogenous fertilizers and farm yard manure.

The significant influence of treatments was noticed on available phosphorus content in the soil. The general increase in the content after the experiment was recorded in all treatments which may be due to the addition of phosphatic fertilizers.

The available potassium and calcium content in the soil was significantly influenced with treatments. The available potassium and calcium content were highest with lime application followed by dolomite application. Soil application of lime and dolomite increased available potassium and calcium in soil. This was in conformity with the findings of Kumar and Halder (1996), Kisanrao (2005), Oluwatoyinbo *et al.* (2009) and Ewulo (2012). Treatment involving recommended dose of nutrients alone and with foliar application showed lower values for available potassium and calcium. Perusal of data indicates that available calcium content in soil is increased by soil application rather than foliar application of calcium sources. The available form of magnesium, zinc and boron in the soil didn't differ significantly with the treatments.

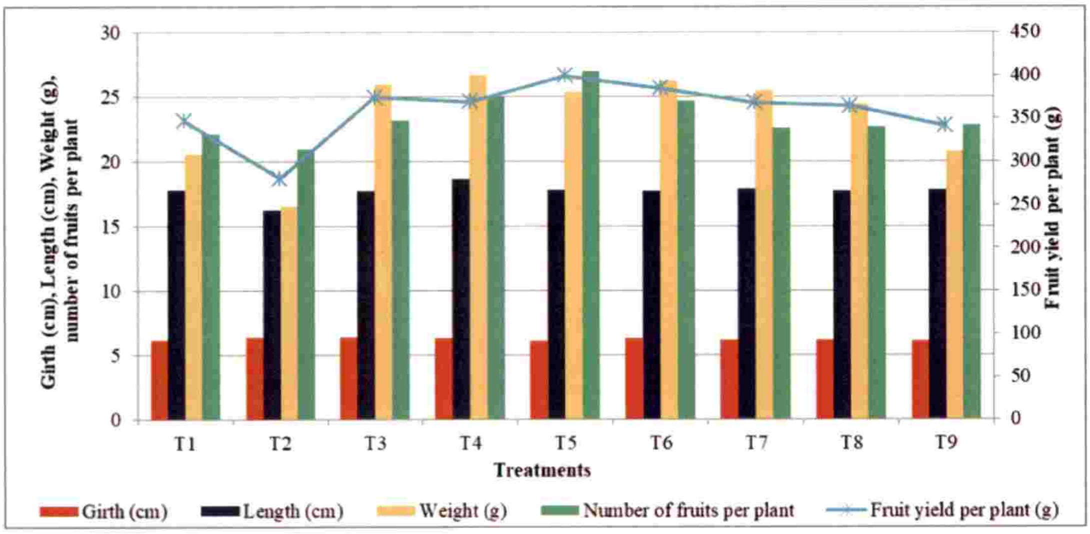

Fig. 3. Relationship of fruit characters, number of fruits and yield per plant as influenced by the treatments in the first half harvests

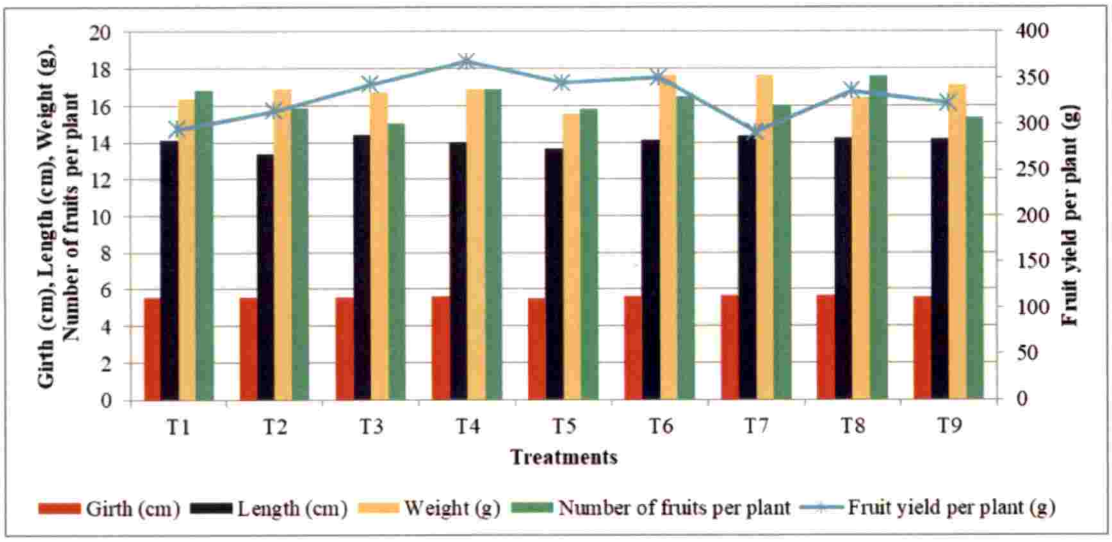

Fig. 4. Relationship of fruit characters, number of fruits and yield per plant as influenced by the treatments in the second half harvests

5.2.4 Plant analysis

5.2.4.1 Dry matter production

The fruit and plant dry matter production showed significant influence with the treatments and maximum dry matter was obtained with foliar spray of calcium chloride and it was on par with foliar spray of calcium nitrate. The fruit and plant dry matter production increased significantly with foliar application of calcium chloride and calcium nitrate. It was observed that nutrient uptake of the nutrients such as phosphorus and calcium (both in fruit and plant) are relatively higher in these treatments. The availability of these nutrients in early stages might have increased photosynthetic rate, meristematic activity and build-up of protein molecules (Marschner, 1995). These two treatments also increased number of leaves which acted as a strong source to fast developing sink. The results was in conformity with Giskin and Nerson (1984) in musk melon and other cucurbits, Al- Hamzavi (2010) in cucumber, Shimaa and Abd-Elkader (2016) in cabbage and Souri and Dehnavard (2018) in tomato. Organic POP, KAU POP and foliar spray of coconut water vinegar had low fruit and plant dry matter.

5.2.4.2 Nutrient content in the plant

The nitrogen content in the plant was the highest with foliar spray of calcium nitrate and was found on par with foliar spray of calcium acetate, dolomite application, KAU POP and foliar spray of calcium chloride. The maximum nitrogen content in foliar application of calcium nitrate may be due to additional supply of nitrogen through foliar application of calcium nitrate.

The phosphorus content in the plant was highest in the foliar spray of calcium nitrate and was found on par with foliar spray of calcium chloride and calcium acetate. All the inorganic calcium foliar application significantly increased the phosphorus in the plant over other treatments. Calcium acts as co-factor or activator of enzymes like hydrolases. It activates phospholipase, arginine kinase, amylase and ATPase enzyme (Marschner, 2012).

The foliar application of calcium nitrate had highest calcium content in the plant and was on par with foliar spray of calcium chloride and calcium acetate. Foliar application of inorganic calcium significantly increased the calcium content in the plant over other treatments. This is in conformity with the results of Kaya *et al.* (2002), Dong *et al.* (2004), Dordas *et al.* (2007), Al-Hamzavi (2010) and Heidari *et al.* (2014). The inorganic foliar application of calcium showed an increasing trend in nitrogen content which was superior to other treatments. Since this calcium is readily available it might have helped the translocation of nitrogen. Addition of either nitrogen or a calcium salt increased nitrogen concentrations (Banath *et al.*, 1966). Increase in calcium concentration enhanced nitrogen in the leaf (Banijamalia *et al.*, 2018). This might be due to the role of calcium in protein formation in the plant (Faust and Klein, 1974). Calcium favours assimilation of nitogen into organic constituents especially proteins (Tejashvini and Thippeshappa, 2017; Ali *et al.*, 2016).

The calcium content was found lowest with foliar spray of coconut water vinegar. This may be because of low calcium content in coconut water vinegar. The spraying of coconut water vinegar caused scorching of leaves. The pH of the spray solution affect rate of penetration and degree of phytotoxicity due to the poly electrolytic nature of cuticle (Schonherr and Huber, 1977). The high osmotic potential and low pH of the spray solution can cause phytotoxicity, affecting photosynthesis and stomata opening (Bai *et al.*, 2008; Fageria *et al.*, 2009, Kluge, 1990). This indicates that coconut water vinegar cannot be considered as a source of calcium as foliar spray. It was observed that calcium content in the plant was less where calcium sources were given through soil application than foliar application. Clarkson and Sanderson (1978) reported that uptake of calcium ions can be done through young root tips only due to the presence of unsuberized cell wall of endodermis.

The magnesium and potassium content in the plant was significantly superior with foliar spray of calcium nitrate. The zinc content in the plant was highest with foliar application of calcium chloride and was on par with organic

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POP and foliar spray of calcium nitrate. The boron content in the plant was superior with foliar spray of calcium chloride. Similar results were reported by Tejashvini and Thippeshappa (2017) and Sidhu *et al.* (2018).

5.2.4.3 Nutrient content in the fruit

The nitrogen content in fruit was highest in foliar spray of calcium nitrate and was statistically on par with foliar spray of calcium chloride, lime application, dolomite application, foliar spray of calcium acetate and organic calcium extracted from egg shell. All the calcium treatments along with KAU POP increased nitrogen content of fruits significantly over other treatments. The results were in conformity with Jena *et al.* (2009), Peyvast *et al.* (2013), Tejashvini and Thippeshappa (2017) and Abd-El- Hamied and El-Hady (2018). The minimal nitrogen content was with organic POP.

The phosphorus content was recorded maximum with foliar spray of one per cent calcium nitrate and was par with all treatments except foliar spray of coconut water vinegar.

The calcium content was the highest with foliar spray of calcium chloride. This was found on par with foliar spray of calcium acetate, organic calcium extracted from egg shell and calcium nitrate. Foliar application of calcium increased fruit calcium content. Calcium is an immobile nutrient and transfer take place only through xylem along with transpiration stream (Epstein, 1972). Moreover rate of transpiration in fruits is less (Bangerth, 1979). This indicates soil application of calcium sources is less efficient in increasing fruit calcium content whereas, foliar fertilization ensures immediate uptake and translocation of nutrients (Fageria *et al.*, 2009), increasing the fruit calcium content. Similar results are reported by McGuire and Kelman (1984), Woo *et al.* (2000), Balasubramanian *et al.* (2010), Badak *et al.* (2015), Madani *et al.* (2015), Shimaa and Abd-Elkade (2016) and Kuchay *et al.* (2018). Foliar application of both organic and inorganic forms of calcium increased calcium content in plants and fruits than other treatments. It was observed that calcium content in the fruit was less compared to the plant. It indicate that only very low amount of calcium is mobilized from sprayed leaves to fruit. Wittwer (1955) reported that polarity and phloem immobility are the causes for calcium immobility. Marschner (2012) also reported limited rates of distribution of calcium from the site of foliar uptake to other plant parts due to phloem mobility. Abundance of negative charges in apoplast may also restrict the calcium movement to other plant parts. But found to have short term and positive effect on plant growth (Fernandez and Brown, 2013). Hence calcium should be applied at frequent intervals than single application (Maynard and Hochmuth, 1996).

The foliar spray of organic calcium extracted from egg shell obtained highest magnesium content and was on par with dolomite application. The high magnesium content in the solution extracted from egg shells and dolomite may be the reason for this. The foliar spray of calcium chloride obtained highest zinc content in the fruit. This was found on par with foliar spray of organic calcium from eggs shell, dolomite application, foliar spray of calcium acetate and calcium nitrate.

5.2.4.4 Nutrient uptake of plant and fruit

The plant uptake of nitrogen was highest with foliar spray of calcium nitrate and was on par with foliar spray of calcium chloride and calcium acetate. However highest phosphorus uptake of plant was obtained with foliar spray of calcium nitrate and was on par with foliar application of calcium chloride. The calcium and zinc uptake in plant was highest in foliar spray of calcium chloride which was on par with calcium nitrate. Foliar application of calcium nitrate and calcium chloride significantly increased phosphorus, calcium and zinc uptake by plants over other treatments. The minimal values of calcium uptake by plant were with foliar spray of coconut water vinegar which may be due to the low calcium content. The potassium and magnesium uptake by plant was significantly superior in foliar spray of calcium nitrate, whereas boron uptake by plant was highest in T_6. Shete *et al.* (2018) reported that foliar application of calcium nitrate increased N, P, K, Ca, Mg, Zn and B uptake by groundnut crop. Tejashvini and

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Thippeshappa (2017) also observed that foliar application of different calcium sources increased nutrient uptake by tomato.

The nitrogen uptake by fruit was highest with foliar spray of calcium chloride and was on par with that of calcium nitrate and dolomite application. The uptake of phosphorus by fruits was obtained highest in foliar spray of calcium nitrate and was statistically on par with foliar spray of calcium chloride and calcium acetate, dolomite and lime application. The fruit P uptake was significantly superior in all the treatments where calcium is applied in the soil or as foliar through inorganic sources. The potassium uptake by the fruits was highest in foliar spray of calcium chloride and was on par with foliar spray of calcium nitrate. The calcium uptake was significantly superior in foliar spray of calcium chloride. The foliar spray of calcium chloride obtained highest values for magnesium uptake by fruits and was on par with foliar spray of calcium nitrate, dolomite application, foliar spray of organic calcium from egg shell and calcium acetate. The zinc uptake by fruits was also obtained highest with foliar spray of calcium chloride and was on par with calcium nitrate foliar application. Foliar nutrition enhanced the intake of mineral nutrients by roots (Adamec, 2002).

Kaushal *et al.* (2014) reported that feeding of nutrients through leaves resulted in higher nutrient uptake than soil application. The point of deliquescence (POD) of calcium chloride, calcium nitrate and calcium acetate are 33 per cent, 56 per cent and 100 per cent respectively (Schonherr, 2000). Salts with points of deliquescence (POD) above the prevailing relative humidity, when applied in the leaves, remain as solutes and leaf penetration is prolonged (Fernandez *et al.*, 2013). This may be the reason for the less effectiveness of calcium acetate than calcium chloride and calcium nitrate in the calcium uptake. The compounds having high point of deliquescence can be reduced by the addition of adjuvants. Schreiber and Schonherr (2009) reported that permeability of cuticle is size selective preventing high molecular weight compounds than low molecular weight compounds. Similar results were reported by Eichert and Goldbach (2008) on the uptake of particles through stomata. Moreover spray solution of calcium chloride is more acidic than calcium nitrate increasing water solubility. The penetration through leaf surface decreases with the diameter of hydrated ion in case of cations having same valency (Franke, 1967).

5.2.5 Quality aspects of fruits

Foliar spray of calcium chloride had maximum shelf life of about 7.33 days and it was found on par with foliar spray of calcium nitrate, foliar spray of calcium acetate and foliar spray of organic calcium extracted from egg shell. The shelf life was lowest in KAU POP, Organic POP, coconut water vinegar, lime application and dolomite application respectively. All treatments with foliar application of calcium significantly increased shelf life of fruits. The per cent increase in the shelf life of foliar treated fruits over the soil application ranged from 17.63 per cent to 29.27 per cent. Similar results were reported by Subbaiah and Perumal (1990) in tomato, Toivonen and Bowen (1999) in bell pepper, Balasubramanian *et al.* (2012) in okra and Islam *et al.* (2016) in tomato. The increased shelf life may be attributed to presence of more amount of calcium in the fruit accumulating as calcium pectate through foliar application and thus preventing loss of turgidity and moisture. This process reduces the evolution of ethylene and the respiration rate and thereby prevents early spoilage of fruits (Singh *et al.*, 1993). This is in conformity with Subbiah (1994), Sumathi *et al.* (2011) and Kazemi (2014).

The ascorbic acid content was highest in foliar spray of calcium nitrate and it was on par with foliar spray of calcium chloride and organic calcium extracted from egg shell. Similar results were shown by Bao *et al.* (2000), Sumathi *et al.* (2011), Kazemi (2014), Shimaa and Abd-Elkader (2016), Asharf *et al.* (2018) and Souri and Dehnavard (2018).

Highest per cent of crude protein was observed with foliar spray of calcium nitrate and was on par with foliar spray of calcium chloride, lime application, dolomite application, foliar spray of calcium acetate and foliar spray of organic calcium extracted from egg shell. Both soil and foliar application of calcium along with KAU POP increased protein content of fruits. It may be due to increased nitrogen content in fruits. Similar results were reported by Kisanrao (2005) and Jena *et al.* (2009). The lowest values were recorded with Organic POP which is due to low nitrogen content in fruit. The effect of treatment on fibre content of okra fruit remained non-significant.

5.2.6 Pest and disease incidence

The lowest number of leaf roller larvae was noticed with foliar spray of calcium nitrate and it was found on par with foliar spray of calcium acetate, foliar spray of organic calcium extracted from egg shell, foliar spray of calcium chloride and foliar spray of coconut water vinegar. The mean per cent of damage caused by fruit and shoot borer was found less when plants were foliar treated with calcium chloride. It was on par with foliar spray of calcium nitrate, calcium acetate, organic calcium extracted from egg shell and lime application in the soil.

The reduced number of leaf roller larvae with foliar spray of coconut water vinegar may be due to the repellent action produced by its smell or taste (Ware and Whitacre, 2004). The increased fruit calcium content and accumulation as calcium pectate enhanced cell wall thickness of fruit reducing the larval incidence. John (1987) reported that cell wall rigidity and membrane stability can be achieved through the addition of calcium.

5.2.7 Economic analysis

The net returns and BCR were generated highest with foliar spray of calcium chloride and was on par with foliar spray of calcium nitrate, dolomite application, foliar spray of calcium acetate and lime application. It was observed that both inorganic calcium foliar application and soil application of lime and dolomite were significantly superior in BC ratio and net returns. These results are in conformity with Banerjee *et al.* (2014), Katiyar *et al.* (2015), Nazrul and Shaheb (2016) and Muhammad *et al.* (2019). The increased net returns in these treatments are due to higher yield involving calcium nutrition. More over cost and quantity required for inorganic fertilizers is less compared to organic fertilizers added the effect.

The low net returns and BCR in Organic POP and foliar spray of coconut water vinegar are due to low yield. The increased cost of coconut water vinegar in market decreased the same. The high quantity requirement of organic fertilizers also increased cost of cultivation (Agbede and Kalu, 1995; Okigbo, 2000), thereby decreased BC ratio.

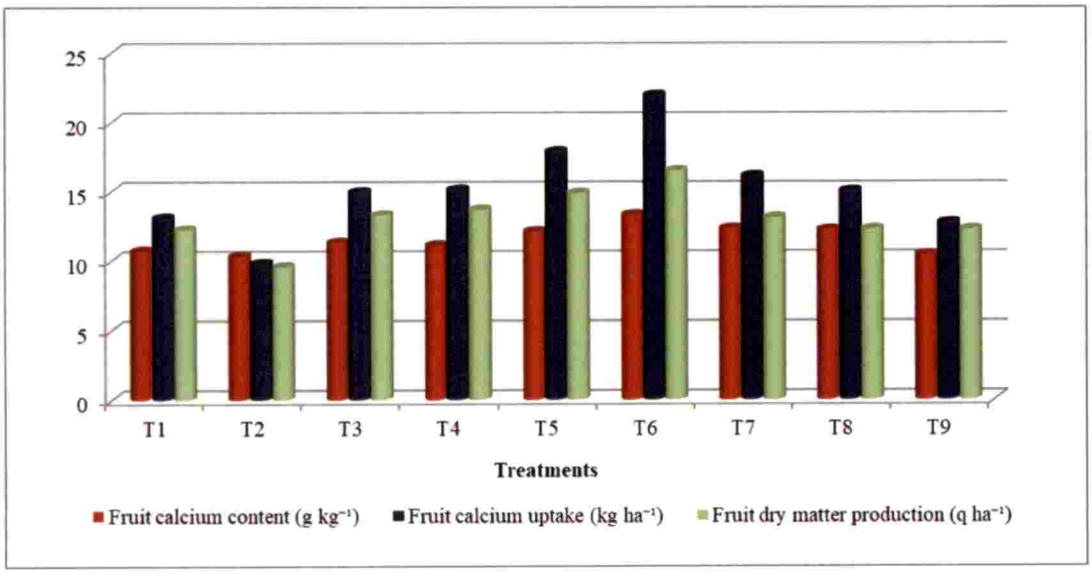

Fig. 5. Relationship between calcium content, calcium uptake and dry matter production of fruit as influenced by treatments

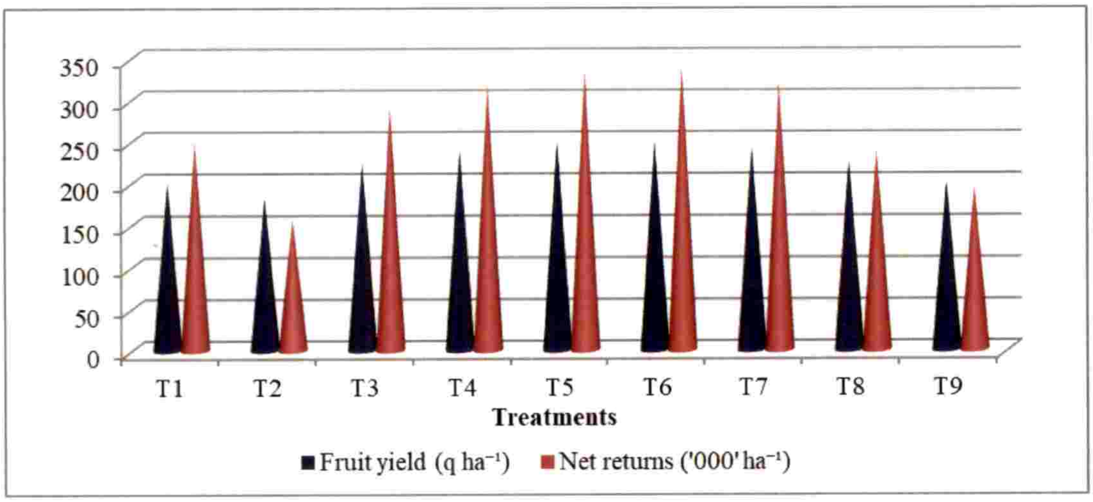

Fig. 6. Relationship between fruit yield and net returns as influenced by the treatments

Summary

6. SUMMARY

An investigation entitled "Evaluation of calcium nutrition in okra (*Abelmoschus esculentus* (L.) Moench)" was undertaken during 2017-18. The study was conducted in two experiments, development and characterization of organic source for foliar spray and field experiment using okra as test crop at College of Agriculture, Padannakkad and Regional Agricultural Research Station, Pilicode respectively. Experiment I was intended to develop and characterize an organic calcium source for foliar spray. Experiment II was aimed to identify the best source and method of calcium nutrition and thereby assessing its impact on growth, productivity, profitability and quality of okra.

The development and characterization of organic source for foliar spray was carried out in completely randomized design with three treatments and five replications. The solutions were prepared by dissolving egg shells (T_1), bone pieces (T_2) and powdered lime shell (T_3) in coconut water vinegar used as solvent. The colour of the solutions was darker after filtering from tenth day up to 2 months of preparation. The pH of the solutions was acidic in nature except for the solutions extracted from bone pieces at 60 days of preparation which was almost increased to neutral. The EC ranged from 0.05-0.13 dS m^{-1}. The nitrogen content in the solution showed no variation with treatments at 10, 30 and 60 days of preparation. The phosphorus content was highest with solutions extracted from bone pieces at 10 and 30 days of preparation, whereas at 60 days of preparation, showed no significance. The potassium content varied with treatments at 10 and 60 days of preparation. The calcium content differed significantly with the treatments at 10 and 60 days of preparation. The highest calcium content was obtained from the solution prepared from lime shells. At 30 days of preparation, calcium content was obtained highest with lime shells followed by egg shells. The organic solutions (lime shell and egg shell) upon five times dilution gave calcium concentration comparable with one per cent calcium nitrate, 0.5 per cent calcium chloride and 0.5 per cent calcium acetate. The solutions extracted from egg shell obtained highest magnesium content which was on par with powdered lime shell at 30 and 60 days of preparation. The maggot development was observed earlier in solutions extracted from lime shells and bone pieces than egg shells. The solution prepared from egg shells are preferred to those from bone pieces and lime shell due to its easy availability and relatively longer period of storage. Hence the solution prepared from egg shells can be used as a source of calcium for foliar spray like calcium nitrate and calcium chloride available in market as foliar fertilizers.

The field experiment was carried out in randomized block design with nine treatments and three replications. The treatment combination were, KAU POP (T_1), Organic POP (T_2), KAU POP + lime as soil application (T_3), KAU POP + dolomite as soil application (T_4), KAU POP + foliar spray of one per cent calcium nitrate (T_5), KAU POP + foliar spray of 0.5 per cent calcium chloride (T_6), KAU POP + foliar spray of 0.5 per cent calcium acetate (T_7), KAU POP + foliar spray of organic calcium extracted from egg shell (T_8) and KAU POP + foliar spray of coconut water vinegar (T_9). The foliar sprays were given at 30, 45, 60 and 75 DAS. The study was carried out with yellow mosaic resistant var. Arka Anamika developed at IIHR, Hesaraghatta. The results of the experiments are summarized below:

1) The plant height and number of leaves was influenced with treatments at 30, 60 and 90 DAS. At 30 DAS, plant height was highest with dolomite application and was on par with T_3, T_9, T_6, T_2 and T_8. The plant height was highest in T_5 at 60 DAS and was on par with T_6, T_8, T_3, T_7, T_4 and T_9. The plant height was highest with foliar application of calcium chloride at 90 DAS and was on par with T_4, T_8 and T_5. At 30 DAS, number of leaves per plant was significantly superior with dolomite application. At 60 DAS and 90 DAS, number of leaves per plant was highest in foliar spray of calcium nitrate and was on par with T_6. At 30 and 60 DAS, treatment having highest plant height recorded maximum number of leaves indicating a linear relationship between the parameters. But this trend was not observed at 90 DAS.

2) The fruit girth was highest in foliar spray of calcium nitrate (5.97 cm) and was on par with T_6, T_4 and T_3. The highest fruit weight was exhibited by foliar application of calcium chloride (25.16 g) and was statistically on par with T_5 and T_7. Foliar spray of calcium nitrate recorded maximum number of fruits per plant (38.94), yield per plant (0.657 kg) and total fruit yield (24.93 t ha^{-1}) and was statistically on par with all treatments except T_2, T_1 and T_9. The minimum value for number of fruits per plant, fruit yield per plant and total fruit yield was in T_2 followed by T_1 and T_9 respectively. The highest fruit and plant dry matter was accumulated with foliar spray of calcium chloride and was on par with T_5.

3) The available soil phosphorus content in the soil was highest in organic POP and was on par with T_4, T_7, T_1, T_3 and T_9. The maximum value for soil available potassium and calcium was with lime application followed by T_4. Organic carbon, available form of nitrogen, magnesium, boron and zinc in soil did not differ with treatments.

4) T_5 recorded maximum nitrogen content in plant and was on par with T_7, T_4, T_1 and T_6. The highest phosphorus and calcium content in the plant was observed in foliar spray of calcium nitrate and it was on par with T_6 and T_7. The calcium content was found to be comparatively more in plant than fruit. T_9 recorded lowest calcium content in plant. The potassium and magnesium contents in the plant were significantly superior in T_5. The zinc in the plant was highest in T_6 and was on par with T_2 and T_5. The boron content was significantly superior in T_6.

5) The nitrogen content in fruit was highest in T_5 and was statistically on par with T_6, T_3, T_4, T_7 and T_8. T_5 recorded highest phosphorus content and was on par with all treatments except T_9. The fruit calcium content was highest with foliar spray of calcium chloride and it was on par with T_7, T_8 and T_5. The magnesium content was highest in T_8 and was on par with T_4. T_6 obtained highest fruit zinc content and was on par with T_8, T_4, T_7 and T_5.

6) The nitrogen uptake by plant was the highest in T_5 and was on par with T_6 and T_7. The plant uptake of phosphorus was the highest in T_5 and was on par with T_6. The uptake of potassium and magnesium by plant was significantly superior in T_5. The calcium and zinc uptake of plant was the highest in T_6 which was found on par with T_5. The boron uptake by plant was significantly superior in T_6.

7) The fruit uptake of nitrogen was highest in T_6 and it was on par with T_5 and T_4. The maximum uptake of phosphorus by the fruits was obtained in T_5 and was statistically on par with T_6, T_7, T_4 and T_3. The potassium uptake was obtained highest in T_6 which was on par with T_5. The uptake of calcium by fruits was significantly superior in foliar spray of calcium chloride. The minimum value for calcium uptake by fruit was obtained in organic POP followed in T_9 and T_1 respectively. The uptake of magnesium in the fruit was highest in T_6 and was on par with T_5, T_4, T_8 and T_7. The zinc uptake of fruit was obtained maximum in T_6 and was statistically on par with T_5.

8) The shelf life was highest in foliar spray of calcium chloride (7.33 days) and it was on par with T_5, T_7 and T_8. The ascorbic acid content was superior in calcium nitrate foliar spray and it was found on par with T_6 and T_8. The crude protein content was obtained highest in foliar application of calcium nitrate and was on par with T_6, T_3, T_4, T_7 and T_8. Organic POP obtained lowest crude protein content.

9) The larval number of leaf roller was lowest in foliar spray of calcium nitrate and was found on par with T_7, T_8, T_6 and T_9. The per cent damage caused by fruit and shoot borer was lowest in foliar spray of calcium chloride and was statistically on par with T_5, T_7, T_8 and T_3.

10) The highest net returns (Rs. 3.38 lakh ha^{-1}) and BCR (3.29) was obtained in foliar spray of calcium chloride and was on par with T_5, T_4, T_7 and T_3. The lowest net returns and BCR was with T_2 followed by T_9.

Perusal of the results revealed that calcium nutrition is having a significant role in enhancement on yield, nutrient uptake, quality, economic returns and lowering pest and disease incidence in okra. Application of recommended dose of nutrients as per KAU POP coupled with foliar spray of either with 0.5 per cent calcium chloride or one per cent calcium nitrate can be suggested for improving calcium nutrition and thereby productivity .

Future line of work

1. Further research is required to explore the possibility of using organic calcium prepared from egg shells in different dilutions and intervals to standardise its efficiency and with reduced number of sprays.
2. Experiments on effect of organic calcium should be conducted in different crops.

References

7. REFERENCES

Abbasi, N.A., Zafar, L., Khan, H.A., and Quershi, A.B. 2013. Effects of naphthalene acetic acid and calcium chloride application on nutrient uptake, growth, yield and post harvest performance of tomato fruit. *Pakist. J. Bot.* 45(5): 1581-1587.

Abd-El-Hamied, A.S. and El-Hady, M.A.A. 2018. Response of tomato plant to foliar Application of calcium and potassium nitrate Integrated with different phosphorus rates under sandy soil conditions. *Egypt. J. Soil Sci.* 58(1) 45-55.

Adamec, L. 2002. Leaf absorption of mineral nutrients in carnivorous plants stimulates root nutrient uptake. *New Phytologist* 155(1): 89-100.

Adams, P and Holder, R. 1992. Effects of humidity, Ca and salinity on the accumulation of dry matter and Ca by the leaves and fruit of tomato (*Lycopersicon esculentum*). *J. Hortic. Sci.* 67: 137-142.

Agbede, O.O. and Kalu, B.A.1995. Constraints of small-scale farmers in increasing crop yield: farm size and fertilizer supply. *Nigerian J. Soil Sci.* 11: 139-159.

Aghofack-Nguemezi, J. and Tatchago, V. 2010. Effects of fertilizers containing calcium and / or magnesium on the growth, development of plants and the quality of tomato fruits in the western highlands of Cameroon. *Int. J. Agric. Res.* 5(10): 821-831.

Agnew, N. 1981. The corrosion of eggshells by acetic acid vapour. *ICCM Bull.* 7(4): 3-9.

Al Ghuzaili, S., Jesil, A., and Saravanan, A.M. 2019. Extraction of calcium phosphate from animal bones. *Int. J. Eng. Res. Technol.* 8(1): 136-138.

Al-Hamzawi, M.A. 2010. Effect of calcium nitrate, potassium nitrate and anfaton on growth and storability of plastic houses cucumber (*Cucumis sativus* L. cv. Al-Hytham). *Am. J. Physiol.* 5: 278-290.

Ali,S.M., Mahmood, G., Fatahi, M.J., and Reza, E. 2016. Efficiency of $CaCl_2$ spray at different development stages on the fruit mineral accumulation in cv. Hayward kiwifruit. *J. Elementology* 21(1): 195-209.

AOAC [Association of Official Analytical Chemists]. 1975. *Official and Tentative Methods of Analysis*. Association of Official Agricultural Chemists, Washington, D.C., 350p.

Ashraf, M.I., Shoukat, S., Hussain, B., Sajjad, M., and Adnan, M. 2018. Foliar application effect of boron, calcium and nitrogen on vegetative and reproductive attributes of tomato (*Solanum lycopersicum* L.). *J. Agric. Sci. Food Res.* 9 (1): 1-3.

Asiegbu, J.E. and Uzo, J.O. 1983. Effects of lime and magnesium on tomato (*Lycopersicon esculentum* Mill) grown in a ferrallitic sandy loam tropical soil. *Plant and Soil* 74(1): 53-60.

Ayyub, C.M., Pervez, M.A., Shaheen, M.I., Ashraf, M.W., Haider, S., and Mahmood, N. 2012. Assessment of various growth and assessment of various growth and yield attributes of tomato in response to pre-harvest applications of calcium chloride. *Pakis. J. Life Soc. Sci.* 10(2): 102-105.

Badak, M., Wall, M., Mirshekari, A., Bah, A., and Mohamed, M.T.M. 2015. Influence of calcium foliar application on plant growth, nutrient concentrations, and fruit quality of papaya. *Hortechnol.* 25(4): 496-503.

Bai, R.Q., Schlegel, T.K., Schonherr, J., and Masinde, P.W. 2008. The effects of foliar applied $CaCl_2$, $Ca(OH)_2$ and K_2CO_3 combined with the surfactants glucopon and plantacare on gas exchange of 1 year old apple (*Malus domestica* borkh.) and broad bean (*Vicia faba* L.) leaves. *Scientia Hortic.* 116: 52-57.

Balasubramanian, P., Balakrishnamoorthy, G., Sivakumar, V., and Balakumbhan, R. 2010. Influence of pre-harvest application growth regulator and calcium on post-harvest fruit calcium content and fruit yield. *Plant Arch.* 10(2): 757-759.

Balasubramanian, P., Balakrishnamoorthy, G., Sivakumar, V., and Balakumbahan, R. 2012. Effect of pre-harvest spray on physiological and bio-chemical changes in bhindi fruits under storage. *Indian J. Agric. Res.* 46(1): 84-87.

Banath, C.L., Greenwood, E.A.N., and Loneragan, J.F. 1966. Effects of calcium deficiency on symbiotic nitrogen fixation. *Plant Physiol.* 41(5): 760-763.

Banerjee, H., Konar, A., Chakraborty, A., and Puste, A. 2014. Impact of calcium nutrition on growth, yield and quality of potato (*Solanum tuberosum*). *SAARC J. Agric*. 12(1): 127-138.

Bangerth, F. 1979. Calcium related physiological disorders of plants. *Annu. Rev. Phytopathol*. 17: 97-122.

Banijamalia, S.M., Feizian, M., Bayata, H., and Mirzaei, S. 2018. Effects of nitrogen forms and calcium amounts on growth and elemental concentration in Rosa hybrida cv. 'Vendentta'. *J. Plant Nutr*. 41(9): 1205-1213.

Bao, L., Haizhou, Z., and Wei, Z. 2000. Influence of calcium and nitrate on yield and quality of vegetables. *Soils and Fertil*. 6(2): 20-22.

Beeson, K.C. 1941. *Mineral composition of crops*. U.S. Dep. Agric. Misc. Publ. 369p.

Bingham, F.T. 1982. Boron. In: Page, A.L. (ed.), *Methods of soil analysis* (2^{nd} Ed.). Am. Soc. Agron. Madison, USA, 438p.

Black, C.A., Evans, D.D., Ensminer, L.E., White, J.L., and Clark, F.E. 1965. *Methods of soil analysis*. Am. Soc. Agron. Madison, USA, 156p.

Blanpied, G.D. 1979. Effect of artificial rain water pH and calcium concentration on the calcium and potassium in apple leaves. *Hortsci*. 14: 706-708.

Bray, R.H. and Kurtz, L.T. 1945. Determination of total organic and available forms of phosphorus in soils. *Soil Sci.* 59: 39-45.

Buczkowska, H., Michaloj, Z., Konapinska, J., and Kowalik, P. 2015. Content of macro- and microelements in sweet pepper fruits depending on foliar feeding with calcium. *J. Elementology* 20(2): 261-272.

Budak, Z. and Erdal, I. 2016. Effect of foliar calcium application on yield and mineral nutrition of tomato cultivars under greenhouse condition. *J. Soil Sci. Plant Nutr.* 4(1): 1-10.

Chang, F.F., Nasr-El-Din, H.A., Lindvig, T., and Qui, X.W. 2008. Matrix acidizing of carbonate reservoirs using organic acids and mixture of HCl and organic Acids. *SPE Int.* 1-9. Available: file:///F:/thesis/Thesis%20print%20I/articles%20to%20be%20printed/chang%202008.pdf. [17 July 2019].

Chang, K.C.S., McGinn, J.M., Weinhert, E., Miller, S.A., Ikeda, D.M., and Duponte, M.W. 2013. Natural farming: Water-soluble Calcium, Sustainable Agriculture, College of Tropical Agriculture and Human Resources, SA-10, 1-3.

Chowdhury, R.S., Kumari, M., Jana, J.C., Basfora, S., and Sikder, S. 2019. Effect of lime and boron on growth and yield of sprouting broccoli under sub-Himalayanfoot hills of west Bengal, India. *Int. J. Curr. Microbiol. App. Sci.* 8(1): 2506-2516.

Clarkson, D, T. and Sanderson, J. 1978. Sites of absorption and translocation of iron in barley roots. *Plant Physiol*. 61: 731 -736.

de Ponte, T., Rijk, B., and Van Ittersum, M. K., 2012. The crop yield gap between organic and conventional agriculture. *Agric. Syst.* 108: 1-9.

Dhanalakshami, V.N. 2017. Validation of liquid organic manures and their effect on crop productivity. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 119p.

Dixit, A., Sharma, D., Sharma, T.K., and Bairwa, P.L. 2018. Effect of foliar application of some macro and micronutrients on growth and yield of tomato (*Solanum lycopersicum* L.) cv. Arka Rakshak. *Int. J. Curr. Microbiol. App. Sci.* 6: 197-203.

Dong, C. X., Zhou, J.M., Fan, X.H., Wang, H.Y., Duan, Z.Q., and Tang, C. 2004. Application Methods of calcium supplements affect nutrient levels and calcium forms in mature tomato fruits. *J. Plant Nutr.* 27(8): 1443–1455.

Dordas, C., Apostolides, G., Goundra, O. 2007. Boron application affects seed yield and seed quality of sugarbeets. *J. Agri. Sci.* 145: 377-384.

Eichert, T., and Goldbach, H.E. 2008. Equivalent pore radii of hydrophilic foliar uptake routes in stomatous and astomatous leaf surfaces - further evidence for a stomatal pathway. *Physiol. Plant* 132: 491-502.

Elad, Y and Volpin, H. 1993. Reduced development of Grey Mould (*Botrytis cinerea*) in bean and tomato plants by calcium nutrition. *J. Phytopathol.* 139: 146-156.

El-Hamdaoui, A., Redondo-Nieto, M., Rivilla, R., Bonilla. I., and Bolanos, L. 2003. Effects of boron and calcium nutrition on the establishment of the Rhizobium leguminosarum–pea (*Pisum sativum*) symbiosis and nodule development under salt stress. *Plant, Cell Environ*. 26: 1003-1011.

Emmel, R.H., Solera, J.J., and Stux, R.L. 1977. *Atomic absorption methods manual.* Instrumentation Laboratory Inc., Wilmington, pp. 67-190.

Epstein, E. 1972. *Mineral nutrition of plants: Principles and Perspectives.* Wiley, New York, 412p.

Ewulo, B.S. 2012. Lime and organic manure effect on acid-clay soil, okra growth and yield parameters. *South Asian J. Exp. Biol*. 2(1): 12-19.

Fageria, N.K., Filho, M.P.B., Moreira, A., and Guimaraes. 2009. Foliar fertilization of crop plant. *J. Plant Nutr*. 32: 1044-1064.

Faust, M. and Klein, J.D. 1974. Levels and sites of metabolically active calcium in apple fruit. *J. Am. Soc. Hortic. Sci.* 99: 93–94.

Ferguson, I.B. 1984. Calcium in plant senescence and fruit ripening. *Plant Cell Environ*. 7: 477-489.

Fernandez, V. and Brown, P.H. 2013. From plant surface to plant metabolism: the uncertain fate of foliar-applied nutrients. *Frontiers in Plant Sci.* 4: 289.

116

Fernandez, V., Sotiropoulos, T., and Brown, P. 2013. *Foliar fertilization: Scientific principles and field practices*. Int. Fertil. Ind. Assoc., Paris, France, 144p.

Franke, W. 1967. Mechanisms of foliar penetration of solutions. *Annu. Rev. Plant. Physiol.* 18: 281-300.

Gao, H., Chen, G., Han, L., and Lin, H. 2006. Calcium influence on chilling resistance of grafting eggplant seedlings. *J. Plant Nutr.* 27(8): 1327-1339.

Ghoname, A., El-Bassiony, A.M., Riad, G.S., and El- Baky M.M.H.A. 2007. Reducing onion bulbs flaking and increasing bulb yield and quality by potassium and calcium application. *J. Basic Appl. Sci.* 1(4): 610-618.

Giskin, M. and Nerson, H. 1984. Foliar Nutrition of Muskmelon: I. Application to seedlings-greenhouse experiments. *J. Plant Nutr.* 7(9): 1329-1339.

GOI [Government of India]. 2017. Horticulture statistics at a glance 2017 [on-line].Available:http://nhb.gov.in/statistics/Publication/Horticulture%20 At%20a%20Glance%202017%20for%20net%20uplod% 20(2).pdf. [17 July 2019].

Gopalan, C., Sastri, R.B.V., and Balasubramanian, S. 2007. *Nutritive Value of Indian Foods*. Natl. Inst. Nutr., ICMR, Hyderabad, 14p.

Gupta, U.C. and Sanderson, J.B. 1993. Effect of sulfur, calcium, and boron on tissue nutrient concentration and potato yield. *J. Plant Nutr.* 16(6): 1013-1023.

117

Haleema, B., Rab, A., and Hussain, S.A. 2018. Effect of calcium, boron and zinc foliar application on growth and fruit production of tomato. *Sarhad J. Agric.* 34(1): 19-30.

Hall, D.A. 1977. Some effects of varied calcium nutrition on the growth and composition of tomato plants. *Plant and Soil.* 48: 199-211.

Hao, X. and Papadopoulos, A.P. 2003. Effect of calcium and magnesium on growth, fruit yield and quality in a fall greenhouse tomato crop grown on rockwool. *Can. J. Plant Sci.* 83: 903-912.

Heidari, S., Soltani, F., Azizi, M., and Hadian, J. 2014. Foliar application of Ca and K improves growth, yield, essential oil yield and nutrient uptake of tarragon (*Artemisia dracunculus* L.) grown in Iran. *Int. J. Biosci.* 4(12): 323-338.

Hollinger, M.E. and Colvin, D. 1945. Ascorbic acid content of okra as affected by maturity, storage, and cooking. *J. Food Sci.* 10(3): 255-259.

Husein, M.E., El- Hassan, S.A., and Shahein, M.M. 2015. Effect of humic, fulvic and calcium foliar application on growth and yield of tomato plants. *Int. J. Biosci*. 7(1):132-140.

Ilyas, M., Ayub, G., Hussain, Z., Ahmad, M., Bibi, B., Rashid, A., and Luqman, A. 2014. Response of tomato to different levels of calcium and magnesium concentration. *World Appl. Sci. J.* 31(9): 1560-1564.

Islam, M.Z., Mele, M.A., Baek, J.P., and Ho-Min Kang, H. 2016. Cherry tomato qualities affected by foliar spraying with boron and calcium. *Hortic. Environ. Biotechnol.* 57(1): 46-52.

Issac, R.A. and Kerber, J.D. 1971. Atomic absorption and flame photometry techniques and uses in soil, plant and water analysis. In: Walsh, L. M. (ed.). *Instrumental methods for analysis of soil and plant tissue*. Soil Sci. Soc. Am., Madison, USA, pp.17-37.

Jackson, M.L. 1958. *Soil chemical analysis*. In Cliffs, E.N.J. (ed.). Soil Sci. Univ. Wisconsin, YSA, Madison, pp.89-102.

Jena, D., Dash, A.K., Mohanty, B., Jena, B and Mukhi, S.K. 2009. Interaction effect of lime and boron on cabbage-okra cropping system in boron deficient acidic laterite soils of Bhubaneswar. *An Asian J. Soil Sci.* 4(1): 74 -80.

John, M.A. 1987. Fruit Softening. *In:* Prinsley, R.T. and Tucker, G (eds), *Mangoes - a review*. Commonwealth Science Council, London. pp.98-106.

Kannan, S. 1980. Mechanisms of foliar uptake of plant nutrients: accomplishments and prospects. *J. Plant Nutr.* 2: 717-735.

Kassa, M., Yebo, B., and Habte, A. 2014. Effects of liming and phosphorus levels on yield and yield components of Haricot Bean (*Pharsalus vulgarism* L.) varieties on Nitosols at Wolaita Zone, Ethiopia. *Asian J. Crop Sci.* 6(3): 245-253.

Katiyar, D., Katiyar, S.K., Gangwar, R.S. 2015. Effect of calcium on growth, yield and economics of potato (*Solanum tuberosum* spp. Tuberosum). *Trends in Biosci*. 8(23): 6559-6562.

KAU (Kerala Agricultural University). 2016. *Package of Practices Recommendations: Crops* (15th Ed.). Kerala Agricultural University, Thrissur, 392p.

KAU (Kerala Agricultural University). 2017. *Package of Practices Recommendations: (ad hoc) for Organic Farming: Crops.* Kerala Agricultural University, Thrissur, 392p.

Kaushal, P., Rana, R., Kumar, S., and Kumar, R. 2014. Foliar feeding of plant nutrients. *Popular Kheti* 2(2): 76-81.

Kawasaki, J. and Fujimoto, A. 2009. Economic and technical assessment of organic vegetable farming in comparison with other production systems in Chiang Mai, Thailand. *J. Int. Soc. Southeast Asian Agric. Sci.* 15(1): 144-169.

Kaya, C., Higgs, D., and Murillo, B. 2002. Influence of foliar application calcium nitrate on cucumber and melon plants drip irrigation with saline water. *J. Plant Nutr*. 26: 1665-1681.

Kazemi, M. 2013. Foliar application of salicylic acid and calcium on yield, yield component and chemical properties of strawberry. Bull. *Env. Pharmacol. Life Sci.* 2: 19-23.

12

Kazemi, M. 2014. Effect of Foliar Application of Humic Acid and Calcium Chloride on tomato growth. *Bull. Env. Pharmacol. Life Sci*. 3(3): 41-46.

Kisanrao, R.P. 2005. Effect of application of lime, Zn and B on soil properties, growth, yield and quality of Soyabean – Cowpea sequence in lateritic soil of Konkan region. Ph.D. thesis, Dr. B.S.K.V.V., Dapoli, 105p.

Kluge, R. 1990. Symptom-related toxic threshold values of plants for the evaluation of excess of boron (B) in selected crops. *Agribiological Res*. 43: 234-243.

Kotur, C.S. 1998. Evaluation of lime, boron and their residue on three cropping sequences of non-cruciferous vegetables for yield, composition of leaf and soil properties on an alfisol. *Indian J. Agric. Sci.* 68(11): 718-721.

Kuchay, M.A., Mallikarjuna, K., and Ali, M.T. 2018. Effect of foliar sprays of nitrogen and calcium on fruit quality attributes, yield and leaf nutrient content of apple. *Int. J. Pure App. Biosci.* 6 (6): 970-977.

Kumar, M.P. and Halder, M. 1996. Effect of dolomite on boron transformation in acid soil in relation to nutrition of green gram. *J. Indian Soc. Soil Sci.* 44: 458-461.

Kumari, M. 2017. Effect of lime and boron on growth and yield of sprouting Broccoli (*Brassica oleracea var. italica* L.). M.Sc. (Hortic.) thesis, Uttar Banga Krishi Viswavidyalaya University, West Bengal, 43pp.

Kwon, H.R., Park, K.W., and Kang, H.M. 1999. Effects of postharvest heat treatment and calcium application on the storability of cucumber (*Cucumis sativus* L.). *J. Korean Soc. Hortic. Sci.* 40:183-187.

Leopold, A.C. and Kriedeman, P.E. 1975. *Plant growth and development* (2nd Ed.). McGrew-Hill, New York, 545p.

Liebisch, F., Max, J.F.J., Heine, G., and Horst, W.J. 2009. Blossom end rot and fruit cracking of tomato grown in net - covered green houses in central Thailand can partly be corrected by calcium and boron spray. *J. Plant Nutr. Soil Sci.* 172: 140-150.

Lurie, S. and Crisosto, C.H. 2005. Chilling injury in Peach and nectarine: a review. *Post-harvest Biol. Technol.* 37: 195-208.

Madani, B., Wall, M.M., Mirshekari, A., Bah, A., Mohamed, M. 2015. Influence of calcium foliar fertilization on plant growth, nutrient concentrations, and fruit quality of papaya. *HortTechnol*. 25: 496-504.

Marme, D. and Dieter, P. 1983. *Role of Ca and calmodulin in plants.* In: Calcium and cell function (4th Ed.). Academic press, Newyork, pp.263-311.

Marschner, H. 1995. *Mineral nutrition of higher plants* (2nd Ed.). Academic press, London, 889 p.

Marschner. P. 2012. *Mineral nutrition of higher plants* (3rd Ed.). Elsevier. 643p.

Maynard, D. and Hochmuth, G. 1996. *Knott's Handbook for vegetable Growers* (4th Ed.). John Willey and Sons, New Jersey, 630p.

Maynard, D.N., Warner, D.C. and Howell, J.C. 1981. Cauliflower leaf tipburn: a calcium deficiency disorder. *HortSci.* 16: 193-195.

McGuire, R.G. and Kelman, A. 1984. Reduced severity of *Erwinia* soft rot in potato tubers with increased calcium content. *Phytopathol.* 74: 1250-1256.

McLaughlin, S.B. and Wimmer, R. 1999. Calcium physiology and terrestrial ecosystem processes. *New Phytologist* 142: 373-417.

Mengel, K., Kirkby, E.A., Kosegarten, H., and Appel, T. 2001. *Principles of Plant Nutrition.* Kluwer Academic Publisher, Netherlands, 849p.

Mitchell, C.C. 2005. Crushed eggshells in the soil. Agronomy and Soils Series. Timely Information S-05-05, Agriculture and Natural Resources. Albama Cooperative Extension System, Department of Agronomy and Soils, Auburn University.

Motamedi, S., Jafarpour, M. and Shams, J. 2013. Evaluation of nutrition on flower number and yield of strawberry in greenhouse. *Int. J. Agric. Crop Sci.* 5: 2091-2095.

Muhammad, W., Khan, M.N., Ilyas, M., Hissam, M., Khan, W., Ali, B., Khan, M.R., and Hilal, M. 2019. Influence of Calcium chloride and Gibberellic acid levels on the growth, yield and quality of tomato in the agro-climatic conditions of Mardan-Pakistan. *Pure Appl. Biol.* 8(2): 1191-1205.

Mumivand, H., Babalar, M., Hadian, J., Fakhr Tabatabaei, S.M. 2010. Influence of nitrogen and calcium carbonate application rates on the minerals content of Summer Savory (*Satureja hortensis* L.) leaves. *Hortic. Environ. Biotechnol.* 51(3): 173-177.

Nazrul, M. and Shaheb, M. 2016. Integrated approach for liming and fertilizer application on yield of cabbage and cauliflower in acidic soil of Sylhet. *Bangladesh Agron. J.* 19(1): 49-57.

Nelson, D.J., Rains, T.C., and Norris, J.A. 1966. High-purity calcium carbonate in freshwater clam shell. *Sci.* 152: 1368-1370.

Nelson, P.V. and Niedziela, C.E. 1998. Effect of calcium sources and temperature regimes on calcium deficiency during hydroponics forcing of tulip. *Sci. Hortic.* 73: 137-150.

Nys, Y., Gautron, J., Garcia-Ruiz, J.M., Hincke, M.T. 2004. Avian eggshell mineralization: biochemical and functional characterization of matrix proteins. *Comptes Rendus Palevol* 3: 549-562.

Ojeniyi, S.O. 2002. *Soil management, national resources and environment.* Oke-Ado: Adeniran press, 24p.

Okigbo, I. 2000. Application of organic and inorganic fertilizers and the response of maize crop. *Nigerian J. Soil Sci.* 18 (2): 22.

Oluwatoyinbo, F.I., Akande, M.O., and Adedrian, J.A. 2005. Response of okra (*Abelmoschus esculentus*) to lime and phosphrous fertilization in an acid soil. *World J. Agric. Sci.* 1: 178-183.

12

Oluwatoyinbo, F.I., Akande, E.A., Makinde, E.A., and Adedrian, J.A. 2009. Growth and yield response of okra to lime and compost on an acid soil in the humid tropics. *Res. J. Agric. Biol. Sci.* 5(5): 858-863.

Pan, W.L. 2000. Bioavailability of calcium, magnesium and sulphur. In: Summer, M.E. *(ed.), Handbook of Soil Science*, CRC Press, Boca Raton, pp.53-69.

Panse, V.G. and Sukhatme, P.V. 1995. *Statistical Methods for Agricultural Workers.* Indian Council of Agricultural Research Publication, 359p.

Peyvast, G., Olfati, J.A., Ramezani-Kharazi, P., and Kamari-Shamaleki, S. 2013. Uptake of calcium nitrate and potassium phosphate from foliar fertilization by tomato. *Intr. J. Agric. Res. Dev.* 1(5): 110-115.

Piper, C.S. 1966. *Soil Chemical Analysis*. Hans Publications, Bombay, 368p.

Poovaiah, B.W. 1986. Role of calcium in prolonging storage life of fruits and vegetables. *Food Technol.* 40: 86-89.

Poovaiah, B.W. 1988. Molecular and cellular aspects of calcium action in plants. *HortSci.* 23: 267-271.

Prasad, B and Singh, A.P. 1980. Changes in soil properties with long term use of fertilizer, lime and farm yard manure. *J. Indian Soc. Soil Sci.* 28(4): 465-468.

Prasad, R., Kumar, D., Rana, D.S., Shivay, Y.S., and Tewatia, R.K. 2014. *Textbook of Plant Nutrient Management.* Indian Soc. Agron., New Delhi, 407p.

125

Pratt, P.F. 1965. *Potassium in methods of soil analysis.* (2^{nd} Ed.). Am. Soc. Agron., Madison, USA, pp. 1019-1021.

Rab, A. and Haq, I. 2012. Foliar application of calcium chloride and borax influences plant growth, yield, and quality of tomato (*Lycopersicon esculentum* Mill.) fruit. *Turk J. Agric.* 36: 695-701.

Rajasekar, M. and Swaminathan, V. 2015. Impact of pre - harvest chemical spray on yield and yield parameters of bitter gourd (*Momordica charantia* L.) cultivars. *Int. J. Agric. Sci. Res.* 5(3): 185-192.

Roychoudhury, A., Chatterjee, R., and Mitra, S.K. 1990. Effect of different doses of nitrogen, phosphorus, magnesium, calcium and iron on growth and development in chilli. *Indian Cocoa, Arecanut and Spices J.* 13(3): 96-99.

Sadasivam, S. and Manickam, A. 1996. *Biochemical methods for agricultural sciences.* Wiley Eastern Ltd., New Delhi, 246p.

Sanwal, S.K., Lakminarayana, K., Yadav, R.K., Rai, N., Yadav, D.S., and Mousumi, B. 2007. Effect of organic manures on soil fertility, growth, physiology, yield and quality of turmeric. *Indian J. Hortic.* 64(4): 444-449.

126

Sarkar, R.K. and Pal, P.K. 2006. Effect of pre-sowing seed treatment and foliar spray of nitrate salts on growth and yield of green gram (*Vigna radiata*). *Indian J. Agric. Sci.* 76(1): 62-65.

Schonherr, J. 2000. Calcium chloride penetrates plant cuticles via aqueous pores. *Planta* 212: 112-118.

Schonherr, J. and Huber, R. 1977. Plant cuticles are polyelectrolytes with isoelectric points around three. *Plant Physiol.* 59: 145-150.

Schreiber, L. and Schonherr, J. 2009. *Water and solute permeability of plant cuticles: Measurement and data analysis*. Springer Verlag, Berlin, Heidelberg, Germany, 298p.

Shafeek, M.R., Helmy, Y.I., El-Tohamy, W.A., and El-Abagy, H.M. 2013. Changes in growth, yield and fruit quality of cucumber (*Cucumis sativus L.*) in response to foliar application of calcium and potassium nitrate under plastic house conditions. *Res. J. Agric. Biol. Sci.* 9(3): 114-118.

Shete, S.A., Bulbule, A.V., Patil, D.S., Pawar, R.B. 2018. Effect of foliar nutrition on growth and uptake of macro and micro nutrients of kharif groundnut (*Arachis hypogaea* L.). *Int. J. Curr. Microbiol. Appl. Sci.* 7(10): 1193-1200.

Shimaa, M.H. and Abd-Elkader, D.Y. 2016. Influence of starter fertilizer and calcium nitrate rates on vegetative growth, yield and nutritional quality of cabbage. *Alexandria Sci. Exchange J.* 37(4): 811-818.

Shobo, B.A., Bodunde, J.G., Akinboye, O.E., Ayo-Bello, T.A., Afodu, O.J., and Ndubusi- Ogbonna, L.C. 2016. Enhancement of growth and yield performance in tomato (*Solanum lycopersicon* L) through foliar application of a nutrient supplement. *J. Exp. Agric. Int.* 14(2): 1-6.

Shwetha, A., Dhananjaya, Kumara, S.M.S., and Ananda. 2018. Comparative study on calcium content in egg shells of different birds. *Int. J. Zool. Stud.* 3(4): 31-33.

Sidhu, R.S., Sangwan, A.K., Singh, S., Brar, G.S., and Singh, N.P. 2018. Impact of foliar feeding of $Ca(NO_3)_2$ on plant growth and leaf nutrients of straw berry (Fragaria × ananassa duch.) cv. winter dawn. *HortFlora Res. Spectrum* 7(2): 115-120.

Simpson, J.E., Adair, C.R., Kohler, G.D., Dawson, E.N., Debald, H.A., and Klick, J.T. 1965. *Quality evaluation of foreign-domestic rice.* Technical Bulletin Series No.1331, USDA, pp.1- 86.

Singh, B.P., Tandon, D.K. and Kalra, S.K.1993. Changes in post harvest quality of mangoes affected by pre-harvest application of calcium salts. *Scientia Hortic.* 54: 211-19.

Smith, C.B., Demchak, K.T., and Ferretti, P.A. 1986. Effects of lime type on yields and leaf concentrations of several vegetable crops as related to soil test levels. *J. Am. Soc. Hortic. Sci.* 111(6): 837-840.

Souri, M.K. and Dehnavard, S. 2018. Tomato plant growth, leaf nutrient concentrations and fruit quality under nitrogen foliar applications. *Adv. Hortic. Sci.* 32(1): 41-47.

Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for estimation of available nitrogen in soils. *Curr. Sci.* 25: 259-260.

Subbiah, K. 1994. Firmness index of tomato as influenced by N, K and $CaCl_2$ sprays. *Madras Agric. J.* 81(1): 32-33.

Subbaiah, K. and Perumal, R. 1990. Effect of calcium sources, concentrations, stages and number of sprays on physico- chemical properties of tomato fruits. *South Indian Hortic.* 38(1): 20-27.

Sumathi, T., Ponnuswami, C., Thangamani, C., and Pugalendhi, L. 2011. Effect of preharvest spray of calcium chloride on cucumber (*Cucumber Sativus* L.) quality. *Plant Arch.* 11(2): 789-792.

Susheela, N., Singh, R.V., and Dwivedi, O.K. 2006. Effect of biofertilizers, nutrient sources and lime on growth and yield of garden pea. *Legume Res.* 29(4): 282-285.

Taylor, H. 1970. How an eggshell is made. *Sci. Am.* 222(3): 88-95.

Taylor, M.D. and Locascio, S. 2004. Blossom end rot: a calcium deficiency. *J. Plant Nutr.* 27:123-139.

Tejashvini, A. and Thippeshappa, G.N. 2017. Effect of foliar nutrition of different sources and levels of calcium fertilizer on nutrient content and uptake by tomato. *Int. J. Curr. Microbiol. Appl. Sci.* 6(12): 1030-1036.

Toivonen, P.M.A. and Bowen, P.A. 1999. The effect of preharvest foliar sprays of calcium on quality and shelf life of two cultivars of sweet bell peppers (*Capsicum annuum* L.) grown in plasticulture. *Can. J. Plant Sci.* 79: 411–416.

Ustun, N.H., Yokas, A.L., and Saygili, H. 2009. Influence of potassium and calcium level on severity of tomato pith necrosis and yield of greenhouse tomatoes. *ISHS Acta Hortic.* 808: 345–350.

Uwah, D.F., Nwagwo, F.A., and Iwo, G.A. 2010. Response of okra (*Abelmoschus esculentus* (L.) moench.) to different rates of nitrogen and lime on an acid soil. *Int. J. Agric. Sci.* 2(2): 14-20.

Valero, D and Serrano, M. 2010. *Postharvest biology and technology for preserving fruit quality*. CRC Press, Newyork, 61p.

Walkely, A.J. and Black, I.A. 1934. Estimation of soil organic carbon by chromic acid and titration method. *Soil Sci.* 31: 21-38.

Ware, G.W. and Whitacre, D.M. 2004. *The pesticide book* (6th Ed.). Willoughby, Ohio, 496p.

Watnabe, F.A. and Olsen, J.R. 1965. Test of an ascorbic acid method for determining phosphorus in water and sodium bicarbonate extract from soil. *Proc. Soil Sci. Soc. Am.* 28: 677-678.

White, P.J. and Broadley, M.R. 2003. Calcium in plants. *Ann. Bot.* 92(4): 487-511.

Wittwer, S.H. 1955. Nutrient uptake, with special reference to foliar absorption. AAAS Symposium on Atomic Energy and Agriculture, Atlanta, Geoigia, pp27-28.

Woltz, S.S., Jones, J.P., and Scott, J.W. 1992. Sodium chloride, nitrogen source, and lime influence Fusarium crown rot severity in tomato. *HortSci.* 27(10): 1087-1088.

Woo, M.B., Taik, L.S., Seung, C.J., and Youngkyu, S. 2000. Effects of pre- or post-harvest application of liquid calcium fertilizer manufactured from oyster shell on the calcium concentration and quality in stored 'Niitaka' pear fruits. *J. Korean Soc. Hortic. Sci.* 41(1): 61-64.

Xiu-rong, S. 2019. A study on making calcium acetate from Egg shells. *J. Xiangfan university.* Available: file:///F:/thesis/review%20of%20literature/1%20exp/xiu,%202019.pdf. [6 June 2018].

Yamazaki, H and Hoshina, T. 1995. Calcium nutrition affects resistance of tomato Seedlings to bacterial wilt. *HortSci.* 30(1): 91-93.

Youssef, S.M.S., El-Hady, S.A.A., El-Azm N.A.I.A., and El-Shinawy, M.Z. 2017. Foliar application of Salicylic acid and calcium chloride enhances growth and productivity of lettuce (*Lactuca sativa*). *Egypt. J. Hortic.* 44(1): 1-16.

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Appendices

Appendix I Weather parameters during the crop season in standard weeks

Standard weeks	Temperature (^{0} C)		Relative humidity (%)	Rainfall (mm)	Sunshine (hrs)
	Maximum	Minimum			
36 (Sept 3 – Sept 9)	31	23	81	5.2	9.12
37 (Sept 10 –Sept 16)	31	22	79	0	9.18
38 (Sept 17 –Sept 23)	31	23.5	77	4.3	8.44
39 (Sept 24 –Sept 30)	31.8	24	77	8.5	5.81
40 (Oct 1 –Oct 7)	32	23.5	82	52.3	6.07
41 (Oct 8 –Oct 14)	32	24.5	84	61.7	5.34
42 (Oct 15 –Oct 21)	30.5	23.9	83	41.3	6.28
43 (Oct 22 –Oct 28)	33	22.5	73	0	9.52
44 (Oct 29 –Nov 4)	33	21	75	8.2	8.22
45 (Nov 5 – Nov 18)	32.5	23	75	0	9.80
46 (Nov 5 – Nov 18)	32.5	19.5	73	0	8.04
47 (Nov 19 – Nov 25)	32.5	24	79	46.8	5.67
48 (Nov 26 – Dec 09)	32.5	20.5	75	0	7.64
49 (Dec 10– Dec 16)	32.5	20.5	77	0	7.05
50 (Dec 17– Dec 23)	32	20.5	79	4.2	7.043
51 (Dec 24– Dec 30)	32.5	17.7	77	0	6.63
52 (Dec 31)	32	22.5	79	13.8	7.00

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Appendix II

Calcium content (ppm) in different calcium sources used for foliar spray

Calcium compounds	Calcium concentration (ppm)
Calcium nitrate (1 %)	1600 ppm
Calcium chloride (0.5 %)	1360 ppm
Calcium acetate (0.5 %)	1250 ppm
Organic calcium solutions from egg shells	12480 ppm

Appendix III

Effect of source and method of calcium application on marketable yield, cost of cultivation and gross returns

Treatments	Cost of cultivation (Rs. lakh ha^{-1})	Marketable yield (t ha^{-1})	Gross Returns (Rs. lakh ha^{-1})
T_1 - KAU POP 2016	1.37	14.95	3.88
T_2 – Organic POP	1.98	13.62	3.54
T_3 - T_1+ Lime as soil application	1.47	16.80	4.37
T_4 - T_1+ Dolomite as soil application	1.45	17.89	4.65
T_5 - T_1+ Calcium nitrate foliar spray (1 %)	1.51	18.70	4.86
T_6 - T_1+ Calcium chloride foliar spray (0.5%)	1.47	18.66	4.85
T_7 - T_1+ Calcium acetate foliar spray (0.5%)	1.52	18.13	4.71
T_8 - T_1+ Organic calcium from Exp.1	1.99	16.86	4.38
T_9 - T_1+ Coconut Vinegar	1.99	15.10	3.93
SE(m)±		0.814	0.212
CD (0.05)		2.46	0.64

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EVALUATION OF CALCIUM NUTRITION IN OKRA

(*Abelmoschus esculentus* (L.) Moench)

GIFFY THOMAS

(2017-11-145)

Abstract of the thesis submitted in partial fulfilment of the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University, Thrissur

Department of Agronomy
COLLEGE OF AGRICULTURE
PADANNAKKAD, KASARGOD-671 314

2019

Abstract

ABSTRACT

The investigation on "Evaluation of calcium nutrition in okra (*Abelmoschus esculentus* (L.) Moench)" was undertaken with the objectives to develop and characterize an organic calcium source for foliar spray and to identify the best source and method of calcium nutrition, thereby assessing its impact on growth, productivity, profitability and quality of okra. The study was conducted in two experiments. Experiment I was done to develop and characterize an organic calcium source for foliar spray at College of Agriculture, Padannakkad. The field experiment was intended for the evaluation of source and method of calcium application in okra at Regional Agricultural Research Station, Pilicode during 2017-2018.

The first investigation was laid out in completely randomized design with three treatments replicated five times. The resultant solutions were obtained by dissolving egg shells (T_1), bone pieces (T_2) and powdered lime shell (T_3) in coconut water vinegar used as solvent. Perusal of the results indicated that the solutions were acidic. The calcium content was highest with solutions extracted from lime shell followed by eggshell. The maggot development was observed earlier in solutions extracted from lime shells and bone pieces (2 DAF) than egg shells (15 DAF). The solution prepared from egg shells are preferred to those from bone pieces and lime shell due to its easy availability and relatively longer period of storage. ***Hence the solution prepared from egg shells can be used as a source of calcium for foliar spray like calcium nitrate and calcium chloride available in market as foliar fertilizers.***

The field experiment was carried out in randomized block design with nine treatments and three replications. The treatment combination were, KAU POP (T_1), Organic POP (T_2), KAU POP + lime as soil application (T_3), KAU POP + dolomite as soil application (T_4), KAU POP + foliar spray of one per cent calcium nitrate (T_5), KAU POP + foliar spray of 0.5 per cent calcium chloride (T_6), KAU POP + foliar spray of 0.5 per cent calcium acetate (T_7), KAU POP + foliar spray of organic calcium extracted from egg shell (T_8) and KAU

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POP + foliar spray of coconut water vinegar (T_9). The foliar sprays were given at 30, 45, 60 and 75 DAS.

Considering the yield and yield attributes, the highest fruit weight was exhibited by T_6 and was statistically on par with T_5 and T_7. The treatment T_5 recorded maximum number of fruits per plant (38.94), yield per plant (0.657 kg) and total fruit yield (24.93 t ha^{-1}) and was statistically on par with all treatments except T_2, T_1 and T_9. Foliar application of calcium chloride and calcium nitrate along with KAU POP increased fruit and plant dry matter production significantly over other treatments.

Organic carbon, available form of nitrogen, magnesium, boron and zinc in soil did not differ with treatments. The maximum value for soil available potassium and calcium was with T_3 followed by T_4.

The highest calcium content in the plant was observed in T_5 and it was on par with T_6 and T_7. T_9 recorded lowest calcium content in plant. The fruit calcium content was highest with T_6 and it was statistically on par with T_7, T_8 and T_5. Foliar application of calcium nitrate and calcium chloride significantly increased calcium uptake by plants over other treatments. The calcium uptake by fruits was maximum in T_6.

The shelf life of fruits was highest in T_6 (7.33 days) and was on par with T_5, T_7 and T_8. The larval incidence of leaf roller was lowest with T_5 and was on par with T_7, T_8, T_6 and T_9. The highest net returns (Rs. 3.38 lakh ha^{-1}) and BCR (3.29) was obtained in T_6 and was on par with T_5, T_4, T_7 and T_3.

Therefore it can be concluded from the study that application of calcium along with recommended dose of nutrients (110:35:70 kg NPK ha^{-1}) either through soil or as foliar spray has a significant role in maximizing the yield of okra. However foliar application of 0.5 per cent calcium chloride or one per cent calcium nitrate is beneficial for getting higher yield per unit area and maximum economic returns. Moreover this nutrient schedule is economically viable and maintaining soil fertility.