EVALUATION OF FERTIGATION *VIS A VIS* NUTRIENT STICK AND FOLIAR SILICON IN ORIENTAL PICKLING MELON (*Cucumis melo var. conomon*)

by

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled "**Evaluation of fertigation *vis a vis* nutrient stick and foliar silicon in oriental pickling melon (*Cucumis melo var. conomon*)**" is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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Certified that this thesis entitled **"Evaluation of fertigation *vis a vis* nutrient stick and foliar silicon in oriental pickling melon (*Cucumis melo var. conomon*)"** is a record of research work done independently by Mr. Mubarack O.P. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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Fondly remembering my father

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LIST OF ABBREVIATIONS

%	-	Per cent
@	-	at the rate of
B	-	Boron
Ca	-	Calcium
CD	-	Critical difference
cm	-	Centimeter
Cu	-	Copper
$dS\ m^{-1}$	-	deci Siemens per meter
DAS	-	Days after Sowing
^0E	-	East
EC	-	Electrical conductivity
Ep	-	Pan Evaporation
et al	-	And others
Fe	-	Iron
Fig.	-	Figure
FUE	-	Fertilizer use efficiency
FYM	-	Farm Yard Manure
g	-	Gram
ha^{-1}	-	Per hectare
K	-	Potassium
KAU	-	Kerala Agricultural University
kg	-	Kilogram
L	-	Litre
LDPE	-	Low Density Polythene
m	-	Meter
Mg	-	Magnesium

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mg kg^{-1}	-	Milligram per kilogram
ml	-	Milli litre
mm	-	Milli meter
Mn	-	Manganese
N	-	Nitrogen
^0N	-	North
NS	-	Not significant
OC	-	Organic carbon
pH	-	Soil reaction
$plot^{-1}$	-	per plot
POP	-	Package of practices
ppm	-	Parts per million
PVC	-	Polyvinyl- Chloride
RDF	-	Recommended dose of fertilizer
S	-	Sulphur
SE(m)	-	Standard error mean
Si	-	Silicon
t ha^{-1}	-	Tonnes per hectare
viz.	-	Namely
WUE	-	Water use efficiency
Zn	-	Zinc

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Introduction

1. INTRODUCTION

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Soil is the fundamental medium for plant growth and one of the critical components of earth system which maintains global environmental balance. It is the chief source of nutrients for crops and is functioning as a support for plant growth and development. It is a limited natural resource that requires good care and management to ensure and improve sustainability of agriculture. In nature, plants use inherent nutrient reserve of soil and upon their death and decomposition, these essential nutrients are recycled back to the soil. In agriculture, the crops take up nutrients during their growth, and then they are harvested from the field, causes gradual decline in the nutrient resources of the soil. With the decline in nutrient content in soil, crop yield and productivity also goes down gradually, resulting high costs of crop production. This prompted use of fertilizers quite often done in an unbalanced manner, resulted in the reduction of soils capacity to retain and supply nutrients even from applied fertilizers and the consequent demur in fertilizer response. An efficient use of indigenous and applied nutrients should be practiced to augment crop production and soil health, without affecting yield. An efficient fertilization means optimization of soil nutrient replenishment with minimization of nutrient losses to the environment (Maene, 2001).

Water and nutrients are two primary inputs in agriculture, their efficient management is essential not only for higher productivity but also for maintaining the soil quality. Plants require nutrients at different stages in different rates throughout the growing period, which varies from plant to plant. An understanding of how, where, and when plants utilize nutrients has led to the development of alternate sound nutrient management practices. Crop production for better nutrient management generally focus on the "4Rs" - applying the right amount of nutrients, from the right source, in the right place, at the right time. Considering the concept of "4Rs", many methods have been tried to get precise basis for nutrient application and predicting crop fertilizer requirements. Better methods of fertilizer application were convincingly advocated for improved crop production. These methods include micro irrigation systems, drip irrigation system along with fertigation or slow releasing fertilizers like nutrient sticks or foliar spray of nutrients.

Fertigation is relatively a new technology of fertilizer application adopted in crop production, where fertilizer is combined with irrigation water and supplied. It is one of the most efficient and convenient methods for supplying nutrients and water, according to crop requirement, and can result in higher productivity and superior quality. Through fertigation, nutrients are applied directly into the wetted volume of soil immediately below the emitter where root activity is concentrated, helping to achieve higher fertilizer and water use efficiency than conventional practice. Since there are different methods of fertilizer application depending on the kind of fertilizer material, the cropping system and equipment, it is difficult to make a blanket statement that a single method is best for plants. Slow releasing fertilizers like nutrient sticks are beneficial to plants as they provide steady supply throughout their active periods of growth. Slow-release fertilizers contain one or more essential nutrients which are released or made available for plant use over an extended period of time, synchronising with plant growth.

Fertilizer stick, a slow releasing fertilizer is also referred to as fertilizer spike or stakes, is a complete fertilizer composition that is manufactured in stick form and contains all the essential nutrients. The nutrients are embedded in suitable matrix. It ensures a constant supply of nutrient, as we irrigate the plants the stick will gradually dissolve and release nutrient into the soil, where they are taken up by the roots. This can be used for potted plants as well as plants grown in the field. Fertilizer stick application can reduce over fertilization. This is because fertilizer spike is available in pre mixed formulae, can be used primarily in vegetables, ornamentals and fruit trees.

Foliar-application of nutrients is an effective method of nutrient application as nutrients are absorbed and used by plants quite rapidly. Absorption begins within minutes after application and is completed within one to two days with most essential nutrients. But this has a major limitation that the quantity applied through foliar is very little compared to total demand, especially of macronutrients. In addition to 17 essential elements, there are other elements that benefit plant nutrition, such as silicon (Si). Silicon is a beneficial element for plants growth and it is essential for improving crop productivity. Beside yield improvement, its role in conferring plant resistance to both biotic and abiotic stresses such as water and chemical stress, nutrient imbalances, disease and pest problems has received increasing attention. In plants Si plays a crucial role in amino acid and protein metabolism. Studies indicate that Si fertilization enhances P utilization by plants by increasing both P content in plants and phosphate uptake efficiency. The foliar application of solution containing Si was proposed an alternative Si fertilization method, which enhance the availability of Si to plants.

Considering the variation in nutrient utilization by different crop species, a crop based nutrient approach will be more rewarding. Diversification of agriculture and increasing awareness of people towards balanced diet promotes the adoption of vegetable cultivation, especially in Kerala. Cucurbitaceous crops are cultivated throughout Kerala. Among them, oriental pickling melon, *Cucumis melo* var *conomon* is commonly cultivated and mostly preferred as a culinary vegetable. It is one the crops grown in the summer rice fallow of Kerala. The ideal seasons for growing this vegetable are September - December and February - May. Different varieties of oriental pickling melon are in cultivation in which variety Soubaghya has gained wide acceptance among the vegetable growers of Kerala due its high yielding quality with concentrated and small attractive fruit and a short maturation period of 65-75 days, suiting with summer rice fallows.

The main constrain for oriental pickling melon production during summer rice fallows is scarcity of water for irrigation. In order to ensure sufficient water and nutrient to irrigated oriental pickling melon cultivated in summer, efficient management practices such as fertigation, nutrient stick and foliar spray of

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nutrients are promising options for efficient management that improves the water as well as fertilizer use efficiencies.

In this context an investigation on "Evaluation of fertigation *vis a vis* nutrient stick and foliar silicon in oriental pickling melon (*Cucumis melo* var. *conomon*)" was conducted with the following objectives.

1. To prepare the nutrient stick for the crop oriental pickling melon
2. To evaluate the performance of nutrient stick and to compare its effect with fertigation on oriental pickling melon and
3. To evaluate the effect of foliar silicon on growth, yield and nutrient uptake in oriental pickling melon (*Cucumis melo* var. *conomon*).

Review of Literature

2. REVIEW OF LITERATURE

Cucurbits are the leading group of summer vegetable crops grown in the state of Kerala. They belong to the family cucurbitaceae and are cultivated for their ripe and unripe fruits. Cucurbits are good source of carbohydrates, vitamin - A, vitamin - C and minerals (Yawalkar, 1980). Among the cucurbits grown in the state, oriental pickling melon is the most popular vegetable. The variety Soubaghya is grown commercially under various agro-climatic situation in Kerala for local as well export marketing. This variety is known for its quick response to nutrient and water application and a stress due to both inputs will diminish the crop yield considerably. Being scarce commodities, the efficient use of these assets are vital for sustainable crop production.

The introduction of synchronized drip irrigation and fertilization through fertigation, nutrient stick, soil test based fertilizer application and foliar spray of silicon can increase use efficiency of water and fertilizers by the crop and help to sustain soil - water - nutrient environment favourable for higher productivity. Literature on yield response of cucurbits and other vegetables on drip irrigation and nutritional managements are reviewed in this chapter.

2.1 NUTRITIONAL MANAGEMENT THROUGH SOIL TEST BASED FERTILIZER APPLICATION

Soil testing is one of the key inputs of a soil scientist and agronomist for advisory work on judicious fertilizer use in crop production. It leads to a proper assessment of the fertility status of the soil and recommend fertilizer for getting targeted or maximum yield (Kanwar, 1971). It provides a means to obtain information concerning nutrient deficiencies and adverse soil condition on specific area of land especially the individual field of a farm and many scientists reported the economic and optimum use of fertilizer based on soil test data (Ramamoorthy *et al.*, 1969; Kanwar, 1971; Reddy *et al.,* 1985; Gowswamy *et al.,* 1976).

Mitscherlich (1909) formulated a model for expression of the growth rate for different levels of an essential nutrient in the soil. He reported that increase in yield per unit of the applied nutrient was proportional to difference between maximum attainable and actual yield. Bray (1948) modified the concept by introducing efficiency coefficients to the soil test hence it was called Mitscherlich- Bray model.

Fitts and Nelson (1956) defined some of the important objectives of soil test as grouping of soils into classes for purpose of fertilizer and lime requirement, prediction of the probability of getting a profitable response to the application of fertilizer nutrients and the determination of specific conditions that may be improved by cultural practices.

The importance of soil testing is perfectly stated by Tisdale (1967) as "Soil testing is to the art of crop production what the thermometer is to the medical profession". A soil test chemically extracts and measures the elements essential to plant nutrition. It also measure soil acidity or alkalinity through pH. These factors are indicator of requirement, nutrient availability and potential of the soil to produce crops. It is a proven technology for optimum resources, utilization and profitable yield.

Welch and Wiese (1973) used calibration and correlation to express the relationship between the soil test results and nutrient uptake of plant. The term calibration was used to express basic principles of relationship between soil test results and yield responses observed from increasing amounts of nutrient applied. Calibration was defined by Cope and Rouse (1973) as a process by which relation between soil test value and crop yield is obtained.

Berger (1954) proposed a new approach to fertilizer prescription based on available nutrient status of the soil for specific crop yield goals taking into account the nutritional requirement of crops and the nutrient supply from soil and fertilizer sources. He also reported the values of nutritional requirement of corn, soil and fertilizer efficiencies presented a simple way of calculating fertilizer requirements. Soil testing gives precise and quantitative information about fertilizer use to get maximum return.

Tamhane and Subbiah (1962) stated on the basis of preliminary soil test-crop response work carried out on the basis of the pot culture and field experiment on all Indian soils that apt time of soil sampling for assessing the fertilizer requirement was just prior to sowing for phosphate and nitrogen and for the potash at the harvest time of the previous crop.

Sharma *et al.* (2015) conducted soil test crop response experiments to assess yield, relationship between soil, plant, fertilizer nitrogen, phosphorus, potassium and to calibrate optimum fertilizer doses for attaining yield targets. Soil fertility status was poor to medium for N, P and medium to good for K. Based on nutrient requirements and contributions from soil and fertilizer, optimum fertilizer doses were derived. The fertilizer doses were validated for attaining yield targets in farmer's fields. The crop yield within 10 per cent deviation was attained, which indicated that soil-test-based fertilizer dose was superior.

Kumar and Parmanand (2018) carried out an experiment to assess the soil test crop response based crop nutrient management at five farmer's field. The results clearly indicated that application of fertilizers to crops based on soil test values approach was effective in getting the higher yield.

Bera *et al.* (2006) conducted soil test crop response correlation studies to quantify the crop production in the context of the variability of soil properties and use of balanced fertilizers based on targeted yield concept. Based on different database regarding nutrient requirement fertilizer recommendation were computed. The percent achievement of targets aimed at different level was more than 90 per cent, indicating soil test based fertilizer recommendation approach was economically viable.

Sakarvadia *et al.* (2012) conducted a field experiment using fertility gradient approach and fertilizer prescription equations were calculated. The results of follow up trials conducted at different location showed that the economics of fertilizer use based on soil test for achieving maximum yield indicated an additional benefit over general recommended dose at tested crop yield targets.

Parker *et al.* (1967) developed the nutrient index approach, which was based on soil test values of different nutrients, where the soil samples are categorised into low, medium and high based on fertility status of that soil. This is useful for formulating area wise fertilizer recommendation.

Nambiar *et al.* (1977) developed the ten class system to advise the fertilizer recommendation for Kerala soil. They classified the lower fertility degree to three classes, medium to four classes, higher to three classes. For all fertility division, recommendations are given primarily based at the package of practices for each crop.

Sajnath (2011) conducted an experiment at Thrissur, Kerala and reported that the yield and dry matter production could be higher in soil test based method over the farmer's practices. Lamina (2009) reported that in oriental pickling melon the soil test crop response approach gave the higher yield and B/C ratio and also revealed that addition of fertilizer increased vitamin C and Si content in melon.

2.2 NUTRITIONAL MANAGEMENT THROUGH FERTIGATION

The technique of fertilizer application is very important in obtaining optimal use of fertilizers. This will influence the amount of fertilizer used by the plants and amount lost through leaching. Applying fertilizers by dissolving them in irrigation water especially with drip irrigation system is most efficient way of fertilizer application. Fertigation allows an accurate and uniform application of nutrient near to the root zone. Therefore it is essential to distribute adequate quantity of nutrients at right concentration to meet the crop demand during growth period. The benefit of fertigation is that it helps in saving fertilizers and labour cost. This practices help to easily supply of nutrients as they are already available to plants root more quickly than solid fertilizers supplied to soil surface (Koo, 1980).

Fertigation is an innovative and attractive technology in modern agriculture as it increases the yield and quality of the product together with improvement of fertilizer and water use efficiency (Papadopoulos, 1992). Nutrient use efficiency of drip fertigation is about 90 per cent compared to that of conventional method where there is only 40 to 60 per cent use efficiency (Solaimalai *et al.*, 2005).

Effective and uniform application of water soluble fertilizers can be done along with the irrigation water (Patel and Rajput, 2004). According to several researches, the fertilizer application through fertigation can save fertilizers up to 20 to 50 per cent and also improves the yield and quality of the product than the conventional method of fertilizer application (Vaezi *et al.,* 2003; Asadi *et al.*, 2005).

According to Fertilizer Association of India (1995) fertigation enjoys various advantages like (a) higher use efficiency of water and fertilizers, (b) minimum losses of nutrients due to prevention of leaching, (c) optimization of nutrient balance by supplying nutrients directly to root zone in available form, (d) control of nutrient concentration in soil solution to effect proper supply, (e) saving the application cost and (f) improvement of soil physical and biological condition due to proper maintenance of soil moisture level.

Fertilizers supplied through traditional methods of irrigation were not efficiently used by the crop. Under fertigation, water and fertilizer are efficiently utilised by the plant. Field studies conducted in different commercial, horticultural and high value crops revealed that implementation of this technology improved the yield and quality of crops. It is also highly beneficial to the farming community in reducing the cost of production. Further it helps in sustaining the soil health for better productivity and reducing environmental hazards (Jayakumar *et al.*, 2015).

Studies conducted by Shinde and Jadhav (1998) revealed that drip with automatic control system saved irrigation water up to 56 per cent and increased the crop yield up to 52 per cent and WUE by 2.5 to 3 fold over surface irrigation. Requirement of chemical fertilizers is reduced if applied through drip irrigation.

Singh *et al.* (2009) revealed that, when N and K fertilizers were applied through drip irrigation, higher tomato yield was obtained with 75 per cent of recommended level compared to 100 per cent and 50 per cent of recommended levels of fertigation through drip.

According to Intrigiliolo *et al.* (1994) the water consumption by orange trees was 21 per cent lower in drip system than normal irrigation and also there were improved water, nutritional and physiological plant status in fertigation compared with the annual application of fertilizers.

Malik and Kumar (1996) observed that the drip irrigation level of 75 per cent pan evaporation with 25 kg N ha^{-1} fertigation was the optimum combination for maximizing the water use efficiency and yields of peas grown on a sandy loam soil.

Parikh *et al.* (1996) studied the response of vegetables, sugarcane and fruit crops to micro irrigation system and fertigation and reported that the water saving ranged from 10 to 56 per cent in various crops with improved yield of 13 to 60 per cent. Fertigation studies in selected crops showed that about 40 per cent of nitrogenous fertilizers can be saved without detrimental effect to yield and quality. The water use efficiency and fertilizer use efficiency were almost doubled due to fertigation.

Pier and Doerge (1995) suggested the increased adoption of subsurface drip irrigation and fertigation with fluid N sources will contribute to a sustainable future for crop production, even though water supplies continue to diminish and can result in optimum crop yield, quality, and economic return, without polluting losses of N to groundwater.

Haynes (1985) suggested that, fertigation is the most effective and convenient means of maintaining optimum fertility level and water supply according to the specific requirement and the savings in the use of fertilizers can be to the tune of 25 to 50 per cent.

Ashraf *et al.* (2012) proved that fertilizers applied through broadcasting were not efficiently utilized by plants, fertigation ensures application of fertilizers directly to root zone, resulting in higher fertilizer use efficiency. Application of fertilizers through drip irrigation is more useful in Indian agro climatic condition. Teixeira *et al.* (2011) reported that fertigation resulted in 36 per cent higher nutrient use efficiency compared to conventional fertilization, for either nitrogen or potassium.

2.3 EFFECT OF FERTIGATION ON GROWTH, YIELD AND QUALITY OF VEGETABLES

In a field experiment conducted by using three varieties of okra (Parbhani Kranthi, Selection 2-2 and Punjab-7) with different doses of fertilizers through fertigation, Somkuwar *et al.* (1997) reported that application of 75 kg N per hectare increased the vegetative growth, number and weight of fruits per plant and yield per hectare. Among the three tested varieties, highest yield was recorded for Parbhani Kranthi (77.70 q ha^{-1}) with low incidence of yellow vein mosaic virus and shoot borer.

Jainu *et al.* (1987) reported that, in drip irrigation system, water and nutrients can be applied directly to crop at the root level, having positive effects on yield and water savings and increasing the irrigation performance by reporting highest brinjal yield in drip fertigation at 180 kg N ha^{-1} compared to surface irrigation with 360 kg N ha^{-1} (202 g $plant^{-1}$).

Bafna *et al.* (1993) observed that fertigation with various amount of N, P and K fertilizers increased the yield of tomato, induced early flowering, and significantly improved the crop quality and water use efficiency.

Muralidhar *et al.* (1999) reported that the drip fertigation at 80 per cent of recommended N and K level with water soluble fertilizers registered higher tomato yield (22.3 t ha^{-1}) compared to 100 per cent and 60 per cent of recommended levels in drip irrigation.

Selvakumar (2006) suggested that decreasing the fertilizer level by 20 per cent than the recommended level especially under fertigated conditions may not affect the yield level in chilli because of improved FUE. Between furrow and drip methods of irrigation, drip irrigation method resulted significantly higher dry chilli yield with 42 per cent higher water use efficiency over furrow method even with the same level and method of normal fertilizer application.

Pitts *et al.* (1991) conducted a field trial to study the effect of flooding against fertigation using staked drip irrigated tomato cv. Sunny, where N and K (about 75 per cent of the total rates) applied as fertigation. It was found that fertigation could reduce the crop damage due to higher water table following heavy rains. However, there was no significant difference in the yields produced by fertigation and conventional flood irrigation. From another study, Ibrahim (1992) reported that fertigation increased the crop yield compared to band application in tomato. It was also found that the fertigation frequency of 2 days interval produced highest yield.

A study conducted to find out the effect of drip irrigation and different rates of N, P and K fertilizers on yield and quality of tomato cultivar Mountain Pride revealed that application of 1000 lb of 10: 10: 10 NPK fertilizers before planting, in combination with drip irrigation produced yield equal to those with higher rates of fertilizers applied partly before planting and partly through irrigation stream (Mullins *et al.* 1992).

In potato, highest tuber yield (15.03 t ha^{-1}) was obtained by soil application of 50 per cent of recommended nitrogen with furrow irrigation and the remaining 50 per cent through drip irrigation at four weekly split applications

(Keshavaiah and Kumaraswamy, 1993). The water use efficiency was highest when daily drip irrigation was provided.

Tumbare and Nikam (2004) studied the effect of planting and fertigation on growth and yield of green chilli (*Capsicum annum*). The treatments included recommended doses of fertilizers (100: 50: 50 kg NPK ha^{-1}) at every irrigation (2 days interval) up to 105 days which resulted in a significantly higher yield of 9.30 and 9.06 t ha^{-1} during first and second year respectively. However, it was found on par with fertigation at 4 days intervals up to 105 days.

Another study on the effects of source and levels of fertigation on capsicum hybrid Green Gold under green house condition during winter revealed that maximum productivity was achieved when water soluble fertilizers were applied at a higher dose (120 per cent RDF). In addition, the fruits were having excellent quality with a shelf life of 11.36 days (Manohar, 2002).

Veeranna *et al.* (2002) reported that decreasing the fertilizer levels by 12 per cent than the recommended level especially under fertigated conditions may not affect the yield level in chilli because of the improved fertilize use efficiency.

Darwish *et al.* (2003) stated that fertigation with continuous nitrogen feeding through drip system based on actual nitrogen demand and available nitrogen in soil resulted in 55 per cent nitrogen recovery. High nitrogen input not only increased the nitrogen derived from fertilizers but also enhanced soil residual nitrogen.

Patel and Rajput (2004), after conducting trial on fertigation reported that the yield of okra under conventional method of fertilization with 100 per cent of recommended dose of fertilizers was on par with that under fertigation with 60 per cent recommended dose of fertilizers. More than 16 per cent increase in yield under fertigation (25.21 per cent) was observed as compared with broadcasting of fertilizers when 100 per cent RDF was applied.

Muralikrishnasamy *et al.* (2006) reported that fertigation with 100 per cent nitrogen and potassium recorded higher yield of chilli as compared to entire NPK as soil application. But, fertigation with 125 per cent of nitrogen and potassium led to marginal decrease in yield over fertigation of 100 per cent N and K. Whereas, fertigation of 75, 100 and 125 per cent N and K observed 50.6, 66.8 and 58.6 per cent increase in pod yield respectively over soil application of 100 per cent nitrogen and potassium with surface irrigation.

Mahajan and Singh (2006) conducted an experiment in greenhouse grown tomato on different fertilizer levels and irrigation methods. They reported that, when the same quantity of water and nitrogen was applied through fertigation, a significantly higher yield (68.5 t ha^{-1}) was obtained as compared to basin method (58.4 t ha^{-1}). Fertigation of 100 per cent N resulted in increased fruit yield by 59.5 per cent over the control.

Shedeed *et al.* (2009) reported that there was a significant increase in yield components like number of fruits per plant, mean fruit weight, fruit yield per plant and total fruit yield in tomato with the application of 100 per cent RDF through fertigation over furrow and drip irrigation and soil application of fertilizers.

Prabhaker *et al.* (2002) reported that application of 50 per cent recommended dose of NPK fertilizers through drip irrigation in summer tomato gave higher plant height, number of branches, lesser number of days for flowering, fruiting and higher marketable fruit yield over the conventional soil application of fertilizers to the tune of 10.75 to 20.69 per cent.

Ruby *et al.* (2012) conducted a field experiment in pointed gourd and reported that the fruit length (10.55 cm), average fruit weight per vine (6.31 kg) was increased with 100 per cent of fertigation. It was statistically par with 80 per cent fertigation with mulch and the highest yield (15.78) was also recorded by 100 per cent of fertigation.

Chattoo *et al.* (2013) reported that, in radish variety Japanese White Long, drip irrigation and fertigation practices were superior in terms of yield, water and fertilizer use efficiency over conventional methods. It was also found that 75 per cent recommended dose of fertilizers through fertigation was significantly superior over conventional method. The advantages include 68.9 per cent yield enhancement, 46.2 q ha^{-1}-cm water use efficiency and 4.78 q ha^{-1}-kg P and K fertilizer use efficiency.

According to Amaranajundeshwara (1997) 100 per cent water soluble fertilizer through fertigation recorded maximum plant height, more number of sprout, higher leaf area, more number of leaves per plant, higher fresh and dry weight of plants and marketable tuber yield, than the conventional method of fertilization in potato.

Carbello *et al.* (1994) studied the effect of drip irrigation with various rates and timings of N and K application on bell pepper fruit quality. They found that higher fertilizers rate (266-309 kg ha^{-1} of N and K, respectively) increased the yield of class I fruits in the first harvest and reduced the total discards. The low fertilizers rate (70-81 kg ha^{-1} of N and K) increased the yields of class I fruits in the first harvest and mid or late season fertigation produced more of second harvest yields and less discards than the first harvest.

2.4 EFFECT OF FERTIGATION IN CUCUMBER

Kretschmen and Zengerle (1973) conducted a field trial for two years in cucumber cvs. Uniflora - B and Sporu. Plants were given the same quantity of N, P and K applied either to the soil or via overhead sprinkler, where the second method gave 6.9 per cent higher yields.

Bhella and Wilcox (1986) conducted a field experiment to study the nitrogen use efficiency in muskmelon under trickle irrigation. There is a significant increase in early maturity; stem growth and total yield were obtained with pre plant nitrogen fertilization rates. The plants were more reactive to increasing nitrogen fertigation in the case of plants growth without the application of fertilizers. Highest yield (29.83 t ha^{-1}) and increased fruit weight of melon

(1.1kg) were noticed with N at 70 kg, P_2O_5 at 60 kg and K_2O at 90 kg per hectare when applied through irrigation water (Harnandez and Aso, 1991).

Pinto *et al.* (1993) conducted a field trial Eldorado melons, nitrogen was applied either daily or thrice a week at eight different growth periods up to 55 days after germination. In the control plot 55 per cent of the total N (90 kg ha^{-1}) and 100 per cent of K (100 kg ha^{-1}) as potassium chloride were applied at planting and the remaining 45 per cent of N was applied 30 days later, but K was applied at different periods up to 42 days after germination in other treatments. The highest yields of 26.4 and 25.89 tonnes per hectare were obtained with daily fertigation up to 42 and 55 days after germination, respectively.

Satisha (1997) reported that through fertigation the nitrogen fertilizer required for vegetative growth, high amount of phosphorous fertilizer in early growth stage to encourage rooting and high potassium fertilizers for flowering and fruiting can be applied. Raman *et al.* (2000) reported the effect of fertigation on growth and yield of gherkins where the treatments were four fertigation with different soluble fertilizer combinations at two levels (100 and 75 per cent NPK) compared with recommended dose of solid fertilizers applied in soil. Application of 75 per cent of recommended dose of NPK with soluble fertilizers through drip irrigation system gave higher yields, resulting in 25 per cent saving of fertilizers.

A field experiment was conducted at Kerala Agricultural University by Gebremedhin (2001) to study the efficiency of drip irrigation with that of basin irrigation in oriental pickling melon. The study found that drip irrigation saved irrigation water by 37 per cent and increased fruit yield by 20 per cent over conventional method.

Shinde and Malunjkar (2010) revealed that 100 per cent recommended dose of nitrogen (100 kg N/ha) applied through fertigation with eight splits in cucumber (cv. Himangi) were recorded higher number of fruits (2.166 kg/plant) and yield (2.55 t/ha).

Ningaraju (2013), Kerala Agricultural University conducted a field trial during December 2012 to March 2013 to standardize drip fertigation under high density planting in oriental pickling melon. The treatments included three fertilizer levels (100, 150 and 200 per cent as recommended by the KAU, POP) and combinations of four irrigation levels (50, 75 and 100 per cent Ep through drip irrigation and farmers practice of pot irrigation @ 10 litres per plant on alternate days from flowering to maturity and half of this quantity from 10 DAS to flowering). Among the treatment combinations, maximum yield (72.4 t ha^{-1}) was obtained at 100 per cent Ep given through drip system with 200 per cent RDF.

2.5 SILICON APPLICATION IN CROPS

Silicon is accumulated typically in the epidermal tissues of both roots and leaves in the form of a silica gel. This thickened epidermis increases the mechanical strength of plants, increasing the light-receiving posture of the plant and hence growth. The deposition of Si within the plant tissues additionally reduces transpiration, thereby diminishing the effect of drought and salinity. Si deposition in tissues has been validated to offer a mechanical barrier against a variety of pests and diseases. Si application will alleviate Mn toxicity in cucurbitaceae plants (Iwasaki and Matsumura, 1999).

The role of silicon in plants are enhancement of growth and yield, resistance against lodging, enhanced photosynthesis, effect on surface properties, resistance against disease resistance to herbivores, resistance to metal toxicity, resistance to salinity stress, reduction of drought stress and protection against temperature extremes (Epstein, 1994).

Adatia and Besford (1986) reported that in cucumber addition of Si (100 mg L^{-1}) could increase the chlorophyll content, RuBP carboxylase activity (ribulose-bis-phosphate), root fresh weight and dry weight when grown in a re-circulating nutrient solution.

Among the dicotyledons most results related to Si and disease resistance were reported from cucumber where Si amendment to the nutrition solution increased resistance against *Sphaerotheca fuliginea* (Adatia and Besford, 1986) and root rot caused by *Pythium ultimum* (Cherif and Belanger, 1994) and *Pythium aphanidermatum* (Cherif *et al.*, 1994). In field experiments with cucumber, Miyake and Takahashi (1983) found a reduction of Fusarium wilt by Si treatment.

Foliar spray of silicon in cucumber (*Cucumis sativus* L.) at the third leaf stage and subsequent bi- weekly application during the season increased the yield up to 46 per cent and the soil application also increased the yields. Additional benefits of silicon included stimulation of fruit formation and accelerated fruit maturation (Matichekov and Bocharnikova, 2001).

The role of Si in P uptake by plants was one of the first effects of Si ever studied. Indeed, Brenchley and Maskell (1927) found that Si fertilization increased the yields of barley crops mainly when phosphorus fertilization was limiting. They concluded that Si fertilization made soil phosphorus more available to plants.

According to Mali and Aery (2008), K uptake was improved even at low Si concentrations through the activation of H-ATPase. They also observed a better absorption of N and Ca for cowpea and wheat fertilized with increasing doses of sodium metasilicate (50-800 mg Si kg^{-1}), as well as a better nodulation and better N_2 fixation in cowpea.

Yoshida *et al.* (1969) have shown that decrease of erectness in rice leaves due to excess N application can be mitigated if Si is supplied to the nutrient solution. In rice, it appears that Si increases the oxidizing capacity of roots, which converts ferrous iron into ferric iron, thereby preventing a large uptake of iron and limiting its toxicity (Ma and Takahashi 2002). Si could regulate Fe uptake from acidic soils through the release of OH^- by roots when supplemented with Si (Wallace 1993).

Bouzoubaa (1991) studied the impact of silicon fertilization in the development of secondary and tertiary cells of the endodermis, thus allowing better root resistance in dry soils and a faster growth of roots.

Gong *et al.* (2005) observed that Si increased antioxidant defences and therefore maintained physiological processes such as photosynthesis.

Marschner *et al.* (1990) studied using the nutrient solution with high phosphorus and low zinc and confirmed that severe leaf chlorosis and depression in flower and fruit formation occurred without silicon supply in cucumber. Si may act as beneficial element under conditions of nutrient imbalances, P-induced Zn deficiency.

Mohaghegh *et al.* (2015) concluded that there was a significant decrease in disease and increase in plant growth with application of Si to shoot and root of pumpkins infected with powdery mildew. It was suggested that Si may act to ameliorate the stress caused by powdery mildew in pumpkin by decreasing destructive activities of fungus on the roots and shoots and increasing of physiological resistance.

2.6 NUTRIENT STICK

Nutrient stick is also referred to as fertilizer spike or stakes, as a complete fertilizer composite that is formulated in stick form and contains ten essential nutrients. It produces a constant supply of nutrient into soil, as we water the plant the stick will dissolve and release nutrient into the soil, for further plant uptake. This can be used for potted plants as well as plants grown in the field.

Apply the fertilizer stick when the ground is moist, driving the stick about two to three inches into the soil. When fertilizing trees and shrubs, place the stick into the ground around the drip line. Drip line is the furthest point that limbs reach from the trunk. Placing the spikes along the drip line encourages plant roots to grow out towards the fertilizer. Each time irrigates the field or rains, fertilizer will be release (Ishee, 2015). Space each sticks a minimum of 10-15 cm apart, keeping them at least 30 to 60 cm away from the trunk or centre of shrub, and water as usual. For potted plants, push the sticks into the soil at the edge of the pot or near the rim and water as usual.

Advantages of using fertilizer spikes includes, spikes dissolve gradually, lot easier to handle and store, stimulate biological activity in the soil which promote pest and disease resistance and over fertilization is not as likely. This is because fertilizer spike are available in pre mixed formulas designed for specific uses such as vegetables, ornamentals or fruit tree application.

Materials and Methods

3. MATERIALS AND METHODS

An investigation entitled "Evaluation of fertigation *vis a vis* nutrient stick and foliar silicon in oriental pickling melon (*Cucumis melo* var. *conomon*)" was carried out at College of Agriculture Padannakkad and Regional Agricultural Research station (RARS), Pilicode during November 2016 to March 2018. The objective of the study was to prepare the nutrient stick for the oriental pickling melon and to evaluate its performance and also to compare its effect with fertigation. The objective was also to compare that of with foliar spray of silicon. The whole study was conducted in two parts.

Part – 1:- Preparation of nutrient stick.

Part – 2:- Field experiment

3.1 PREPARATION OF NUTRIENT STICK

Nutrient stick is a complete fertilizer composite that is formulated in stick form and contains ten essential nutrients such as nitrogen, phosphorous, potassium, calcium, magnesium, sulphur, zinc, boron, iron cupper and manganese at needed concentration. It's evaluated for stability in soil and water. The raw materials used for the preparation of stick are Factomphos, Potassium sulphate, Gypsum, Magnesium sulphate, Zinc sulphate, Borax, Copper sulphate, and Manganese sulphate. The technique has been standardized after trying a series of combination by mixing the powdered fertilizer materials along with suitable binding agents and heat for 20 minutes. Finally the stick was formulated and evaluated for their solubility in water and soil. Then the nutrient sticks were evaluated with oriental pickling melon as test crop in soil application.

3.2 FIELD EXPERIMENT

The field experiment was conducted at Regional Agricultural Research Station, Pilicode, Kasaragod, Kerala during the period March to May 2017. The experiment was conducted in randomized block design with nine treatments and three replications, such a way that twelve plants were maintained in each plot.

Cultural management practices were followed as per the package of practices. The details of materials used and technique adopted during the course of investigation are given below.

3.2.1 Location

Geographically, the experimental site lies in tropic region, at 12° 12' N latitude and 75° 10' E longitude and at an altitude of 15m above mean sea level. The region mostly experiences a warm humid tropical climate.

3.2.2 Cropping History

The experimental field is a double cropped paddy wet land in which a semi dry sown crop on April - September and a transplanted crop September - December was cultivated as second crop. Then the land is left fallow during summer months. The soil type of the experimental field is sandy clay loam.

3.2.3 Crop and Variety

The oriental pickling melon, (*Cucumis melo* var. *conomon*) variety Soubaghya, used in this experiment, was developed by Department of Olericulture, College of Horticulture, Vellanikkara, Kerala agricultural university, Thrissur. The fruits of oriental pickling melon variety Soubaghya are small to medium sized with uniform oblong shape. The developing fruits are green in colour with light green lines and on ripening the fruits turns attractive golden colour. The main advantages of variety Soubaghya are its short duration (65 - 75days), less vegetative growth and small to medium sized attractive fruits, suiting summer rice fallows and market preferences.

3.2.4 Season

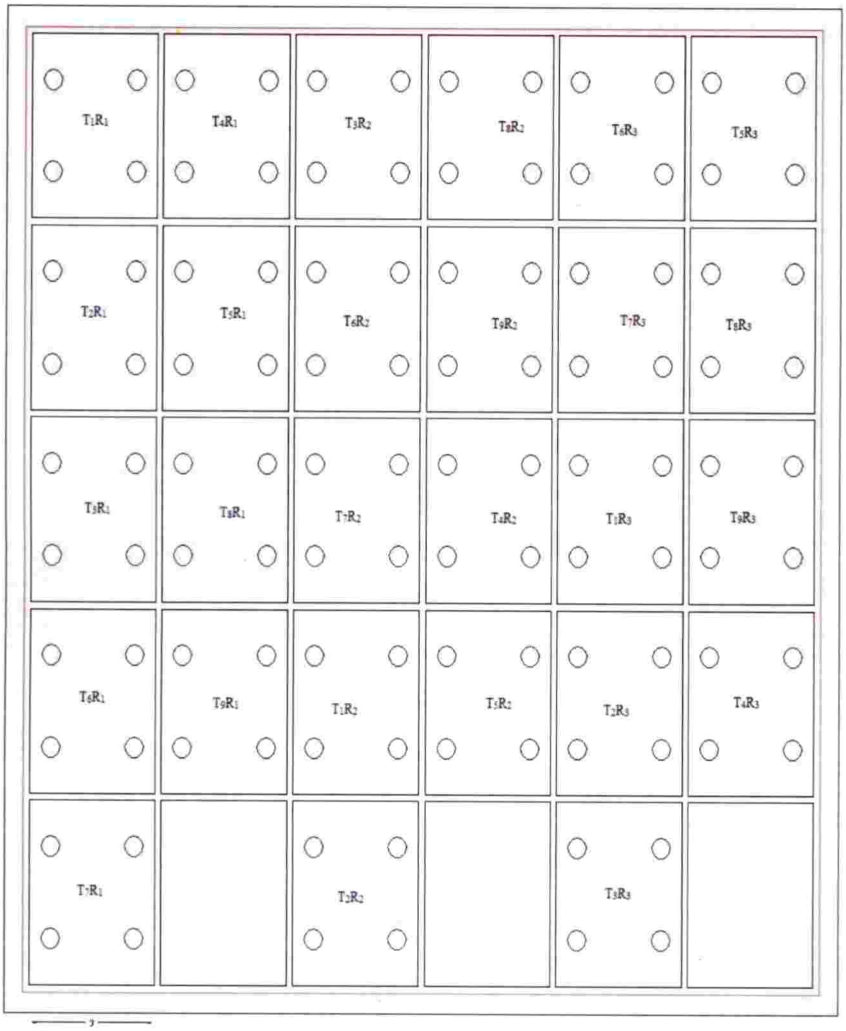
The field experiment was conducted during summer, from 21st March to 27th May 2017. Meteorological data during that period are presented in the appendix I.

3.2.5 Design and layout

The layout of the field experiment is given in the plate.1. The details are presented below.

Crop	: Oriental pickling melon
Variety	: Soubaghya
Design	: Randomized block design (RBD)
Replication	: 3
Total number of treatments	: 9
Total number of plots	: 27
Plot size	: 4m x 3m
Spacing of pits	: 2m x 1.5m
Number of plants per pit	: 4
Date of sowing	: 21st March
Date of first harvest	: 15th May
Date of last harvest	: 24th May

EXPERIMENTAL LAYOUT



DESIGN	: RBD
Treatments	: 9
Replications / Blocks	: 3
Plot size	: 4m x 3m
Bund width	: 15 cm
Crop	: CUCUMBER
Total Area	: 400 Sq.m (10 cents)

Crop	. Oriental pickling melon
Spacing	: 2m x 2m
Pits per Plot	: 4 nos

Plate: 1- Layout of the field experiment

3.2.6 Treatments

T_1 - KAU POP with conventional irrigation practices

T_2 - Drip irrigation + Soil test based nutrient application as per modified KAU POP

T_3 - Drip irrigation + nutrient stick (100%)

T_4 - 75% of NPK as per KAU POP through fertigation + 25% nutrient stick

T_5 - 50% of NPK as per KAU POP through fertigation + 50% nutrient stick

T_6 - T_2 + Potassium silicate spray (0.25per cent)

T_7 - T_3 + Potassium silicate spray (0.25 per cent)

T_8 - T_4 + Potassium silicate spray (0.25 per cent)

T_9 - T_5 + Potassium silicate spray (0.25 per cent)

3.2.7 Cultural practices

3.2.7.1 Land preparation

The land was ploughed with a tractor drawn disc plough and then the cultivator was passed over to weigh down the clods and make the soil to an excellent tilth. Thereafter stubbles have been removed and the experimental plots had been laid out as per the plan shown in plate 1. Pits (50 x 50 x 30 cm) were opened at spacing of 2 x 2 m. Each plot was bordered by bunds of width 45cm on all of the four sides.

3.2.7.2 Manures and fertilizer application

Farmyard manures was applied uniformly in all the pits at a rate equivalent to 25t ha^{-1} as basal dose. After thorough mixing with top soil, the pit was filled and irrigated using drip lines. Standardized 100 per cent, 50 per cent and 25 per cent nutrient stick was prepared and inserted into the soil, 30cm away from seed sown and covered in surface soil. In the treatments without stick nitrogen, phosphorous and potassium were applied through drip in six split doses at weekly interval from 10 day after sowing to 50 day after sowing. The treatment receiving soil test based fertilizer application, entire dose of phosphorous and potassium and half dose of nitrogen was applied as basal and remaining dose of nitrogen was applied at the time of flowering stage. Fertilizers were applied according to the treatments in the form of fertilizer stick, 19:19:19, urea, factomphos and sulphate of potash.

3.2.7.3 Sowing

Seeds were sown in each pit. Gap filling was done after one week and thinning on 12th days after planting by keeping four plants per pit and one at a point.

3.2.7.4 Irrigation

A uniform irrigation of ten litters per pit per day was provided to all drip irrigation pits by operating drip system. The required amount of water was provided as a single spray jet. One storage tank of 1000 litters' capacity was kept on a platform and the outlet of the tank connected to motor pump and it was connected to main line made of rigid PVC pipe having 1 inch diameter. The main line laterals made of LDPE having 16mm internal diameter were connected at appropriate interval. For each line of laterals a separate control valve was provided at the beginning. Micro tube having 4 mm diameter was connected in the main lateral at appropriate point and spray jet are connected at the end of micro tube, water was provided at the centre of pit. From each spray jet, the discharge rate was 72 litters per hour. In conventional practices hoses were used for irrigating the crops. The tank was constantly kept filled with water by connecting to a 1 hp motor pump. Screen filter was provided on the beginning of main line to prevent entering of impurities into the drip system.

3.2.7.5 After cultivation

Hand weeding, raking and earthing up were carried out on 15th days after planting and for KAU POP with conventional irrigation practices and soil test based fertilizer application treatment gentle raking was given to soil at the time of fertilizer application with help of hand fork. Second and third weeding was done one 30th and 45th day after sowing.

3.2.7.6 Plant protection

Malathion 57 per cent EC and chlorpyriphos 20 per cent EC sprays were given to control the attack of red pumpkin beetle, mole cricket and other small sucking pest like jassids and white fly, at the initial stages of the crop.

3.2.7.7 Harvesting

Fruits were harvested when they were fully matured (they got attractive dark golden yellow stripes from stalk end to pedicel end). This was judged by visual appearance. First harvest was done at 15th May 2017.

3.3 BIOMERTIC OBSERVATION

Observations on different yield attributes were taken to study the effect of treatments on growth and development of the crop. Four plants were randomly selected and tagged from each pit to record the periodical observations. The characters analyzed using the average values of tagged four plants. All the growth parameters were taken from the same plant, during the course of investigation.

3.3.1 Germination percentage

Germination test was carried out to study the germination percentage of Soubaghya variety by placing its seeds in moistened filter paper for three days and recorded the number of seeds germinated on fourth day.

3.3.2 Days to first male flowering

Number of days from date of sowing to date of emergence of male flowers from four tagged plants of each pit was recorded and calculated the average.

3.3.3 Days to female flowering

Number of days from date of sowing to date of emergence of female flowers from four tagged plants of each pit was recorded and calculated the average.

3.3.4 Number of fruits per plant

The number of fruits harvested from all the plants in each plot was noted and the average number of fruits per plant is intended.

3.3.5 Days to harvest

The crop was harvested from second week of May 2017 onwards. It took almost 65 days from sowing to complete harvest of the crop.

3.3.6 Weight of fruits (g)

The weight of the fruit was calculated from total fruit yield and total number of fruit per plot.

3.3.7 Fruit length (cm)

Four fruits having mean weight were randomly selected for fruit length determination. The length of fruits was recorded in cm and calculated the average.

3.3.8 Yield of fruit per hectare

Total weight of the fruit harvested from each plot was recorded and the yield was calculated in kg per plot and yield in tones per hectare were calculated.

3.3.9 Incidence of pest and disease

Presence of mole cricket and red pumpkin beetles were noticed from initial stage of the plant growth to flowering stage. All of them brought under control by appropriate plant protection measures. No disease was noticed during cropping period.

3.4 SOIL ANALYSIS

3.4.1 Initial soil analysis

Soil sample for initial soil analysis was collected from the prepared site at different places of the field and the soil was thoroughly mixed, reduced to required quantity and air dried. The air dried soil samples were powdered and sieved with 2 mm sieve and then stored in air tight container.

The soil samples were analyzed for bulk density, particle density, texture, pH, EC, organic carbon, available nutrients such as N, P, K, Ca, Mg, S, Fe, Cu, Zn, Mn, B and Si following standard procedures given in table 1. The initial soil properties were given in table 4.

3.4.2 Experimental soil analysis

Soil samples for laboratory analysis were collected from all the plots at 45^{th} day after sowing and harvest. The soil samples were air dried, ground, sieved with 2mm sieve and stored in air tight cover. They were analyzed for available nutrients such as N, P, K, Ca, Mg, S, Fe, Cu, Zn, Mn, B and Si as per the standard procedures.

3.5 LEAF ANALYSIS

Leaf samples were collected at harvest and analyzed for various macro and micronutrient content using standard procedures as given in the Table 2.

Table.1:- Analytical methods followed for soil analysis

Sl.No	Parameters	Method	Reference
1.	Ph	pH meter	Jackson (1958)
2.	EC	Conductivity meter	Jackson (1958)
3.	Organic carbon	Chromic acid wet digestion method	Walkley and Black (1934)
4.	Bulk density	Undisturbed core sample	Black *et al.* (1965)
5.	Particle density	Pycnometer method	Black *et al.* (1965)
6.	Textural analysis	International pipette method	Robinson (1922)
7.	Available N	Alkaline permanganate method	Subbiah and Asija (1956)
8.	Available P	Bray extraction and photoelectric colorimetry	Jackson (1958)
9.	Available K	Flame photometry	Pratt (1965)
10.	Available Ca	Atomic absorption spectroscopy	Jackson (1958)
11.	Available Mg	Atomic absorption spectroscopy	Jackson (1958)
12.	Available S	Photoelectric colorimetry	Massoumi and Cornfield (1963)

13.	Available Zn	Atomic absorption spectroscopy	Emmel *et al.* (1977)
14.	Available B	Photoelectric colorimetry	Bingham (1982)
15.	Available Fe	Atomic absorption spectroscopy	Sims and Johnson (1991)
17.	Available Cu	Atomic absorption spectroscopy	Emmel *et al.* (1977)
17.	Available Mn	Atomic absorption spectroscopy	Sims and Johnson (1991)
18.	Available Si	Photolectric colorimetry	Korndorfer *et al.* (2001)

Table.2:- Analytical methods followed for plant analysis

S.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 S	Turbidimetric method	Bhargava and Raghupathi (1995)

7.	Total Zn	Atomic absorption spectroscopy	Emmel *et al.* (1977)
8.	Total B	Azomethane - H colorimetric method	Bingham (1982)
9.	Total Fe	Atomic absorption spectroscopy	Piper (1966)
10.	Total Cu	Atomic absorption spectroscopy	Emmel *et al.* (1977)
11.	Total Mn	Atomic absorption spectroscopy	Piper (1966)
13.	Total Si	Photolectric colorimetry	Korndorfer *et al.* (2001)

3.6 BENEFIT COST RATIO

The benefit cost ratio of cultivation for all the treatments was worked out on the basis of prevailing input cost and market price of fruits. The benefit cost ratio (BCR) was worked out as follows. The data on shelf life of the fruit are given in the appendix II.

$$BCR = \frac{\text{Gross return ha}^{-1}\text{ (Rs.)}}{\text{Cost of cultivation ha}^{-1}\text{(Rs.)}}$$

3.7 STATISTICAL ANALYSIS

Analysis of variance was done separately for all the parameters at different stages as per the statistical design randomized block design and significant was tested as per the "F" test (Snedecor and Cochran, 1964).

Plate 2 A: Germination stage

Plate 2 B: Vegetative growth

Plate 2 C: Male flower emergence

Plate 2 D: Female flower emergence

Plate 2 E: Field view at flowering stage

Plate 2: Field view of the experimental plot at RARS farm, Pilicode

Plate 3 A: Main line

Plate 3 B: Lateral

Plate 3 C: Spray jet

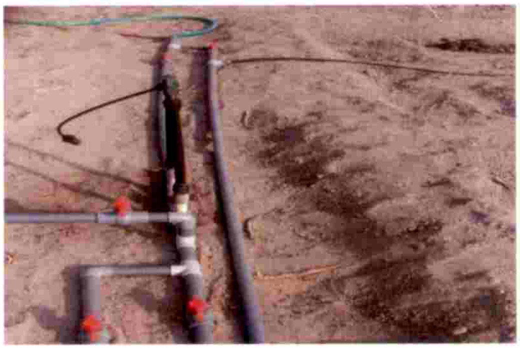


Plate 3 D: Fertigation unit

Plate 3 E: Spray jet

Plate 3: Irrigation unit

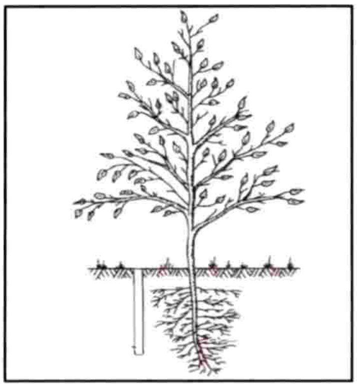


Plate 4 A: Field application

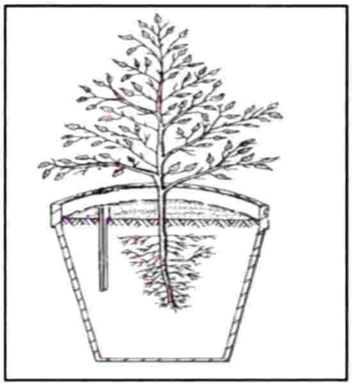


Plate 4 B: Pot application

Plate 4: Application of nutrient stick

Plate 5: Fruit development stages

Results

4. RESULTS

The results obtained from the experiment on "Evaluation of fertigation *vis a vis* nutrient stick and foliar silicon in oriental pickling melon (*Cucumis melo* var. *conomon*)" are furnished in this chapter.

4.1 FORMULATION OF NUTRIENT STICK

Nutrient stick is a complete fertilizer composite that was formulated in stick form and contains ten essential nutrients and it was developed by using different fertilizers. Different combinations were tried by mixing the powdered fertilizer materials along with suitable binding agents and heated for 20 minutes. Finally the stick was formulated and the sticks were evaluated for their solubility in water and soil. It was completely dissolved in water within two days and in soil within three weeks. The stick contains factomphos, potassium sulphate, gypsum, iron sulphate, magnesium sulphate, zinc sulphate, borax, copper sulphate, and manganese sulphate in appropriate proportion based on plant requirement. Finally the stick was standardized with cylindrical shape having 5 cm length and 1.5 cm diameter for field application. Nutrient stick was applied at two to three inches depth when the soil was moist by keeping them at least 30 to 60 cm away from the trunk or centre of shrub and irrigated by using drip irrigation technique.

Table: - 3 Composition of nutrient stick (for a plant)

Sl No	Nutrient content (for a plant)	Amount(g)
1	Factomphos	50.0
2	Urea	20.0
3	Potassium sulphate	20.0
4	Gypsum	20.0
5	Magnesium sulphate	10.0
6	Iron sulphate	5.0
7	Zinc sulphate	5.0
8	Borax	2.0

9	Copper sulphate	2.0
10	Manganese sulphate	1.0

4.2 INITIAL SOIL CHARACTERISTICS

The soil samples collected from the field were analyzed for various physical and chemical properties. The soil physical properties *viz.* bulk density, particle density, particle size distribution and the chemical properties *viz.* pH, EC, OC and available nutrients such as N, P, K, Ca, Mg, S, Fe, Cu, Zn, Mn, B, and Si are given in the table 4.

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Plate 6 a: Cake shaped stick

Plate 6 b: Triangular shaped stick

Plate 6 c: Standardized stick

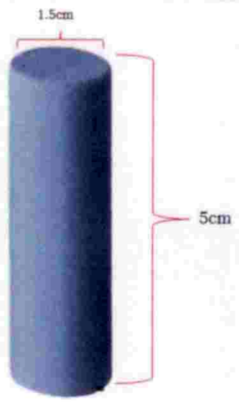

Plate 6 d: Standardized stick size and dimension

Plate 5 d: Nutrient stick

Plate 6: Preparation of nutrient stick

Table:-4, Properties of the initial soil sample

S.No	Parameter	Value
I. Physical properties		
1.	Bulk density (g cm^{-3})	1.31
2.	Particle density (g cm^{-3})	2.35
II. Textural composition		
1.	Coarse sand (%)	27.4
2.	Fine sand (%)	27.6
3.	Silt (%)	22.6
4.	Clay (%)	22.4
5.	Textural class	Sandy clay loam
III. Chemical properties		
1.	pH (1:2.5)	4.39
2.	EC (dS m^{-1})	0.33

3.	Organic carbon (%)	0.7
4.	Organic matter (%)	1.20
5.	Available N ($kgha^{-1}$)	217.40
6.	Available P($kgha^{-1}$)	89.60
7.	Available K($kgha^{-1}$)	106.40
8.	Available Ca ($mgkg^{-1}$)	156.25
9.	Available Mg ($mgkg^{-1}$)	39.65
10.	Available S ($mgkg^{-1}$)	5.91
11.	Available Zn ($mgkg^{-1}$)	3.29
12.	Available B ($mgkg^{-1}$)	0.21
13.	Available Fe ($mgkg^{-1}$)	80.40
14.	Available Cu ($mgkg^{-1}$)	1.16
15.	Available Mn ($mgkg^{-1}$)	12.10
16.	Available Si ($mgkg^{-1}$)	27.14

The soil was sandy clay loam and extremely acidic. The available Ca and Mg were also good whereas available N was medium. Available P was high and available K low.

4.3 BIOMETRIC OBSERVATION

4.3.1 Germination per cent

Germination per cent of the seed was calculated before sowing, 100 per cent germination was obtained for the seed of oriental pickling melon.

4.3.2 Days to male flower emergence

Days taken for first male flower emergence of crop oriental pickling melon var. Soubhagya as influenced fertigation, nutrient stick and foliar spray of silicon are presented in the table 5.

The effect of fertigation nutrient stick and foliar spray of potassium silicate on male flower emergence of the crop was not significant. Days taken to male flower emergence varied almost 21 to 23 days for all the treatments.

4.3.2 Days to female flower emergence

Days taken to first female flower emergence of crop oriental pickling melon var. Soubhagya as influenced by fertigation, nutrient stick and foliar spray are given in the table 5.

The female flower emergence of var. Soubhagya was also not significantly influenced by treatments, as indicated in data presented in table 5. Days taken to female flower emergence were almost 27 to 29 days for all the treatment combination.

Table 5:- Effect of fertigation, nutrient stick and foliar spray of silicon on male flower emergence, female flower emergence and days to first fruit set

Treatment	Days to male flower emergence	Days to female flower emergence	Days to first fruit set
T_1	21.1	28.4	32.0
T_2	22.4	28.6	32.6
T_3	22.0	28.3	31.4
T_4	22.0	29.2	33.0
T_5	21.5	27.0	32.6
T_6	23.0	29.3	32.5
T_7	21.5	27.6	31.4
T_8	21.4	28.8	32.2
T_9	21.6	27.3	31.3
C.D.	NS	NS	NS
SE(m)	0.451	0.672	0.521

4.3.3 Days to first fruit set

The days taken for formation of first fruit on crop oriental pickling melon are also presented in the table 5.

The levels of fertigtion, nutrient stick and foliar spray of silicon has not influenced the time taken for the formation of first fruit. Showing no significant effects. Days taken to first fruit formation varied between 31 to 33 days.

4.3.4 Days to harvest

The numbers of days taken from sowing to harvest were recorded for the treatments. The data were subjected to analysis of variance for RBD. The result indicated the influence of treatments (table 6) and showed significant difference with respect to crop duration for harvest. The shortest duration recorded was 59.6 days for T_4 (75 % of NPK as per KAU POP through fertigation + 25 % nutrient stick), which was on par with almost all treatments except T_1 (KAU POP with conventional irrigation practices) and T_6 (Drip irrigation + Soil test based nutrient application as per modified KAU POP + Potassium silicate spray @ 0.25per cent). The usual harvest duration of the crop variety Soubhagya was 65 to 75 days. The best treatment T_4 could reduce the duration by 5 to 15 days from the normal duration. This will be very advantages in summer rice fallows. In the summer rice fallows initial ploughing operation for the first crop of rice has to be done immediately after the receipt of summer showers, and that is why the short duration variety Soubhagya variety is preferred by farmers. The results of the experiment indicate that precision nutrient management can further reduce the duration of harvesting by another 5 to15 days.

4.3.7 Average fruit length (cm)

The data on average fruit length (cm) are given in the table 6. The result indicated significance influence of treatments on fruit length. Among the treatments, maximum fruit length (20.1cm) was recorded in T_8 (T_4 + Potassium silicate spray 0.25 per cent) and lowest mean fruit length (17.26cm) value was reordered from T_1 (KAU POP with conventional irrigation practices).

4.3.5 Number of fruits per plants

The data on number of fruits per plant are presented in the table 7. The number of fruits per plant was significantly influenced by the nutrient stick, foliar spray and fertigation. T_7 (T_3 + Potassium silicate spray - 0.25 per cent) recorded the maximum number of fruits per plants (3.12) while T_1 (KAU POP with conventional irrigation practices) recorded the lowest fruit number (2.23). T_7 is statistically on par with treatment T_3 (Drip irrigation + nutrient stick).

4.3.6 Average weight of the fruit (g)

The data on average weight of the fruit is given in the table 7. The levels of fertigation, nutrient sticks and foliar sprays of potassium silicate significantly influenced the average weight of the fruit of crop oriental pickling melon var. Soubhagya.

Maximum average weight of the fruit (981g) was observed with the treatment T_8 (T_4 + Potassium silicate spray @ 0.25 per cent) and it was significantly superior to all other treatments and minimum average fruit (770g) weight was recorded in the treatment T_1 (KAU POP with conventional irrigation practices). T_8 is statistically on par with treatment T_4 (941g).

4.3.8 Total fruit yield (kg plot^{-1})

Fruit yield is the major economic factor considered in cucumber cultivation. The data on mean fruit yield (kg plot^{-1}) of the crop is given in the table 7.

The application of nutrient stick, level of fertigation and foliar spray of silicon influenced the fruit yield. The maximum fruit yield (44.98 kg/plot) was observed with the treatment T_7 (T_3 + Potassium silicate spray @ 0.25 per cent) and minimum fruit yield (27.53 kg plot^{-1}) was recorded in the treatment T_1 (KAU POP with conventional irrigation practices). T_7 was statistically on par with treatment T_8 (T_4 + Potassium silicate spray @ 0.25 per cent) and T_3 (Drip irrigation + nutrient stick). The highest yield recorded 44.98 kg plot^{-1} corresponds to 37.48 t ha^{-1}.

4.3.9 Shelf life of the fruits at ambient condition

Treatment application on shelf life of fruits was recorded from the day of harvest to six months duration. There was a notable increase in shelf life of the fruit as influenced by the treatments. The highest keeping quality was observed on the treatments T_3, T_6, T_7, T_8 and T_9 up to six months and minimum shelf life was recorded in the treatment T_4 (75 % of NPK as per KAU POP through fertigation + 25 % nutrient stick) with 33 days. Shelf life at ambient condition is an important parameter in oriental pickling melon as its supply and market chains does not include any cold storage operations. The data on shelf life of the fruit are given in the appendix III.

4.3.10 Incidence of pest and disease

The red pumpkin beetle (*Aulacophora foveicollis)* was prevalent up to one month after planting and mole cricket attack was noticed at the seedling stages of the crop. Necessary control measures were taken uniformly for all the plants.

Table:-6 Effect of fertigation, nutrient stick and foliar spray of silicon days to harvest and average fruit length

Treatment	Average fruit length (cm)	Days to harvest
T_1	17.26	64.3
T_2	17.86	60.3
T_3	17.93	60.3
T_4	19.30	59.6
T_5	19.16	62.3
T_6	18.53	64.0
T_7	19.28	60.3
T_8	20.10	62.0
T_9	18.63	61.3
C.D.	0.685	2.42
SE(m)	0.227	0.801

Table:-7 Effect of fertigation, nutrient stick and foliar spray of silicon average weight of the fruit, total fruit yield and number of fruits per plants

Treatment	Average weight of the fruit (g)	Total fruit yield (kg plot $^{-1}$)	Number of fruits per plant
T_1	770	27.53	2.23
T_2	822	31.11	2.36
T_3	848	41.00	3.02
T_4	941	39.49	2.62
T_5	889	37.20	2.61
T_6	826	32.56	2.44
T_7	900	44.98	3.12
T_8	981	42.85	2.73
T_9	926	38.82	2.62
C.D.	48.13	4.587	0.232
SE(m)	15.917	1.517	0.077

4.4 SOIL ANALYSIS

4.4.1 pH

The effect of application of fertilizers on pH of the soil at 45 days after planting of crop and at harvest is given in the table 8. There was no considerable difference in soil pH at 45 DAS among the treatments. The lowest (3.85) pH was recorded in the treatment T_4. T_9 had the highest pH (4.18) and followed by T_7 and T_1.

At harvest, there was also no considerable difference in pH among the different treatments. The highest pH (4.2) was recorded in the treatment T_1 and followed by T_8, T_7 and T_9. Lowest pH was recorded on T_4 (3.93) and followed by T_5.

4.4.2 EC (dS m^{-1})

The data on EC at both stages are given in the table 8. The data indicated that treatment T_3 was superior at 45 DAS followed by T_6, T_8 and T_3 and the lowest EC value observed with treatment T_2. At harvest treatment T_5 was superior, followed by T_8, T_3 and T_7. The values were 0.331, 0.321, 0.321, and 0.311 dS m^{-1} respectively. The lowest soil EC value was recorded with treatment T_2 (0.283).

4.4.3 Available nitrogen in soil (kg ha^{-1})

The effects of treatments on available nitrogen in soil at two different stages of the crop are given in the table 9.

The levels of fertilizer application significantly influenced the available nitrogen in the soil. At 45 days the available nitrogen varied from 244 kg ha^{-1} to 318 kg ha^{-1} with the maximum value with the treatment T_8 (318 kg ha^{-1}) followed by T_9, T_4 and T_5. The minimum value of available nitrogen was recorded in the treatment T_7.

At harvest stage, there were significant differences among the treatments. The highest value was recorded with treatment T_4 (288 kg ha^{-1}) followed by T_8 (281 kg ha^{-1}) and T_9 (279 kg ha^{-1}). The lowest nitrogen was recorded in T_1.

Table:-8 Effect of fertigation, nutrient stick and foliar spray of silicon on soil pH and EC at 45 DAS and at harvest

Treatment	pH		EC (dS m^{-1})	
	45 DAS	**Harvest**	**45 DAS**	**Harvest**
T_1	4.01	4.2	0.292	0.290
T_2	3.95	4.18	0.217	0.283
T_3	3.91	4.15	0.355	0.321
T_4	3.85	3.93	0.315	0.308
T_5	4.05	3.96	0.307	0.331
T_6	3.95	4.01	0.348	0.309
T_7	4.15	4.10	0.295	0.311
T_8	3.91	4.11	0.315	0.321
T_9	4.18	4.10	0.305	0.308
C.D.	NS	NS	NS	NS
SE(m)	0.217	0.105	0.027	0.024

4.4.4 Available phosphorous in soil (kg ha^{-1})

The effect of treatments on available phosphorous in soil (kg ha^{-1}) is given in the table 9. The effect of treatment application was found to be significant in case of available P content of soils. The data indicated that, highest phosphorous content was recorded in the treatments T_4 (112.3 kg ha^{-1}) followed by T_9, T_5 and T_8 where as T_3 was found to have lowest phosphorous (91 kg ha^{-1}) at 45 day after sowing.

At harvest stage, the highest phosphorous was recorded in treatment T_4 (97.2 kg ha^{-1}) followed by T_8 (96.98 kg ha^{-1}) and T_5 (88.2 kg ha^{-1}) and the lowest phosphorus was found in the treatment T_1 (79.6 kg ha^{-1}). The available phosphorous in soil gradually decreased from 45 day after sowing to harvest.

4.4.5 Available potassium in soil (kg ha^{-1})

The data relevant to available potassium in soil (kg ha^{-1}) as influenced by the treatments is given in the table 9. The effect of treatment application was significant in the case of available potassium content of the soil at both stages.

The highest available potassium in the soil at 45 DAS was recorded in the treatment T_8 (352 kg ha^{-1}) which was statistically on par with treatment T_1 (327 kg ha^{-1}) and T_4 (322 kg ha^{-1}) and the minimum available potassium was recorded at T_3 (190 kg ha^{-1}).

At harvest stage, the highest available potassium in soil was also recorded in the treatment T_1 (256 kg ha^{-1}) which was statistically on par with treatment T_8 (217 kg ha^{-1}) while lowest potassium was found in the treatment T_5 (134.5 kg ha^{-1}). The available potassium in soil decreased gradually from 45 days after sowing to harvest.

Table:-9, Effect of fertigation, nutrient stick and foliar spray of silicon on available N, P and K in soil.

Treatment	Available nitrogen (kg ha^{-1})		Available phosphorous (kg ha^{-1})		Available potassium (kg ha^{-1})	
	45 DAS	Harvest	45 DAS	Harvest	45 DAS	Harvest
T_1	252	212	94	79.6	327	256
T_2	246	228	95	86.6	235	174
T_3	245	234	91	81.3	190	181
T_4	313	288	112	97.2	322	156
T_5	304	267	109	88.2	298	134
T_6	248	216	97	87.7	251	179
T_7	244	269	98	83.14	215	158
T_8	318	281	108	96.9	352	217
T_9	312	279	111	83.4	269	178
C.D.	53.730	12.411	NS	6.23	39.290	49.977
SE(m)	17.769	4.105	6.600	2.061	12.994	16.528

4.4.6 Available calcium in soil (mg kg^{-1})

The data on effect of treatment application on the available calcium in soil are given in the table 10. The effect of treatment application was significant in the case of available calcium content of the soil at both stages. The maximum calcium at 45 DAS was found in treatment T_6 (164 mg kg^{-1}) followed by T_5, T_9 and T_8 and the minimum in treatment T_2.

At harvest stage, available calcium content varied between 161.2 to 140.8 mg kg^{-1} with the maximum in the treatment T_6 and followed by T_5 and T_7 and minimum in the treatment T_4.

4.4.7 Available magnesium in soil (mg kg^{-1})

The data on available magnesium in soil under different treatments at 45DAS and harvest are given in the table 10. At both stage significant difference was noticed among the treatments. At 45 DAS the highest magnesium in the soil was recorded in the treatment T_3 (48.46 mg kg^{-1}) and lowest magnesium in soil was found in T_8. T_3 was on par with the treatment T_5 (44.62 mg kg^{-1}).

At the time of harvest, the highest magnesium was found in the treatment T_2 (45.3 mg kg^{-1}) and followed by T_3, T_5 and T_4 and the minimum magnesium content in the soil was recorded in the treatment T_9 (37.1 mg kg^{-1})

4.4.8 Available sulphur in the soil (mg kg^{-1})

The effect of treatment application on available sulphur in soil at 45 DAS and at harvest is given in the table 10. The available sulphur in soil were statistically non significant at both stages. The highest suphur was recorded in the treatment at T_3 (7.37 mg kg^{-1}) and followed by T_1 and T_7 and minimum was recorded in treatment T_6 at 45 day after sowing.

At harvest stage, the highest available sulphur in soil was recorded in the treatment T_9 (6.93 mg kg^{-1}) and followed by T_7 and T_1 while lowest sulphur was found in the treatment T_2 (5.64 mg kg^{-1}). The available sulphur in soil decreased gradually from 45 day after sowing to harvest.

Table:-10 Effect of fertigation, nutrient stick and foliar spray of silicon on available Ca, Mg and S in soil.

Treatment	Available calcium mg kg^{-1}		Available magnesium mg kg^{-1}		Available sulphur mg kg^{-1}	
	45 DAS	Harvest	45 DAS	Harvest	45 DAS	Harvest
T_1	151.6	147.5	41.45	40.26	7.29	6.45
T_2	149.1	143.0	43.51	45.30	7.21	5.64
T_3	151.6	149.1	48.46	43.30	7.37	5.74
T_4	158.3	140.8	42.37	43.00	7.12	6.43
T_5	163.6	157.0	44.62	44.10	7.17	5.99
T_6	164.0	161.2	43.20	38.80	6.10	5.79
T_7	157.0	156.0	43.53	38.00	7.24	6.56
T_8	161.2	158.7	38.91	39.00	6.90	5.68
T_9	162.0	146.6	43.16	37.10	6.51	6.93
C.D.	6.44	7.53	4.17	3.19	NS	NS
SE(m)	2.131	2.490	1.382	1.057	0.461	0.642

4.4.9 Available zinc in soil (mg kg^{-1})

The effect of treatment application on available zinc content of soil at 45 DAS and at harvest is presented in table11. The available zinc in soil were statistically non significant at both stages. The highest zinc was recorded in the treatment T_7 (4.94 mg kg^{-1}), followed by T_9 and T_4 and minimum was recorded in treatment T_1 at 45 DAS.

At harvest stage, available zinc content in soil was maximum was in the treatment T_7 (3.43 mg kg^{-1}) and followed by T_4 and T_9. Minimum available zinc (2.25 mg kg^{-1}) content in soil was found in the treatment T_1.

4.4.10 Available iron in soil (mg kg^{-1})

The data related to available iron in soil under the different treatments at two different stages of the crop are given in the table 11. Fertilizer levels significantly influenced the available iron at both stages. At 45 days, the available iron varied from 72.29 mg kg^{-1} to 85.80 mg kg^{-1} with the maximum value in the treatment T_7 (85.80 mg kg^{-1}) followed by T_3 (84.87 mg kg^{-1}), T_4 (82.41 mg kg^{-1}) and T_5 (81.20 mg kg^{-1}). The minimum value of available iron recorded in the treatment T_1 (72.29 mg kg^{-1})

At harvest stage, the highest available Fe in soil was recorded in the treatment T_4 (77.45 mg kg^{-1}) while lowest Fe was found in the treatment T_2 (69.20 mg kg^{-1}). The available iron in soil decreased gradually from 45 days after sowing to harvest.

4.4.11 Available manganese in soil (mg kg^{-1})

The effect of treatments on available manganese in soil is presented in the table 11. The effect of treatment application was found to be significant in case of available manganese content of soils at 45 DAS and harvest stage. The data indicated that, highest manganese content was recorded in the treatments T_7 (18.33 mg kg^{-1}), followed by T_5 (15.70 mg kg^{-1}) and T_3 (14.66 mg kg^{-1}) where as T_6 (11.35 mg kg^{-1}) was found to have lowest manganese in soil.

At harvest stage, the highest available manganese in soil was recorded in the treatment T_7 (14.96 mg kg^{-1}) which was statistically on par with treatment T_5 (13.6 mg kg^{-1}) while lowest manganese was found in the treatment T_6 (11.41 mg kg^{-1}).

Table:-11 Effect of fertigation, nutrient stick and foliar spray of silicon on available Zn, Fe and Mn in soil.

Treatment	Available zinc mg kg^{-1}		Available iron mg kg^{-1}		Available manganese mg kg^{-1}	
	45 DAS	Harvest	45 DAS	Harvest	45 DAS	Harvest
T_1	3.58	2.25	72.29	71.62	12.70	11.87
T_2	3.80	2.63	75.45	69.20	13.54	12.89
T_3	4.26	2.91	84.87	70.95	14.66	12.51
T_4	4.39	3.19	82.41	77.45	14.26	12.50
T_5	4.19	2.86	81.20	70.87	15.70	13.62
T_6	4.42	2.71	72.70	71.91	11.35	11.41
T_7	4.94	3.43	85.87	75.91	18.33	14.96
T_8	4.41	3.01	76.12	73.70	14.20	12.33
T_9	4.87	3.08	73.87	72.58	13.79	13.33
C.D.	NS	NS	5.771	4.33	1.719	1.45
SE(m)	0.394	0.264	1.909	1.434	0.569	0.481

4.4.12 Available copper in soil (mg kg^{-1})

The data on available copper in soil under different treatments at 45DAS and harvest are given in the table 12. At 45 DAS, significant difference was noticed among the treatments. The highest copper in the soil was recorded in the treatment T_3 (2.11 mg kg^{-1}) which was statistically on par with treatments T_7, T_9, T_5 and T_8. T_6 was found to have lowest copper content of 1.29 mg kg^{-1}.

At harvest stage, available copper content in soil maximum was in the treatment T_9 (1.97 mg kg^{-1}), followed by T_7 and T_3 and minimum available copper content in soil was found in the treatment T_6 (1.22 mg kg^{-1})

4.4.13 Available boron in soil (mg kg^{-1})

The data on available B content of soil is presented in Table 12. The highest B content at 45 day after sowing was recorded in T_3 (0.284 mg kg^{-1}), followed by the treatments T_7 and T_8. T_6 was found to have lowest B content of 0.21 mg kg^{-1}.

At harvest stage, available boron content in soil maximum was in the treatment T_3 (0.252 mg kg^{-1}) and followed by T_7 and T_8 and minimum available boron content in soil was found in the treatment T_1 (0.203 mg kg^{-1})

4.4.14 Available silicon in soil (mg kg^{-1})

The data on available silicon content of soil is presented in table 12. The effect of treatment application was found to be significant in the case of available silicon content of soil at 45DAS. The highest silicon was recorded in the treatment T_6 (33.48 mg kg^{-1}) followed by T_1 (29.10 mg kg^{-1}) and minimum was recorded in treatment T_4 (26.73 mg kg^{-1}) at 45DAS.

At harvest stage, available silicon content in soil maximum was in the treatment T_1 (29.03 mg kg^{-1}), followed by T_6 (29.00 mg kg^{-1}) and minimum available silicon content in soil was recorded in the treatment T_7 (25.70 mg kg^{-1}).

Table:-12 Effect of fertigation, nutrient stick and foliar spray of silicon on available Cu, B and Si in soil.

Treatment	Available Cu (mg kg^{-1})		Available B (mg kg^{-1})		Available Si (mg kg^{-1})	
	45 DAS	Harvest	45 DAS	Harvest	45 DAS	Harvest
T_1	1.79	1.58	0.223	0.203	29.10	29.03
T_2	1.54	1.38	0.235	0.215	27.92	27.00
T_3	2.11	1.87	0.284	0.252	27.20	27.07
T_4	1.74	1.43	0.236	0.210	26.73	26.00
T_5	1.88	1.55	0.220	0.219	27.11	26.10
T_6	1.29	1.22	0.219	0.209	33.48	29.00
T_7	2.06	1.79	0.270	0.251	26.51	25.70
T_8	1.87	1.70	0.252	0.220	28.57	27.10
T_9	1.96	1.94	0.231	0.211	28.62	28.17
C.D.	0.318	0.249	NS	NS	2.91	NS
SE(m)	0.105	0.082	0.024	0.016	0.963	2.104

4.5 NUTRIENTS CONTENT IN PLANT

Various chemical analyses of oriental pickling melon leaf samples were conducted in order to examine the effect of treatments on leaf nutrient content. Leaf samples were collected at the time of harvest, dried in hot air oven, powdered and were analyzed using standard analytical procedures as described in materials and methods.

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4.5.1 Nitrogen

The concentration of nitrogen in the leaf at the time of harvest is given in the table 13. There was significant difference among the treatments. The treatments T_8 recorded the highest leaf nitrogen content of 3 per cent, which was on par with treatments T_3, T_7 and T_2. T_1 (2.68 per cent) recoded the lowest nitrogen content in the plants.

4.5.2 Phosphorous

The effect of treatments application on phosphorous content of oriental pickling melon leaf is given in the table 13. There was a significant difference between the treatments. T_8 shows significantly higher amount of phosphorous in plants (0.21per cent) which was on par with treatments T_7, T_3, T_2 and T_6. The lowest concentration of phosphorous was recorded by T_9 (0.175 per cent).

4.5.3 Potassium

The effect of treatments on concentration of leaf potassium content of plants is given in the table 13. The treatments exhibit reflective potassium content in plants. Treatments T_7 (1.49 per cent) gave significantly higher amount of potassium in leaf, which was found to be on par with treatments T_6, T_3, T_4 and T_8. T_9 (1.22 per cent) recorded the lowest potassium in plants.

4.5.4 Calcium

Calcium content in the leaf of plant at the time of harvest is given in the table 14. There was a noticed significant difference in calcium content among the treatment applications. T_5 (3.89 per cent) recorded highest calcium content in the plants. The lowest calcium was found in the treatments T_4 (3.12 per cent).

Table:-13 Effect of fertigation, nutrient stick and foliar spray of silicon on N, P and K content in plant 75

Treatment	Nitrogen (%)	Phosphorous (%)	Potassium (%)
T_1	2.68	0.198	1.34
T_2	2.94	0.196	1.30
T_3	2.95	0.201	1.45
T_4	2.71	0.193	1.42
T_5	2.74	0.183	1.32
T_6	2.73	0.197	1.45
T_7	2.89	0.207	1.49
T_8	3.00	0.210	1.40
T_9	2.79	0.175	1.22
C.D.	0.168	0.018	0.104
SE(m)	0.056	0.006	0.034

4.5.5 Magnesium

The effect of treatment application on magnesium content of oriental pickling melon in leaf at harvest is presented in Table 14.

There was no appreciable difference found among the treatments with respect to magnesium content in plant sample. The highest magnesium (0.196 per cent) content was recorded in treatment T_7 and followed by treatment T_3 (0.194 per cent). The lowest magnesium (0.178 per cent) in plant was found in the treatment T_9.

4.5.6 Sulphur

The effect of treatment application on sulphur content in oriental pickling melon leaf is given in the table 14. There was a significant difference among the treatments with respect to sulphur content. The highest sulphur was recorded in the treatment T_7 (0.37 per cent) which was on par with the treatments T_3 (0.366 per cent), followed by T_8 (0.358 per cent). The lowest sulphur (0.244 per cent) in leaf was found in T_1.

Table:-14 Effect of fertigation, nutrient stick and foliar spray of silicon on Ca, Mg and S content in plant

Treatment	Ca (%)	Mg (%)	S (%)
T_1	3.20	0.181	0.244
T_2	3.34	0.186	0.280
T_3	3.38	0.194	0.366
T_4	3.12	0.182	0.333
T_5	3.89	0.188	0.315
T_6	3.47	0.179	0.313
T_7	3.68	0.196	0.370
T_8	3.48	0.179	0.358
T_9	3.55	0.178	0.312
C.D.	0.172	NS	0.021
SE(m)	0.057	0.005	0.007

4.5.7 Iron

The iron content in the oriental pickling melon leaf at the time of harvest is given in the table 15. There was a significant difference with respect to iron content in the leaf. The highest iron content was recorded in the treatment T_3 (776 ppm). This was statistically on par with the treatments $T_{7,}$ where as lowest iron content was recorded in T_1 (500ppm).

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4.5.8 Zinc

The effect of treatment application on the zinc content in leaf is given in the table 15. There was significant difference among the treatment in the zinc content of leaf. The highest concentration of zinc was recorded in the treatments T_4 with 67 ppm and the lowest was recorded in T_9 (53 ppm)

4.5.9 Manganese

The effect of treatment application on the manganese content in leaf is given in the table 15. Manganese content of the leaf was significantly influenced by the treatments. The highest manganese was recorded in the treatment T_3 (151.56 ppm) which was statistically on par with treatments T_7 (150.00 ppm) where as T_1 recorded the lowest manganese in leaf (106.46 ppm).

4.5.10 Copper

The copper content of oriental pickling melon leaf at the time of harvest is given in the table 16. There was significant difference among the treatments with respect to Cu content of leaves at harvest stage. T_8 recorded highest Cu content of 27.30 ppm and lowest was found in T_4 with 19.6 ppm. T_8 was statistically on par with T_5.

4.5.11 Boron

The effect of treatments on boron content in oriental pickling melon leaf at harvest is presented in table 16. There was no significant difference among the treatments with respect to boron content in leaf at harvest stage. The highest boron content was recorded in the plant treatment T_7.

Table:-15 Effect of fertigation, nutrient stick and foliar spray of silicon on Fe, Zn and Mn content in plant

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Treatment	Fe (ppm)	Zn (ppm)	Mn (ppm)
T_1	500.0	65.0	106.46
T_2	610.0	60.0	143.33
T_3	776.6	64.0	151.56
T_4	676.0	67.3	120.00
T_5	620.0	61.0	140.13
T_6	590.0	63.0	110.00
T_7	760.0	64.0	150.00
T_8	630.0	64.0	120.00
T_9	623.0	53.0	136.60
C.D.	154.49	5.40	16.188
SE(m)	51.09	1.786	5.354

4.5.12 Silicon

The effect of treatments on silicon content of oriental pickling melon leaf at harvest is presented in table 16. There was a significant difference among the treatments. The highest silicon content in leaf sample was observed in treatments T_6 with 0.203 %, which was statistically on par with treatments T_9, T_7 and T_8. The lowest silicon was observed in T_5 (0.117 %).

Table:-16 Effect of fertigation, nutrient stick and foliar spray of silicon on Cu, B and Si content in plant

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Treatment	Cu (ppm)	B (ppm)	Si (%)
T_1	20.6	23.46	0.131
T_2	20.0	22.26	0.151
T_3	21.0	23.13	0.145
T_4	19.6	23.20	0.129
T_5	24.4	23.70	0.117
T_6	20.1	23.33	0.203
T_7	23.5	25.20	0.176
T_8	27.3	24.00	0.170
T_9	21.2	23.53	0.182
C.D.	3.12	NS	0.038
SE(m)	1.032	0.747	0.012

Discussion

5. DISCUSSION

The results obtained on the investigation on "Evaluation of fertigation *vis a vis* nutrient stick and foliar silicon in oriental pickling melon (*Cucumis melo* var. *conomon*)" are briefly discussed below.

5.1 FORMULATION OF NUTRIENT STICK

The nutrient stick was formulated in such a way to provide almost all essential elements to the crop. The study on dissolution pattern of nutrient stick (5cm length and 1.5cm diameter) in soil and water showed its proper and complete dissolution facilitating a constant supply of nutrients into the soil, which will be taken up by the plant roots at different stages of its life cycle. The nutrients stick composition of Factomphos, Potassium sulphate, Gypsum, Magnesium sulphate, Zinc sulphate, Borax, Copper sulphate, and Manganese sulphate in appropriate proportion. It was completely dissolved in water within two days and in soil within three weeks. It contains all the essential nutrients to provide balanced nutrient supply to the soil unlike granular or liquid fertilizers which causes over fertilisation. The proper and timely uptake of nutrients can improve the plant health and can result in better yield responses in crop as in the study. It can also promote the activity of soil flora and fauna. The improvement in soil nutrient content and its biological activity can assure a healthy crop production.

5.2 PLANT GROWTH AND YIELD ATRIBUTES

5.2.1 Effect of treatments on flower emergence and fruit setting

The treatment application had no significant effect on male and female flower emergence and days to first fruit. The days to first male flower emergence was 21 to 23 days. The influence of treatments on female flower production was also non significant. The days varied from 27 to 29. Days to first fruit set were also found non significant. The days varied from 31 to 33. Similar finding was reported by Ningaraju (2013) and Ashly (2015) in oriental pickling melon with fertigation of nutrients under high density planting. They had reported that fertilizer application had no significant influence on days taken to first flowering.

5.2.2 Effect of treatments on yield attributes

The effect of treatment application exhibits significant influence on average fruit length, fruit weight, number of fruits per plant, mean yield and days taken for fruit harvest. It shows that fertilizer application could make substantial effect on yield attributes of crop oriental pickling melon.

Number of fruits per plant and total fruit yield were increased significantly with treatment application. The highest number of fruit per plant and total fruit yield per plot were recorded with drip irrigation + nutrient stick (100 per cent) + potassium silicate spray @ 0.25 per cent (T_7). This treatment has registered its favourable and positive results with respect to yield parameters of the oriental pickling melon. This might be attributed to the reason that nutrient supplied in this treatment are sufficient and balanced. The lowest number of fruits per plant and total fruit yield per plot was recorded in the treatments T_1. It indicated that the crop requires fertilizer in sufficient quantity for higher yield and increased availability of nutrients. Proper balanced fertilizer application enable higher uptake of nutrients by the plants and had resulted in increased yield. Increase in fruit yield per plot could be related to significantly higher number of fruits per plant in nutrient stick applied plot and increase of fruit weight in fertigation over the conventional method. Abduljabbar and Ghurbat (2010) reported that mineral nutrients influence sex expression in soils that are deficient in K, where the inclusion of K in the compound fertilizer increased the female flowers and subsequently enhanced fruit yield in squash. Similar result was reported by Shaymaa *et al.* (2009) in tomato under fertigation and Ningaraju (2013) in oriental pickling melon. Ningaraju reported a linear increase in yield and yield attribute due to increase in levels of fertilizer application.

Among the treatment levels, average weight of fruit and fruit length increased in the treatment requiring 75 per cent of NPK as per KAU POP through fertigation + 25 per cent nutrient stick + potassium silicate spray @ 0.25 per cent, the values obtained were 981g and 20.1cm respectively. Similar result were obtained by Aramini *et al.* (1995) who reported that when percentage of fertigated N and K increased above 70 per cent, fruit weight increased in sandy loam soil.

Days to fruit harvest differed significantly as influenced by treatments. Days to fruit harvest were early in treatment T_4, which was 75 per cent of NPK as per KAU POP through fertigation + 25 per cent nutrient stick. Early maturity was recorded in fertigated plot. Days to first fruit harvest in nutrient stick and fertigated field was 59 to 62 days respectively and in conventional method of irrigation plus fertilizer application (KAU POP recommendation) was 64 days. The result indicates that application of balanced fertilizer application reduces the days taken for maturity of fruits from flowering.

The positive relations between fertilizer application and irrigation on enhancing fruit yield in a melon have been reported by Harnandez and Aso (1991).

5.3 QUALITY ATTRIBUTES

Foliar spray of silicon recorded the maximum shelf life of more than six months. The minimum shelf life was recorded in treatment T_4 (75 per cent of NPK as per KAU POP through fertigation + 25 per cent nutrient stick) with 33 days. All other treatments recorded more than three months of shelf life. Similar result was reported by Lalithya *et al.* (2014) in sapota, where foliar spray of potassium silicate extended shelf life of sapota up to nine days. Silicon application might help in improving fruit quality due to suppression of respiration and reduction ethylene evolution and thus minimized physiological loss in weight of fruit. This result is in conformity with Babak and Majid (2011).

5.4 INCIDENCE OF PEST AND DISEASE

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There was no severe attack of pest and disease observed in the plot. However the attack of pumpkin beetle and mole cricket was observed during early stage of crop. The attack was controlled by proper plant protection measures. No disease was recorded during cropping period.

5.5 EFFECT OF TREATMENTS ON SOIL NUTRIENT STATUS

The effect of treatment application on soil nutrient status were studied and found that N, P, K, Ca, Mg, Fe, Mn and Cu content in the soil varied significantly with respect to treatment application while pH, EC, S, Zn and B content of the soil was found to be non significant.

There was no appreciable change on soil pH and electrical conductivity with respect to treatment application. Generally average pH at 45 DAS was lower than that of harvest stage. This is due to the fact that, concentrated application of fertilizer by drip fertigation or other method suddenly increases small variation in soil acidity. The fertigated plot had influence on pH of the soil. The lowest pH was recorded at fertigated plot. Haynes and Swift (1987) reported that nitrification occurs in fertigation due to high rate of nitrogen addition and so the pH decreases in soil. The nutrient stick applied plot maintained a constant soil pH.

The electrical conductivity of the soil did not show significant differences with respect to fertilizer application. Electrical conductivity at both stages were almost constant. However the nutrient stick applied plot had high EC compared to other plot. This might be due to sustainable release of soluble nutrients to the soil. Lipman *et al.* (1926) reported that the EC of soil solution was controlled sum of concentration of cation and anions.

Available nitrogen in soil was significantly influenced by application of treatments. The highest available nitrogen (318 kg/ha) was given in plot with 75% of NPK as per KAU POP through fertigation + 25 per cent nutrient stick +

Potassium silicate spray @ 0.25 per cent (T_8) at 45 DAS and 75 per cent of NPK as per KAU POP through fertigation + 25 per cent nutrient stick (T_4) at harvest. Lowest nitrogen was recorded in the treatment of drip irrigation + nutrient stick + potassium silicate spray @ 0.25 per cent at 45 DAS and T_1 at harvest stage. There was an increase in the quantity of available nitrogen at 45 DAS due to split application of nitrogen. It was observed that from 45 DAS the available nitrogen in the soil decreased progressively in all the plots due to uptake of nitrogen by the plants and also losses through different ways. Similar result was showed by Mashuma (2014).

Treatments showed significant effect on available phosphorus in the soil. The amount of available phosphorus content in the soil increased to 112 kg ha^{-1} in treatment T_4 (75 per cent of NPK as per KAU POP through fertigation + 25per cent nutrient stick) at 45DAS. It may be due to the application of fertilizer through fertigation. While the available phosphorus content in the soil decreased to a minimum 79.6 kg ha^{-1} in treatment T_1 (KAU POP with conventional irrigation practices) at harvest stage, may be due to the absorption of phosphorous by the plants and phosphorus fixation in soil. The highest available phosphorous was recorded in 75 per cent of NPK as per KAU POP through fertigation + 25% nutrient stick. Anoop (2009) and Iqbal *et al.* (2013) reported similar results.

Available potassium content in the soil was also improved with treatment application. The highest potassium content at 45 DAS was recorded in the treatment T_8 (352 kg ha^{-1}), which were 75 per cent of NPK as per KAU POP through fertigation + 25 per cent nutrient stick + foliar spray of 0.25 per cent potassium silicate. The increased available K might be due to intrinsic properties of soil or due to the addition of fertilizers. Even though, the soil has more amount of available K, the macronutrients along with micronutrients applied as priming dose would enhance the availability of K to the crop (Sekhon and Singh, 2013). At harvest stage, highest available potassium (256 kg ha^{-1}) in soil was recorded in treatment application of KAU POP with conventional irrigation practices. Lowest soil available potassium was recorded in the treatment T_3 (190 kg ha^{-1}) at 45 DAS, which was drip irrigation + nutrient stick. It might be due to slow nutrient releasing character of nutrient stick. The potassium in soil linearly decreased from 45 DAS to harvest stage in all the treatments in direct proportion. This was in conformation to the findings of Vasane (1996) and Rajees (2013).

The available calcium and magnesium content in the soil was found to be significant with the treatment applications. The highest available calcium content in the soil at 45 DAS (164.0 mg kg^{-1}) and harvest stage (161.2 mg kg^{-1}) was recorded in the treatment T_6, which were soil test based fertilizer application + foliar spray of potassium silicate. The highest available magnesium content in the soil at 45 DAS was recorded at treatment T_3 (48.46 mg kg^{-1}), which was drip irrigation + nutrient stick. This may be due to availability of magnesium through fertilizer stick. At harvest stage highest magnesium in the soil was in treatment T_2 which was drip irrigation + soil test based nutrient application as per modified KAU POP. This may be due to the effect of combined use of organic manure and fertilizers on the availability of other nutrients. This was confirmed by the finding of Prasad and Prasad (1993). The application of FYM along with the fertilizers enhances the availability of the nutrients and improves the fwertilizer use efficiency.

Available sulphur content in the soil did not show significant effect on application of treatment. Soil test based fertilizer along with foliar spray of potassium silicate (T_6) showed lowest value (6.10 mg kg^{-1}) of available sulphur in soil at 45 DAS. The highest value (7.37 mg kg^{-1}) of available sulphur was recorded on treatment T_3, treated with nutrient stick + drip irrigation. This might be due to the ability of nutrient stick providing more sulphur than any other fertilizer. At harvest stage the highest available sulphur (6.93 mg kg^{-1}) was recorded on the treatment T_9, which was 50 per cent of NPK as per KAU POP through fertigation + 50 per cent nutrient stick + 0.25 per cent foliar spray of potassium silicate.

There was significant effect on iron content in the soil caused by the application of treatments. Application of drip irrigation + nutrient stick along with 0.25 per cent potassium silicate (T_7) spray showed highest iron (85.87 mg kg^{-1}) content in the soil at 45 DAS. At harvest stage the highest available iron (77.45 mg kg^{-1}) content was in treatment T_4 (75 per cent of NPK as per KAU POP through fertigation + 25 per cent nutrient stick). It might be due to the balanced secondary and micronutrient application through nutrient stick which increased the availability of nutrients in the soil over a period and thereby improved crop growth and yield. Malakouti (2007) reported that application of macro and micronutrients at deficient condition increases the availability of nutrient status of soil.

Zinc content in the soil was not exhibited significant difference among treatment application. Application of the treatment T_7 (nutrient stick along with 0.25 per cent potassium silicate spray) recorded maximum zinc content (4.94 mg kg^{-1}) in the soil at 45 DAS whereas minimum zinc content (3.58 mg kg^{-1}) was observed on treatment T_1 at 45 DAS. At harvest stage treatment T_7, drip irrigation + nutrient stick + potassium silicate spray @ 0.25 per cent recorded more Zn content (3.43 mg kg^{-1}) in the soil. Availability of zinc in the soil is due to the humus - zinc chelating process. Rutkowska *et al.* (2015) reported that total concentration and activity of the zinc in the soil solution increased with increasing zinc content in the soil and rising soil acidity, whereas they decrease with increasing organic carbon content and clay particle.

The available manganese concentration in soil significantly varied with the treatment application. The highest manganese content in the soil was recorded in the treatment (T_7) drip irrigation + nutrient stick along with 0.25 per cent potassium silicate spray, 18.33 and 14.96 mg kg^{-1} at 45DAS and harvest stage respectively. Lowest was on treatment T_6 at 45 DAS (11.35 mg kg^{-1}) and at harvest stage (11.41 mg kg^{-1}). Neilsen (1992) reported that various organic compounds capable of complexing Mn and changing solubility equilibrium. This process increases the solubility and availability of manganese. Barber (1995) reported that, in aerated soil Mn^{2+} in soil solution should theoretically decrease 100 fold for every unit of pH increase.

Treatment showed significant effect on available copper content in the soil. The highest amount of copper (2.11 mg kg^{-1}) was recorded in the treatment T_3 with drip irrigation + nutrient stick application 45 DAS and T_9 at harvest stage (19.7 mg kg^{-1}) whereas lowest concentration of copper (1.29 mg kg^{-1}) in soil was at treatment T_6 at 45 DAS and at harvest. Application of nutrient stick in the soil improved the copper status of the soil. Reuther (1957) reported that application of copper containing fertilizer produce strong residual effect, which may persist for many years. This is because copper is held tightly by the soil, it is not subjected to leaching out of the main root zone, and the removed amount is small when a crop is harvested compared to the amount usually applied.

Available boron content in the soil not showed significant effect with the treatment application. Application of Drip irrigation + nutrient stick showed highest boron content in both 45 DAS (0.284 mg kg^{-1}) and harvest stage (mg kg^{1}). Lowest boron content was recorded in treatment T_6 during 45 DAS and T_1 during at harvest stage. This might be due to the soil application of boron containing fertilizer, which may enhance the soil solution boron. Similar result was showed by Gudade *et al.* (2016).

Application of treatment T_6 (drip irrigation + soil test based nutrient application as per modified KAU POP + potassium silicate spray @ 0.25 per cent) showed significant increase in available silicon content (33.48 mg kg^{-1}) in the soil at 45 DAS and minimum was recorded in treatment T_4 (26.73 mg kg^{-1}). At harvest stage, available silicon content in soil maximum (29.3 mg kg^{-1}) was in treatment T_1 (KAU POP with conventional irrigation practices) whereas minimum (26.08 mg kg^{-1}) level of available silicon content was at treatment T_4.

5.6 EFFECT OF TREATMENTS ON NUTRIENT CONTENT IN PLANT

Leaves nutrient status of primary, secondary and micronutrients increased with the treatment application. It indicates application of balanced fertilizers show tendency to absorb and accumulate more nutrients in plants. However the rate of increase in concentration of nutrients in the plants due to increasing levels of fertilizer application is competitively a smaller amount. This result was in conformity with the result of Veesar (2004) and Tunacy *et al.* (1999).

The nitrogen content in the leaves showed a significant difference with treatments. Application of treatment T_8 (75 per cent of NPK as per KAU POP through fertigation + 25% nutrient stick + Potassium silicate spray @ 0.25 per cent) showed higher nitrogen content (3 per cent) in the plants than other treatments. The lowest nitrogen concentration (2.68 per cent) in plants was recorded by the treatment T_1 (KAU POP with conventional irrigation practices). This result was in conformity with the result of Joesph (1985). Where the highest per cent of N, P and K resulted higher concentration of nitrogen in plant. It may be due to that, the availability of nitorgen evenly with frequent fertigation are responsible for nitrogen uptake and recovery in the root zone coupled with reduced loss of nitrogen primarily because of less leaching under high fertigation rate. Similar result of increased uptake with fertigation has been reported earlier by Vasane *et al.* (1996). Bradley and Warren (1960) reported that, the best result of nitrogen under low moisture tension.

The treatment application showed significant effect in amount of phosphorous by the plant. The highest amount (0.21 per cent) of phosphorous content by the plant was observed in treatment T_8 (75 per cent of NPK as per KAU POP through fertigation + 25 per cent per cent nutrient stick along with 0.25 per cent spray of potassium silicate). This might be due to the availability of phosphorus from the applied phosphatic fertilizer. In soil most of the applied phosphrous may turned to non soluble form within a short time after its application, and the observed concentration build up in the upper soil layer could affect root growth and create unfavourable condition for P uptake. This suggests higher response to P fertigation compared to soil application. Research has shown that the mobility of phosphorus can be increased when they are applied by fertigation (Vasane *et al.*, 1996; Badr and Shafei, 2002).

Potassium content of leaf was found to be significant with the treatment application. Application of treatment (T_7) drip irrigation + nutrient stick with 0.25 per cent potassium silicate spray recorded the highest potassium (1.49 per cent) in plants. This might be due to uptake of potassium by plants from foliar application of potassium silicate and readily available potassium ions from nutrient stick. Conventional potassium fertilizer application causes the leaching loss of potassium, the nutrient was lost from soil exchangeable potassium that was moved vertically by water flow. The use of slow releasing fertilizers reduces the leaching losses of potassium (Bley *et al*, 2016). The result of the study also revealed that the foliar application of potassium silicate increase the availability of potassium to plants. Similar observations were also reported by Lalithya *et al.* (2014) and Mongia *et al.* (2003).

Application of treatments showed significant amount of calcium in leaves. The treatment (T_5) application of 50 per cent nutrient stick along with 50 per cent NPK through fertigation recorded highest calcium content (3.89 per cent) in the leaf. This might be due to the balanced fertilizer application through fertigation and through nutrient stick.

Application of treatment resulted significant amount of magnesium and sulphur in leaf. Treatment application of drip irrigation + nutrient stick along with foliar spray 0.25 per cent potassium silicate (T_7) reported highest concentration of magnesium (0.196 per cent) and sulphur (0.370 per cent) in plants. This might be due to the availability of magnesium and sulphur from nutrient stick. Suresh-kumar *et al.* (2013) and Sangamithre (2014) reported that, availability of magnesium is very low in Kerala soil due to heavy rain fall and leaching. About 45-80 per cent of Kerala soil is deficient in available magnesium. In addition to being nutrients are essential for superior yield and quality. Foliar spray of silicon also improved the uptake of magnesium. Application of sulphate fertilizer can take care of sulphur requirement of the crop Mini and Mathew (2016).

Effect of treatment on concentration of iron in leaf was found to be significant. The treatment application of drip irrigation + nutrient stick reported highest concentration (776.6 ppm) of iron in plants. This might be due to availability of iron from nutrient stick. The acidic environment in the root zone causes the reduction of Fe^{3+} to Fe^{2+} form which is water soluble and available to plants. (Mohamadipoor *et al.,* 2013).

The treatment application significantly influenced zinc content in the leaves. Treatment (T_4) with 75 per cent NPK through fertigation + 25 per cent nutrient stick was recorded highest zinc content (67.3 ppm) and lowest zinc content in leaf (53 ppm) was at treatment T_9 (50 per cent nutrient stick + 50 per cent NPK through fertigation along with 0.25 per cent potassium silicate).

The manganese content in plant was significantly influenced the treatment application. Highest manganese content in the plant (151.56 ppm) was recorded in the treatment T_3 with 75 per cent NPK through fertigation along with 25 per cent nutrient stick. This might be due to the increase in manganese content in the soil by nutrient sick. Silicon treated plants showed less manganese concentration compared to other treatments, might be due to the decrease in manganese uptake with the application of silicon. Similar result was observed by Kamenidou *et al.* (2008).

The treatments are significant in the case of amount of copper in the leaves. Leaf concentration of copper was slightly increased in plants which were supplemented with the nutrient stick. The treatment (T_8) application of 25 per cent nutrient stick + 75 per cent NPK through fertigation along with 0.25 per cent potassium silicate recorded highest concentration of Cu (27.3ppm) in plants. Similar finding was reported by Lalityha *et al.* (2014) and Azeez *et al.* (2015).

The treatment application did not show significant effect on the content of boron in leaves. There was no definite pattern of variation in content of boron with respect to the treatments. The highest content of boron (25.2ppm) in leaf reported in the treatment (T_7) drip irrigation + nutrient stick along with the foliar spray 0.25 per cent potassium silicate. Similar result was also reported by Jose (2015).

Silicon concentration in leaf showed significant increase by the foliar spray of 0.25 per cent potassium silicate. Treatment with soil test based fertilizer application along with foliar spray of 0.25 per cent potassium silicate recorded highest Si in leaves. Si treatments increased tissue Si concentration relative to untreated plants. These results are in conformity with finding of Sing *et a*l. (2006) in rice, Milne *et al.* (2012) in lettuce Lalithya *et al.* (2014) and Abd-Alkarim *et al.* (2017) in cucumber. Si uptake and deposition in cucumber tissue may be responsible for the improved quality observed in some of the Si treatments of this study.

Summary

6. SUMMARY

The salient findings of the study entitled "Evaluation of fertigation *vis a vis* nutrient stick and foliar silicon in oriental pickling melon "(*Cucumis melo* var. *conomon*)" are summarized in this chapter.

The investigation was undertaken with the objectives to prepare nutrient stick, to evaluate the performance of nutrient stick and to compare its effect with fertigation and to evaluate the effect of foliar silicon on growth, yield and nutrient uptake in oriental pickling melon. The experiment was carried out in two parts, nutrient stick formulation and field experiment at College of Agriculture Padannakkad and Regional Agricultural Research Station, Pilicode during 2016 - 18.

Nutrient stick is a complete fertilizer composite that is formulated in stick form and contains almost all the essential nutrients at needed concentration. The technique has been standardized after trying a series of different combinations of fertilizer materials. Finally the stick was formulated and evaluated for solubility in water (two days) and soil (three weeks). Then the nutrient stick was evaluated with oriental pickling melon as a test crop.

The field experiment was conducted at Regional Agricultural Research Station, Pilicode, Kasaragod, Kerala, during the period March to May 2017. The experiment was carried out in randomized block design with nine treatments and three replications. The treatment combinations were, KAU POP with conventional irrigation practices (T_1), drip irrigation + soil test based nutrient application as per modified KAU POP (T_2), drip irrigation + nutrient stick (T_3), 75 per cent of NPK as per KAU POP through fertigation + 25 per cent nutrient stick (T_4), 50 per cent of NPK as per KAU POP through fertigation + 50 per cent nutrient stick (T_5), T_2 + potassium silicate spray @ 0.25 per cent (T_6), T_3 + potassium silicate spray @ 0.25 per cent (T_7), T_4 + potassium silicate spray @ 0.25 per cent (T_8), T_5 + potassium silicate spray @ 0.25 per cent (T_9). The study was carried out with the short duration and less spreading oriental pickling melon variety Soubhagya.

The application of treatments showed significant improvement in biometric characters, yield and yield attributes. Application of drip irrigation + nutrient stick + potassium silicate spray @ 0.25 per cent showed more number of fruits per plants and highest total yield per plot. Application of 75 per cent of NPK as per KAU POP through fertigation + 25 per cent nutrient stick + potassium silicate spray @ 0.25 per cent showed highest fruit weight and fruit length. The shortest duration for days to harvest of the crop was recorded 59.6 days for T_4 (75 per cent of NPK as per KAU POP through fertigation + 25 per cent nutrient stick). Days to male flower emergence, female flower emergence and days to first fruit set did not show significance under treatment application. In general days taken for male flower emergence were 21-23 days, days taken for female flower emergence were 27- 29 days and days to first fruit set formation were 31 -33 days for all the treatment combinations.

Foliar spray with silicon recorded the maximum shelf life of more than six months. The minimum shelf life of 33 days was recorded on treatment T_4 (75 per cent of NPK as per KAU POP through fertigation + 25 per cent nutrient stick). No severe attack of pest and diseases was recorded in the experimental plot, though the attack of pumpkin beetle, mole cricket was observed during early stage of crop.

The effects of treatment application on soil nutrient status were studied at 45 DAS and at harvest stage, found that N, P, K, Ca, Mg, Fe, Mn Cu and Si status were significant with treatment application whereas pH, EC, S, Zn and B content of soil were found to be non significant.

The effects of treatment application on soil pH and EC were non significant at 45 day after sowing and at harvest stage. Available nitrogen phosphorus and potassium in soil were significantly influenced by the application of treatments. The treatment T_4 showed highest available nitrogen and phosphorus at harvest stage. Whereas T_1 showed highest available potassium in the soil at harvest stage.

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The treatment T_6 showed the highest available Ca content in the soil at 45 DAS and harvest stage. The highest available magnesium content in the soil at 45 DAS and harvest stage was recorded in the treatment T_3 and T_2 respectively. S content of the soil was not significantly influenced by treatment application.

Application of treatment with drip irrigation + nutrient stick along with 0.25 per cent potassium silicate (T_7) spray significantly increased iron content in the soil at 45 DAS. At harvest stage the highest available iron content was at treatment T_4 (75 per cent of NPK as per KAU POP through fertigation + 25 per cent nutrient stick). Zinc and B content in the soil was not exhibited significant difference among treatment application.

The highest manganese content in the soil was recorded on treatment T_7 both 45 DAS and at harvest stage. Application of treatment with drip irrigation + nutrient stick showed highest copper content in the soil at 45DAS and T_9 at harvest stage. Application of the treatment T_6 showed significant increase in silicon content of soil at 45 DAS.

As leaf nutrient concentrations of oriental pickling melon is considered, significant influence of treatment application in N, P, K, Ca, S, Zn, Fe, Mn, Cu and Si content was recorded at harvest stage. Application of treatmentT_8 showed higher nitrogen and phosphorus content in the leaf. Application of treatment T_7 recorded significantly higher amount of potassium content in leaf.

Application of treatment T_5 recorded significantly higher calcium content in leaf. Treatment application of T_7 reported highest concentration of magnesium and sulphur and the application of drip irrigation + nutrient stick reported significantly highest concentration of iron and manganese. T_4 and T_8 recorded highest zinc and copper content respectively in leaf.

Treatment with soil test based fertilizer application along with foliar spray of 0.25 per cent potassium silicate recorded highest silicon content in leaves and treatment application did not show significant effect on boron content in leaf.

The results obtained from this experiment clearly indicate that application of fertilizers through nutrient stick along with foliar silicon was found to be highly effective. In fertigation treatments residual available soil nutrients were higher as compared to fertilizer through nutrient stick, indicating better efficiency of nutrient sticks. Therefore application of nutrient along with foliar spray of potassium silicate can be recommended to the farmers for a cost effective and eco friendly crop production in oriental pickling melon. The effect can be further evaluated under poly house condition and other crops.

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EVALUATION OF FERTIGATION *VIS A VIS* NUTRIENT STICK AND FOLIAR SILICON IN ORIENTAL PICKLING MELON (*Cucumis melo var. conomon*)

by

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ABSTRACT

The investigation on "Evaluation of fertigation *vis a vis* nutrient stick and foliar silicon in oriental pickling melon (*Cucumis melo* var. *conomon*)" was undertaken with the objectives to prepare and formulate nutrient stick, to evaluate and compare its effect with fertigation and foliar silicon on growth, yield and nutrient uptake in oriental pickling melon. The investigation was carried out in two parts, formulation of nutrient stick and field experiment at College of Agriculture Padannakkad and Regional Agricultural Research Station, Pilicode during 2016 -18.

Nutrient stick is a complete fertilizer composite that is formulated in solid form. It contains ten essential nutrients. The formulation technique was standardized after trying a series of combination by mixing the finely powdered fertilizer materials. The stick was evaluated in laboratory for dissolution pattern and found completely dissolving in water within two days and in soil solution within three weeks.

The field experiment was carried out in randomized block design with nine treatments and three replications. The treatment combinations were, KAU POP with conventional irrigation practices (T_1), drip irrigation + soil test based nutrient application as per modified KAU POP (T_2), drip irrigation + nutrient stick (T_3), 75 per cent of NPK as per KAU POP through fertigation + 25 per cent nutrient stick (T_4), 50 per cent of NPK as per KAU POP through fertigation + 50 per cent nutrient stick (T_5), T_2 + potassium silicate spray @ 0.25 per cent (T_6), T_3 + potassium silicate spray @ 0.25 per cent (T_7), T_4 + potassium silicate spray @ 0.25 per cent (T_8), T_5 + potassium silicate spray @ 0.25 per cent (T_9)

The application of different treatments showed significant improvement in biometric characters, yield and yield attributes of the oriental pickling melon crop. The shortest duration for days to harvest of the crop was recorded (59.6 days) for the treatment combination of 75 per cent of NPK as per KAU POP through fertigation + 25 per cent nutrient applied as stick.

More number of fruits per plants and highest total fruit yield per plot were observed in the treatment with drip irrigation + nutrient stick + potassium silicate given as 0.25 per cent foliar spray.

Application of 75 per cent of NPK as per KAU POP through fertigation + 25 per cent nutrient stick along with potassium silicate spray at a rate of 0.25 per cent solution showed highest fruit weight and fruit length. The treatments which included application of silicon as foliar spray recorded maximum shelf life of fruits, extending to six months after harvest. The spray of silicon as potassium silicate was given covering the complete foliage of the crop.

The effect of treatments on soil nutrient status were studied at 45 DAS and at harvest stage, showed that N, P, K, Ca, Mg, Fe, Mn, Cu and Si status of the soil varied significantly with treatment application, while pH, EC, S, Zn and B content of soil showed no significant variation among the treatments. Highest available nutrients in the soil at 45 DAS and at harvest were recorded with application of 75 per cent of NPK as per KAU POP through fertigation along with 25 per cent nutrient stick.

The leaf nutrient concentrations of oriental pickling melon at harvest were also analysed and it was noticed that, there was significant influence with respect to treatments receiving all the ten nutrients as compared to package of practices recommendations alone.

The results obtained from this experiment clearly indicate that application of fertilizers through nutrient stick along with foliar silicon was found to be highly effective. In fertigation treatments residual available soil nutrients were higher as compared to fertilizer through nutrient stick, indicating better efficiency of nutrient sticks.

APPENDIX I

Daily average weather parameters of RARS, Pilicode

Date	Temperature		Relative humidity		Rainfall (mm)
	Max	Min	I	II	
20-03-2017	33	22	87	63	0
21-03-2017	31.5	24	90	60	0
22-03-2017	35	24	88	67	0
23-03-2017	33.5	23	88	70	0
24-03-2017	33	23.5	85	63	0
25-03-2017	34	23.5	83	55	0
26-03-2017	34	23.5	92	70	0
27-03-2017	32.5	23.5	88	66	0
28-03-2017	32.5	24	88	75	0
29-03-2017	33	22.8	85	67	0
30-03-2017	33	24	84	73	0
31-03-2017	33	23.5	89	67	0
01-04-2017	33.2	25	88	66	0
02-04-2017	33.5	27.5	85	67	0
03-04-2017	34	24.5	88	65	0
04-04-2017	32.8	26	85	66	0
05-04-2017	32.5	26	92	70	0
06-04-2017	33	25	82	70	0
07-04-2017	33	21	96	64	15.2
08-04-2017	32.5	25.5	88	65	0
09-04-2017	33	25	84	61	0
10-04-2017	34	25	94	66	0
11-04-2017	32.5	24.5	91	60	0
12-04-2017	33	22	88	70	13
13-04-2017	32.5	25	89	67	0
14-04-2017	33	24	84	67	0
15-04-2017	33	24	92	65	0

16-04-2017	33	25.5	92	67	0
17-04-2017	33	25.5	92	64	0
18-04-2017	32.5	24.5	84	64	0
19-04-2017	33.5	26	88	64	0
20-04-2017	33.5	26	85	67	0
21-04-2017	33.2	25	84	82	0
22-04-2017	31.5	23.5	88	66	0
23-04-2017	32.5	25	77	64	0
24-04-2017	33.5	23.5	77	64	0
25-04-2017	34.5	24.5	77	63	0
26-04-2017	33.5	25	81	70	0
27-04-2017	34.5	24.5	82	64	0
28-04-2017	34.5	27	85	67	0
29-04-2017	33	25.3	81	64	0
30-04-2017	34	22.5	76	64	0
01-05-2017	34	22.5	88	66	0
02-05-2017	33	22.5	78	61	0
03-05-2017	33.2	23	76	64	0
04-05-2017	33.7	23.5	78	64	0
05-05-2017	34	24	78	64	0
06-05-2017	33.5	25	71	64	0
07-05-2017	34	25.5	76	61	0
08-05-2017	34	22.5	96	60	4.9
09-05-2017	31.8	25	88	66	0
10-05-2017	33	24.2	87	65	0
11-05-2017	33	22	96	60	2.6
12-05-2017	32.5	23.8	81	56	0
13-05-2017	34.5	26	88	68	0
14-05-2017	32	23	84	34	22.8
15-05-2017	33	23	84	67	0
16-05-2017	33.5	24	77	61	0
17-05-2017	33.5	25.5	81	61	0
18-05-2017	33.5	24.5	81	60	0

19-05-2017	33.3	20.3	88	60	23.6
20-05-2017	32.5	24	81	70	0
21-05-2017	32	21	74	78	32
22-05-2017	31	21	92	70	0.8
23-05-2017	32	23	89	70	0
24-05-2017	32.5	24.5	95	70	0
25-05-2017	30.8	24.6	88	67	2.5
26-05-2017	33.5	25	96	61	0
27-05-2017	33	24.5	94	69	1
28-05-2017	32.5	25	88	64	0
29-05-2017	32.5	24.3	93	67	0
30-05-2017	33.2	23.5	90	70	5
31-05-2017	31.2	22	88	77	28.8
01-06-2017	29.9	22.2	84	80	8.5

APPENDIX – II

Effect of fertigation, nutrient stick and foliar spray of silicon on B: C Ratio

Treatments	Cost of cultivation (Rs)	Gross returns (Rs)	B : C Ratio
T_1	224500	338830	1.50
T_2	247700	382892	1.54
T_3	274692	504615	1.83
T_4	300364	486030	1.61
T_5	291610	457864	1.57
T_6	257100	400738	1.55
T_7	287192	553600	1.92
T_8	309864	527384	1.70
T_9	301110	477784	1.58

APPENDIX III

Effect of treatments on shelf life of fruit up to six month

Treatment	Shelf life of fruit
T_1	2 months
T_2	3 months and 15 days
T_3	6 months
T_4	33 days
T_5	2 months and 18 days
T_6	6 months
T_7	6 months
T_8	6 months
T_9	6 months