PERFORMANCE EVALUATION OF TOMATO IN SOILLESS CULTURE

by

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(2013-11-126)

Thesis Submitted in partial fulfillment of therequirement
for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

2015

Department of Agronomy

COLLEGE OF AGRICULTURE

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DECLARATION

I,hereby declare that this thesis entitled **"PERFORMANCE EVALUATION OF TOMATO IN SOILLESS CULTURE"** 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 of any degree, diploma, associate ship, fellowship or other similar title, of any other University or Society.

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Acknowledgement

I feel immense pleasure to express my profound and heartfelt thankfulness to Dr. Usha C. Thomas, AssistantProfessor (Agronomy), AICRP on forage crops and Chairperson of the advisory committee, for her guidance, suggestions, constant encouragement, support, unfailing patience and above all the kind of understanding throughout the course of this research work and preparation of the thesis.

I wish to express my sincere gratitude to Dr. Meerabai, M. Professor and Head, Department of Agronomy and member of advisory committee, for the help rendered for the smooth conduct of research work, co-operation and critical evaluation of thesis.

I am grateful to Dr. V. L. Geethakumari, Professor, Department of Agronomy and member of advisory committee for her valuable suggestions, timely support and critical evaluation during the course of this work.

I am thankful to Dr. Sreelathakumari, I., Departmentof Olericulture, for her valuable suggestios, encouragement and co-operation rendered throughout the study, as amember of advisory committee.

I wish to express my heartfelt thanks to Dr. Babu Mathew, Professor and Head, Instructional Farm, College of Agriculture, Vellayani for providing me the necessary facilities during the whole course of study.

I take this opportunity to express my obligation to every teaching and non-teaching staff members of Agronomy Department for their sincere co-operartion and assistance rendered during the course of investigation.

I greatly acknowledge the help rendered by Dr. C. Narayanan Kutty, Professor (Hort) ARS, Mannuthy for providing the seeds of tomato variety to carry out the research work in proper time.

I also express my sincere thanks to all my classmates, friends, my seniors and juniors for their help, good company, positive criticism, unconditional love, care and moral support throughout my P.G. programme.

I am most indebted to Amma, Achan, Kuttyoppa, Sariyoppa and Chipputten for their affection, constant encouragement, moral support and blessings that have enabled me to finish this work, without which I would not have completed this research.

The assistance and co-opeartion extended to me by the labourers of College of Agriculture, Vellayani are very much appreciated. I thank them sincerely.

Above all, I believe it is the unbound love and blessings of God, which is the prime factor that led to the successful completion of my entire work. I humbly bow my head before that almighty for the numberless blessings that he showered upon my life.

Soumya A.

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LIST OF ABBREVIATIONS AND SYMBOLS USED

et al.	And other co workers
cm	Centimeter
CD	Critical difference
°C	Degree Celsius
FYM	Farm Yard Manure
Fig.	Figure
g	Gram
g $plant^{-1}$	Gram per plant
ha	Hectare
KAU	Kerala Agricultural University
Kg	Kilo gram
L	Litre
mg	Milli gram
ml	Millilitre
viz.	Namely
pH	Negative logaritham of hydro carbon ions
N	Nitrogen
NS	Non-significant
No.	Number
POP	Package of practice
%	Per cent
P	Phosphorus
PGPR	Plant Growth Promoting Rhizobacteria
Rs	Rupees

SE	Standard error
i.e.	that is
WUE	Water Use Efficiency

APPENDICES

Introduction

1. INTRODUCTION

Urban areas hold great appeal for populations seeking a better life, livelihood and education opportunities. However, urban malnutrition is becoming priority issues in low- and middle-income countries as well as in high-income countries. Main reason for malnutrition is due to over dependence on processed food rather than raw and fresh ones. Hence it is highly essential to take immediate steps for meeting the requirement of fresh and safe vegetable in urban sector for ensuring nutritional and health security. Vegetables are integral part of a balanced diet and are considered as protective foods. The requirement of vegetables is 300 g $person^{-1}day^{-1}$. But actual consumption in India is very low i.e.174g $person^{-1}$ day^{-1} (Gajanan and Hedge, 2009).

Unlike rural residents, city dwellers have limited opportunities to grow their own food and are thus more likely to purchase their food mainly due to inadequate land and availability of good quality soil. The scarcity of land available for cultivation can be compensated by terrace farming. The problem of inadequate availability of good quality soil for cultivation can be solved to a great extent by promoting soilless culture. Reports are available from different parts of the world indicating the feasibility of soilless culture.

Soilless culture in bags, pots, or troughs with a lightweight medium is the simplest, most economical, and easiest to manage of all soilless systems. Successful production of container-grown plants is largely dependent on the chemical and physical properties of the growing media. An ideal potting medium should be free from weeds and diseases, heavy enough to avoid frequent tipping over and yet light enough to facilitate handling and shipping. The media should also be well drained and yet retain sufficient water to reduce the frequency of watering. Other parameters to consider include cost, availability and stability in the media over time.

It is assessed that around 7.5 million tonnes of coirpith is being produced annually in India (Kamaraj, 1994). The use of coirpith waste in agriculture as a rooting medium, mulch and soil conditioner to improve soil drainage has proved beneficial (Hume, 1949). Coir pith can be successfully utilized as a soilless medium for vegetable crops such as tomato, bhindi and brinjal (Jeyaseeli and Raj, 2010). Coir pith has very high moisture retention capacity of 500- 600 per cent and can be as high as 1100% of dry weight (Evans *et al.,* 1996). High CEC enables it to retain large amounts of nutrients and the adsorption complex has high contents of exchangeable K, Na, Ca and Mg (Verhagen and Papadopoulos, 1997).

Presence of large concentration of complex polymeric organic compounds such as lignin (Deivanai and Kasturibai, 1995) of low bio degradability, non-availability of essential nutrients, such as nitrogen and phosphorous, as these are mostly organically bound and high C:N ratio may reduce yield in coir pith media (Kunchikannan *et al*., 2007). An alternative to this is coir pith compost. Cuckoorani (2013) reported that coir pith compost along with FYM in 2:1 proportion is an ideal medium for the cultivation of bhindi in soilless culture.

Coir pith, which is available in areas were coir processing is done, along with different proportions of FYM can be used as the medium of soilless culture. Composting of coir pith increases the nutrient status and decreases the C:N ratio making it suitable for growing crops. Farm yard manure, a traditional manure, supplies both major and minor nutrients, improves physical condition of soil and supplies substances that stimulate plant growth. Neopeat is an eco-friendly organic soil conditioner with high water holding capacity and highly suitable for commercial floriculture and horticulture. PGPR Mix 1 is a consortium of nitrogen fixer, phosphorus and potassium solubilizing bacteria that reduce the use of chemical fertilizers and enhance the productivity of the crops.

Tomatoes have been reported to be an important source of antioxidants such as lycopene, phenolics, and vitamin C in human diet and have been linked with reduced risk of prostate and various other forms of cancer, as well as heart diseases. Tomatoes, aside from being tasty, are very healthy as they are a good source of vitamins A and C. Lycopene is a very powerful antioxidant which can help to prevent the development of many forms of cancer.

With this background this study was undertaken with the objectives of standardizing the growth media, scheduling of nutrients and to work out economics of different treatments.

Review of literature

2. REVIEW OF LITERATURE

2.1 Soilless culture

Soilless culture is the modern cultivation system of plants that use either inert organic orinorganic substrate through nutrient solution nourishment. It is an artificial means of providing plants with support and reservoir for nutrients and water (Ghehsareh *et al.,* 2011).

According to Schwarz (1994) soilless culture can be water culture, gravel culture, aeroponics, tube culture and nutriculture. It can be done on open or closed systems (Baas *et al*., 1995; Papadopoulos *et al*., 1999).

In recent years, the use of soilless culture has increased significantly throughout the world (Grillas *et al*., 2001).

Primarily, gravel or sand was used in soilless culture system to provide plant support and retain mineral nutrient and water. Afterward, several substrates have been evolved due to their unique properties for holding moisture, aeration, leaching or capillary action, and reuse potentiality. Soilless growing media are easier to handle and it may provide better growing environment (in terms of one or more aspects of plant growth) compared to soil culture (Bilderback *et al*., 2005; Mastouri *et al*., 2005).

Organic substrates includes sawdust, cocopeat, peat moss, woodchips, fleece, marc, bark etc. whereas, inorganic substrate of natural origin are perlite, vermiculite, zeolite, gravel, rockwool, sand, glass wool, pumice, sepiolite, expanded clay, volcanic tuff and synthetically produced substrates are hydrogel, foam mates (polyurethane), oasis (plastic foam) etc. (Mahamud and Manisah, 2007; Dorais *et al*., 2007; Ehret and Helmer, 2009 and Olle *et al*., 2012).

2.2 Coir pith compost

Coconut (*Cocos nucifera* L.) pith or coir, the mesocarp of the fruit, is a waste product of the coconut industry and proposed as an alternative to peat in growth media due to its suitable physical and chemical properties (Bragg *et al*., 1993 and Savithri and Khan, 1994).

Coir pith, an underutilized by-product of the coconut and its use in agriculture as a rooting medium, mulch and soil conditioner to improve soil drainage has proved beneficial (Hume, 1949).

Studies on the physical properties of the material have established that it has a porosity of about 70% and the water holding capacity is above 500% (Anida Das, 1992).

Cresswell (1992) reported the use of coir as horticulture medium for several agronomic and ornamental crops. Similar reports were given by several others also. (Evans and Stamps, 1996; Meerow, 1994 and Pill and Ridley, 1998).

Coir pith has several qualities that recommend it as a peat substitute (Cresswell, 1992). Evans *et al.* (1996) stated that coir pith has very high moisture retention capacity of 500- 600 per cent. It has high potassium content and low bulk density and particle density. High CEC enables it to retain large amounts of nutrients and the adsorption complex has high contents of exchangeable K, Na, Ca and Mg (Verhagen and Papadopoulos, 1997).

A recent study revealed that being a poor conductor of heat, the coir helps to keep soil temperature low and being considered as an ideal medium for plant growth (Reghuvaran and Ravindranath, 2013).

Coirpith compost (CPC) has been successfully used in the cultivation of groundnut (Nagarajan *et al*., 1986), rice (Selvi and Augustine Selvaseelan, 1992), coconut (Joshy *et al*., 1985) and horticultural plants (Theradi Mani and Marimuthu, 1994; Ravi Chandra *et al*., 1996).

Jeyaseeli and Raj (2010) noticed that coir pith can be successfully exploited as a soilless medium for vegetable crops such as tomato, bhindi and brinjal. At present, composted coir pith with organic supplements is being widely used for many horticulture and floriculture crops.

Several workers have reported the use of cocopeat in germination of seeds, nursery raising, rooting of cutting and other vegetative plant propagation methods, hardening of tissue and embryo cultured plants, hydroponic systems of plant cultivation, cultivation of glass house plants, soil conditioning, lawn making *etc*. (Bavappa and Gurusinghe, 1978, Anitha Karon *et al.,* 1999, Rao, 1999).

Nagarajan *et al.* (1986) noted that composting of coir pith results in increased content of N, P, K , micronutrients and reduction in lignin and C:N ratio. Decomposed coir pith has very high moisture retention capacity and its wettability is much better than peat (Evans and Stamps, 1996).

Coir pith has been shown to be a suitable alternative to sphagnum peat in soilless container media (Pill and Ridely, 1998).

Biodegraded coir pith was shown as an effective medium for the cultivation of medicinal plants such as *Andrographis paniculata*, *Bacopa monneiri* and *Piper longum*. They reported an increase in the growth of garden plants with composted coir pith as growth media and this was attributed to increased availability of NPK (Reghuvaran and Ravindranath, 2010).

Reghuvaran and Ravindranath (2013) reported the suitability of biodegraded coir pith as an efficient cultivating medium for garden plants. Studies elsewhere reported similar observations with the medium (Lokesha *et al*., 1988; Baskaran and Saravanan (1997); Reghuvaran *et al*., 2012).

Cuckoorani (2013) observed maximum growth characters like height, number of leaves, LAI and shortest crop duration for bhindi grown in coir pith compost + FYM (2:1 by weight). Similar results were obtained by Saravanan *et al*. (2012) where Casuarina seedlings grown in decomposed coir pith along with bioinoculants enhanced the growth and biomass.

2.2.1 Effect of coirpith compost on growth characters

Humic substances in cocopeat must have a role in making it suitable for use in plant propagation and culture of plants, as humic substances are known to have hormone-like activity and can stimulate plant growth (Lee and Bartlett, 1976) and enhance rooting (Schenitzer and Poapst, 1967).

Increase in plant height and root fresh mass in cocopeat grown plants is a common observation (Evans and Stamps, 1996; Evans and Iles, 1997; Sreerama *et al.,* 1999).

Composted coir pith has been recommended for use as an amendment and serve as an alternative for FYM and other organic manures (Savithri and Khan,1994). According to Awang *et al.* (1997) leaf number, plant height and flower number were more in anthurium grown with coir pith medium. Zinnia,Celosia and marigold also performed better in the same media.

Evans and Iles (1997) observed that *Viburnum dentatum* and perston lilac grew better with high fresh root and shoot biomass in coco peat when compared to peat-based media. *Pelargonium hortorum, Tagetes patula* and *Petunia hybrid* also performed better in coir pith medium (Evans and Stamps, 1996).

Meerow (1995) reported that *Pemas lanceolata* and *Ixora coccinia* exhibited higher growth index, top and root weight when grown in coir pith medium as compared to sedge peat based medium. He himself reported that growth index and root and shoot growth were more in *Ravenea* and *Anthurium* grown in coir pith containing media.

The suitability of cocopith as growth media has been reported by several workers. It can be used for growing *Begonia semperflorms* (Saravanan and Nambisan, 1995) and *Gerbera jamesonii* (Pillai *et al.,* l999a), Chrysanthemum (Sreerama *et al.,*1999) and a number of other ornamental palms (Pillai *et al.,* 1999b).

Use of coir pith as a potting medium for the orchid *Vanda rothschildiam* resulted in higher production of flowers (Rajamani *et al.,* 1999). In addition to the use of coir pith as a potting medium, it has been found to be effective in hydroponic cultivation of economically important plants such as tomato (Caraveo-Lopez *et al.,*1996).

Lokesha *et al.* (1988) observed higher rooting percentage when cocopeat was used as a medium for rooting of cuttings of *Acalypha* and *Bougainvillea.* This pronounced effect might be due to the presence of phenolics

Effectiveness of cocopeat as a rooting medium for the vegetative propagation of *Eucalyptus* using single node cuttings has been recorded by Warrier *et al.*(1998).

2.2.2 Effect of coir pith compost on yield and yield attributes

Anabayan (1988) explained the use of coir pith compost in increasing the yield (10%- 30%) of a number of crops namely, sorghum, pearl millet, maize and cotton under rainfed condition. Similar observations were obtained by Veerabadran (1991).

Time required for flowering in plants such as *Tagetes* grown in coco peat usually gets reduced (Evans and Stamps, 1996).

Composted coir pith has advantages in improving crop productivity of plants, in the management of certain root diseases, and also in increasing the capability of the soils to store moisture and nutrients (Vinodhini *et al*., 2005).

Plants grown in cocopeat substrate produced higher fruit number and total yield (Luitel *et al.,* 2012).

Higher yield and yield attributes of bhindi in coir pith compost + FYM (2:1) have also been reported by Cuckoorani (2013).

2.2.3 Effect of coir pith compost on quality attributes

Tuber quality of white yam in terms of starch and crude protein contents were markedly improved by coir pith compost application (Suja, 2001)).

Elevated levels of carbohydrate and chlorophyll were seen with the biodegraded coir pith in *Jasmine sambac and Rosa rubiginosa.* (Reghuvaran and Ravindranath, 2013).

2.2.4 Effect of coir pith compost on soil properties

Hangarge *et al*. (2002) found that application of coir pith compost improved the physical condition of the soil by reducing bulk density, increasing porosity, water holding capacity and infiltration rate.

2.3 Farm yard manure

Farm yard manure supplies both major and minor nutrients, improves physical condition of soil and supplies substances that stimulate plant growth.

2.3.1 Effect of farm yard manure on growth characters

Addition of organic matter through farmyard manure increased soyabean crop growth with higher root biomass production (Acharya *et al*., 1988 and Benbi *et al*., 1998).

Zhang *et al*. (1998) reported an increase in water-use efficiency of soyabean with the combined application of fertilizer and manure that might be ascribed to more rapid crop biomass growth during periods when vapour pressure deficit was low, which decreased the evaporation: transpiration (E_s/T) ratio and in turn improved transpiration efficiency of the crop.

Ribeiro *et al.* (2000) found that 20 t ha^{-1} cattle manure increased yield over the mineral fertilizer in case of sweet pepper.

The growth parameters of chilli *viz.*, plant height, number of branches, leaf area, leaf area index and dry matter production in various plant parts were significantly higher with combined application of organic compost and FYM (Sunitha, 2000).

Application of organics *viz*., FYM @ 10 t ha $^{-1}$ resulted in higher fruit yield and uptake of nutrients like N, P, K, Ca, S and Fe over RDF alone (Kattimani, 2004).

Different organic nitrogen sources significantly influenced the growth and yield of tomato. Substitution of 100 per cent N as FYM recorded plant height, number of branches per plant and yield comparable to that of 100 per cent nitrogen as urea (Kannan *et al*. 2006).

2.3.2 Effect of farm yard manure on yield and yield attributes

Yadav (2001) observed that 20 kg nitrogen through FYM significantly increased stover yield over the control in cowpea.

2.3.3 Effect of farm yard manure on quality attributes

Application of 20 kg nitrogen through FYM significantly increased nitrogen content in cowpea seeds (Yadav, 2001).

Maheswari and Haripriya (2007) noted that application of FYM 25 t ha^{-1} along with neem cake at 2 t ha $^{-1}$ recorded the maximum ascorbic acid (179.30 and 180.34 mg/100 g) and capsaicin (0.83 and 0.85 per cent) content in chilli.

2.3.4 Effect of farm yard manure on soil properties

Krishnaswamy *et al.* (1984) noticed that the application of FYM increases the availability of phosphorus from the native and applied sources.

Incorporation of organic matter either in the form of crop residues or farmyard manures has been shown to decrease bulk density (Khaleel *et al*., 1981), increase infiltration rates (Acharya *et al.*, 1988) and improve soil structure and water retention capacity (Bhagat and Verma, 1991).

Continuous application of manure in tropical areas has shown an improved soil organic carbon and microbial biomass carbon with balanced fertilization (Goyal et al, 1993).

Schjonning *et al*. (1994) also reported reduction in the bulk density of the soil due to application of cattle manure in a long-term integrated nutrient management experiment.

FYM treated plots showed an increase in available phosphorus than inorganic fertilizers which was due to the coating of sesqui oxides by organic materials that reduced phosphorus fixing capacity of soil (Bharadwaj and Omanwar, 1994).

Addition of organic matter through farmyard manure increased the organic carbon concentration (Acharya *et al*., 1988 and Benbi *et al*., 1998).

A study on effect of FYM on soil pH revealed that soil pH decreased from 7.99 to 7.65 with each increment of FYM and the soil pH reduced significantly due to organic acid production during its decomposition (Patil *et al.*, 2003). EC was also found to be reduced significantly by application of FYM (Rathod *et al.,*2003).

Application of organic manures such as FYM, vermicompost, crop residues enhanced the soil available nitrogen, phosphorus and potassium as compared to recommended dose of fertilizers (Patil *et al.,* 2003).

Mastol (2006) reported that FYM application significantly increase soil organic carbon, microbial biomass and microbial coefficient.

2.4 Oil cakes

Islam and Haque (1992) considered oil cake as good manure to be applied during land preparation of brinjal, chilli and bhindi for better yield.

2.4.1 Effect of oil cakes on growth characters

Chinnaswamy (1967) observed better growth in tomato plants with the application of groundnut cake and FYM in organic mixture.

The seedlings of tomato, chilli and egg plant grew larger when grown in soil amended with oilcakes (Mashkoor *et al*., 1980).

Higher percentage of NPK in oilcakes increased the growth of plants (Aridoss *et al.,*2004).

2.4.2 Effect of oil cakes on yield and yield attributes

Application of oil cake during land preparation of brinjal, chilli and bhindi for better yield has been suggested by Islam and Haque (1992).

While studying the influence of different organic manures on growth and yield in brinjal, Som *et al*. (1992) found that maximum fruit length, fruit diameter, maximum fruit weight, highest per plant yield and highest fruit yield by the application of oil cake.

Sharu (2000) reported that in chilli the growth characters like plant height, number of primary branches and dry matter accumulation as a result of oil cake application was found to be on par with that of the POP recommendation by Kerala Agricultural University.

In amaranthus, application of oil cake produced higher yield as compared to chemical fertilizers, but was inferior to that of FYM (Arunkumar, 2000).

2.4.3 Effect of oil cakes on quality attributes

Sahrawat and Mukherjee (1997) reported that application of mahua cake improved grain protein content in rice.

2.4.4 Effect of oil cakes on soil properties

Biswas *et al*. (1969) found that application of groundnut cake in a rice fallow rotation for 10 years improved the water retention capacity of alluvial sandy loam soil.

2.5 PGPR

Bio-fertilizers containing beneficial microorganisms are known to improve plant growth in many ways when compared to synthetic fertilizers by enhancing plant nutrient availability and thus help to sustain the eco-friendly environment and soil productivity (O'Connell, 1992).

Plant growth promoting rhizobacteria (PGPR) are bacterial species mostly associated with the plant rhizosphere and found to be beneficial for plant growth, yield and crop quality.

The PGPR is a group of rhizosphere colonizing bacteria, which produce substances that increase the growth of plants and protect them against pathogens (Harish *et al*., 2009 and Glick, 1995).

Glick *et al*. (1999) reported that PGPR promote plant growth by several mechanisms which involve nitrogen fixation, sequestration of iron for plants by siderophores, production of plant hormones like auxins, cytokinins and gibberellins and lowering of plant ethylene levels.

Not all PGPR are biofertilizers. Many PGPR stimulate the growth of plants by helping to control pathogenic organism (Whipps, 2001; Zehnder *et al*., 2001).PGPR is having biofertilizing effects on forest tree species (Elo *et al*., 2000; Shishido *et al*., 1999).

Kim *et al*. (1998) found that P content was increased with inoculation with either the AM, *Glomus etunicatum*, or the phosphate solubilizing PGPR, *Enterobacteria glomerans*; however, the highest N and P uptake was observed when tomatoes were inoculated with both the organisms.

Plant growth promotion by some PGPR has been associated with the solubilization and increased uptake of phosphate (Gyaneshwar, *et al*.,2002). PGPR have also been reported to affect nitrate uptake by plants (Mantelin and Touraine, 2004; Adesemoye, *et al*.,2008).

Among the various PGPRs identified, *Pseudomonas fluorescens* is one of the most extensively studied rhizobacteria, because of its growth promoting activity and antagonistic action against plant pathogens (Kavino *et al*., 2007, Saravanakumar and Samiyappan, 2007 and Harish *et al*., 2008).

2.5.1 Effect of PGPR on growth characters

Numerous studies have shown the improvement in plant growth and development in response to seed or root inoculation with various microbial inoculants capable of producing plant growth regulators (Zahir *et al*., 2004).

Bacterial mediated increase in root weight are commonly reported response to PGPR inoculations (e.g., Bashan and Dubrovsky, 1996; Bertrand *et al*., 2001; Frommel *et al*., 1991; Vessey and Buss, 2002).

Increase in root length and root surface area are reported (Galleguillos *et al*., 2000; German *et al*., 2000; Holguin and Glick, 2001; Jacoud *et al*., 1999; Volkmar and Bremer, 1998) by the inoculation of PGPR.

Fallik *et al*. (1994) found that inoculation of maize with *Azospirillum brasilense* resulted in the proliferation of root hairs which could have dramatic effects on increasing root surface area.

Inoculation of various plant species with Azospirillum has shown to increase root respiration rates (Sarig *et al*., 1992; Vedder-Weiss *et al*., 1999).

Indole-3-acetic acid is a phytohormone which is known to be involved in root initiation, cell division, and cell enlargement is very commonly produced by PGPR (Barazani and Friedman, 1999).

Highly significant increase in tomato and pepper transplant growth occurred by inoculation of PGPR (Kokalis–Burelle *et al.,* 2002).

Many PGPR systems cause stimulation of root growth via production of phytohormones by the plant or the bacteria (Shaharooma *et al*., 2008; Lucy *et al*., 2004).

Biswas *et al.* (2000) noted that PGPR promoted the growth of the plant and increased the root surface area or the general root architecture. Similar observations were made by Lucy et al. (2004).

Along with the general increase in plant height, some PGPR promote root development (Adesemoye, *et al.*, 2008) and alter root architecture by the production of phytohormones such as indole acetic acid (IAA) (Kloepper, *et al.*, 2007).

Application of growth promoting rhizobacteria (PGPR) to the foliage and floral parts of apple increased growth of the plant (Lutfi *et al.*, 2007).

Enhanced seed germination and seedling vigour of maize have been reported by seed inoculation of PGPR @ 2% (Gholami *et al.*, 2009).

2.5.2 Effect of PGPR on yield and yield attributes

Facilitating plant nutrition could be the mechanism by which PGPR enhance crop yield and fruit size, since the nutritional plants status is enhanced by increasing the availability of nutrients in the rhizosphere (Bar-Ness *et al.*, 1992; Richardson, 2001).

PGPR stimulate growth and increase yield in apple, citrus, high bush blueberry, mulberry, sweet cherry, raspberry and apricot (Kloepper, 1994; De Silva *et al.*, 2000; Sudhakar *et al.*, 2000; Esitken *et al.*, 2002, 2003, 2006; Orhan *et al.*, 2006).

It also promoted plant growth and yield in barley, sugar beet, tomato, pepper and apricot (Cuppels *et al.*, 1999; Kotan *et al.*, 1999; Sahin *et al.*, 2000; Cakmakci *et al.*, 2001; Esitken *et al.*, 2003;).

In a study on tomato (Hernandez and Chailloux, 2004), the dry weight of tomato transplants grown in the greenhouse was significantly greater with two PGPR strains and 75% fertilizer than with the full amount of fertilizer and without PGPR and yields with combinations of PGPR and mycorrhizal fungi at 50%

recommended field fertilization were greater than the yield of the 100% fertilizer control without microbes.

Without inoculants, use of fertilizer rates lower than the recommended resulted in significantly less plant growth, yield, and nutrient uptake or inconsistent impacts (Adesemoye, *et al*., 2008).

PGPR strains that produce plant hormones can stimulate plant cell elongation or cell division, and/or change bacterial 1- aminocyclopropane-1-carboxylate (ACC) deaminase activity(Patten and Glick, 2002), which prevents the production of plant growth-inhibiting hormone, ethylene.

The use of PGPR in sugar beet and barley (Cakmakci *et al*., 2001), corn (Ataoglu *et al*., 2004) and tomatoes (Turan *et al*., 2004) stimulated yield and quality parameters tested.

Floral and foliar application of PGPR has increased yield, growth and plant nutrient element contents of leaves and decreased shot-hole disease in apricot (Esitken *et al*., 2002, 2003).

Inoculations with PGPR increased sugar beet root weight by 2.8–46.7% depending on the species. Leaf, root and sugar yield were increased by the bacterial inoculation by 15.5–20.8, 12.3–16.1, and 9.8–14.7% respectively (Cakmakci *et al.,* 2006).

2.5.3 Effect of PGPR on quality attributes

Potassium content in the fruit increased in PGPR treated tomato plants, compared to control treatment. The usage of PGPR can increase lycopene, antioxidant activity, shoot and fruit potassium contents of tomato plant (Ordookhani *et al*., 2010).

It is interesting that firmer fruits are obtained from PGPR-inoculated plants since the main cause that reduces fruit quality is excessive softening (Giovannoni, 2001).

Sugar yield was increased by the bacterial inoculation at 9.8–14.7% by the inoculations with PGPR (Cakmakci *et al.,*2006).

Application of rhizobacteria under water stress improved the antioxidant and photosynthetic pigments in basil plants (Heidari and Golpayegani, 2011).

2.5.4 Effect of PGPR on soil properties

Raj *et al.* (2011) reported that PGPR was effective in reducing the use of chemical fertilizers, improving the availability and uptake of nutrients and maintaining sustainability.

Mode of action of many PGPR is by increasing the availability of nutrients for the plant in the rhizosphere (Glick, 1995; Rodriguez and Fraga, 1999). The method by which these increases take place involve solubilization of unavailable forms of nutrients and/or siderophore production which facilitate the transport of certain nutrients (notably ferric iron).

The solubilization of P in the rhizosphere is the most common mode of action implicated in PGPR that increase nutrient availability to host plants (Richardson, 2001).

Materials and methods

3. MATERIALS AND METHODS

The pot culture experiment entitled “Performance evaluation of tomato in soilless culture” has been carried out at College of Agriculture, Vellayani during the year 2014-15. The study aims at standardizing media and nutrient schedule for tomato production in soilless culture and to work out the economics of different treatments. The investigation comprised of two separate experiments (1)Standardization of different growth media for soilless culture and (2) Nutrient scheduling for soilless culture.

3.1 MATERIALS

3.1.1 Experimental site

The experiment was conducted at the Instructional Farm attached to College of Agriculture, Vellayani, Kerala, located at 8^{o} 25’ 46”North latitude, 76^{o}59’24”East longitude and an altitude of 29m above mean sea level.

3.1.2 Growth media

The growth media used in the experiment were prepared with potting mixture and organic materials like neopeat, coirpith, coirpith compost along with FYM. These organic materials were combined in different proportions and details are furnished in the technical programme. Grow bags of 12 litre capacity were filled compactly with 7kg media for growing tomato.

3.1.3 Weather

Data on weekly averages of maximum and minimum temperature, relative humidity and rainfall received during the cropping period were collected from the Agro-meterological observatory attached to the Department of Agronomy, College of Agriculture, Vellayani and is presented in Fig 1.

3.1.4 Season

The experiments were conducted during August 2014 to December 2014.

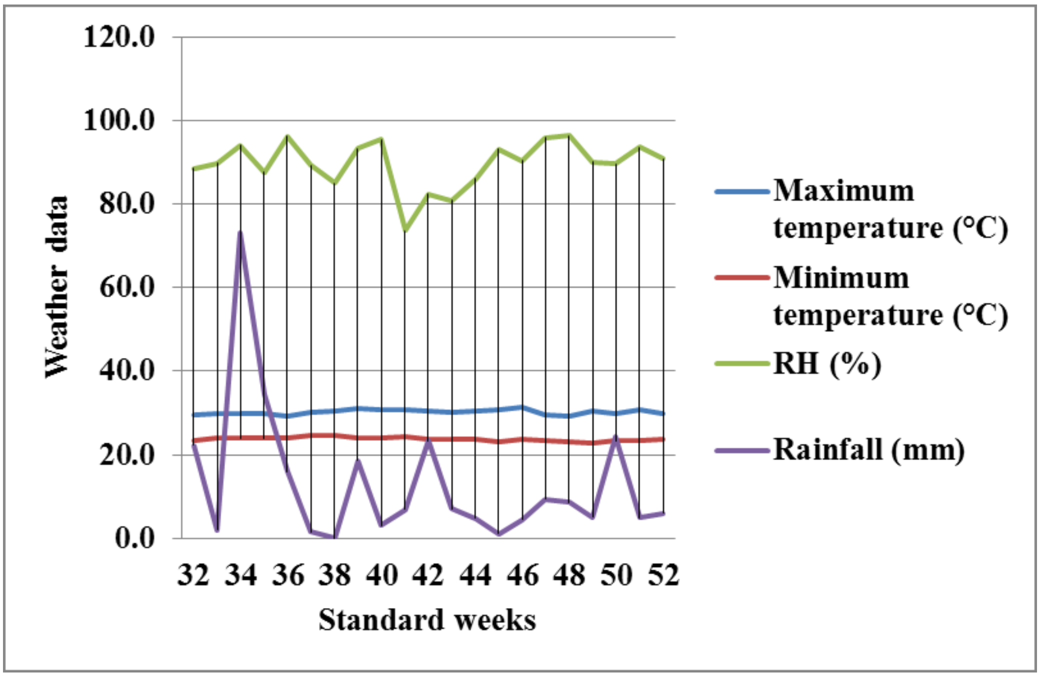

Fig 1. Weather parameters during the cropping period

3.1.5 Crop

The latest tomato variety Manulakshmi, released by Kerala Agricultural University, Thrissur resistant to bacterial wilt was used as the test crop.

3.1.6 Biofertilizer

PGPR mix I was the biofertilizer used in this study. The culture was obtained from Department of Microbiology, College of Agriculture, Vellayani. It is a compatible consortium of N, P and K biofertilizers.

3.1.7 Manures and fertilizers

FYM (0.5%N:0.2% P_2O_5:0.5% K_2O) and groundnut cake (6.3%N, 0.69% P_2O_5 and 1.4% K_2O) were used as the organic nutrient sources. Fertilizers used for the study were 19:19:19, Urea (46% N), Rock Phosphate (20% P_2O_5) and MOP (60% K_2O).

3.2 METHODS

3.2.1 Design and layout

Part 1: Standardization of different growth media for soilless culture

The layout of experiment is presented in Fig 2.

Design : CRD

Treatment combinations: 8

Replication : 3

Season : October 2014

Crop : Tomato

Variety : Manulakshmi

N

↑

M_1	**M_4**	**M_7**	**M_2**	**M_5**	**M_8**	**M_3**	**M_6**
M_2	**M_5**	**M_8**	**M_3**	**M_6**	**M_1**	**M_4**	**M_7**
M_3	**M_6**	**M_1**	**M_4**	**M_7**	**M_2**	**M_5**	**M_8**

Fig.2. Layout plan of the experiment

3.2.2 Treatments

Growth media (M)

M_1 : Coir pith + FYM 1:1

M_2 : Coir pith + FYM 1:2

M_3 : Coir pith compost + FYM 1:1

M_4 : Coir pith compost + FYM 2:1

M_5 : Coir pith compost alone

M_6 : Neopeat + FYM 1:1

M_7 : Neopeat + FYM 1:2

M_8 : Potting mixture (1:1:1 soil, sand and FYM)

The best media was selected for Part II study with respect to growth and yield of the crop.

Part II: **Nutrient scheduling of tomato for soilless culture**

Design : CRD

Treatment combinations : 3 x 4

Replication : 4

Season : October 2014

Crop : Tomato

Variety : Manulakshmi

Nutrient levels (N) - 3

N_1 : Package of Practices recommendations (POP)(75:40:25 kg NPK ha^{-1})

N_2 : 75 % of POP (56:30:19 kg NPK ha^{-1})

N_3 : 125 % of POP (94:50:31kg NPK ha^{-1})

Nutrient sources (S) - 4

S_1 - Fermented groundnut cake

S_2 - Incubated (groundnut cake + PGPR mix 1)

S_3 - As chemical fertilizers in solid form, direct media application

S_4 - As chemical fertilizers in liquid form, direct media application

Nutrients from the potting media was accounted for nutrient scheduling.

n_1s_1	n_2s_3	n_3s_1	n_1s_2	n_1s_4	n_3s_2
n_3s_2	n_2s_1	n_2s_3	n_3s_4	n_2s_2	n_1s_3
n_2s_1	n_1s_4	n_1s_1	n_2s_1	n_2s_3	n_1s_1
n_1s_2	n_2s_2	n_1s_3	n_2s_4	n_3s_1	n_3s_3
n_3s_1	n_3s_3	n_1s_4	n_1s_1	n_3s_3	n_2s_2
n_1s_3	n_3s_1	n_1s_2	n_3s_2	n_2s_1	n_2s_4
n_2s_2	n_2s_4	n_3s_2	n_1s_3	n_3s_4	n_1s_2
n_1s_4	n_2s_3	n_3s_4	n_2s_4	n_3s_3	n_3s_4

Fig.3. Layout plan of the experiment

3.3 Crop husbandry

3.3.1 Nursery

Seedlings were raised in pro trays filled with coirpith compost and vermi compost in 1:1 ratio.

3.3.2 Land preparation

The experimental area was cleared of weeds and stubbles. The grow bags were arranged at a spacing of 60 x 60 cm.

3.3.3 Transplanting

The seedlings were ready for transplanting one month after sowing. Plants were given uniform irrigation. Necessary shade was also provided for first four days after transplanting.

3.3.4 Application of manures and fertilizers

FYM (0.5%N, 0.2% P_2O_5 and 0.5% K_2O) and groundnut cake (6.3%N, 0.69% P_2O_5 and 1.4% K_2O) were used as the organic sources. 19:19:19, urea (46% N), rock phosphate (20% P_2O_5) and muriate of potash (60% K_2O) were used as inorganic sources for the experiments.

Fermented groundnut cake was prepared by adding 1 kg of groundnut into 10 litres of water and applied after fermenting it for 7 days. Incubated groundnut + PGPR mix I was prepared by mixing groundnut cake and PGPR mix I (2%), incubated overnight and applied to the growth media on the next day.

3.3.5 Other management practices

Crop was irrigated and weeding was carried out.

3.3.6 Plant protection

Drenching with copper oxychloride @ 0.3 per cent was done twice in all grow bags as a prophylactic measure against wilt disease.

Plate 1. General view of the experimental plot (Experiment 1)

Plate 2. General view of the experimental plot (Experiment 2)

3.3.7 Harvest

The crop was ready for first harvest one month after transplanting and subsequent harvests were made at regular intervals.

3.4 OBSERVATIONS

Observations were taken from five plants from each replication and average was calculated.

3.4.1 Growth characters

3.4.1.1 Height of the plant (cm)

Height of the plant was measured from the base of the plant to the terminal leaf bud at 30 days interval and expressed in centimeter.

3.4.1.2 Number of primary branches

The number of primary branches per plant was recorded and average was worked out.

3.4.1.3 Crop duration

The number of days from sowing to final harvest was calculated.

3.4.2 Yield and yield attributes

3.4.2.1 Days to first flowering

Number of days from the date of transplanting to the first flowering of observational plants was recorded and the average was worked out.

3.4.2.2 Days to fruit set

Four inflorescences were selected randomly and tagged from each observational plant and number of days taken from flowering to emergence of young fruits from the calyx was counted and the average was worked out.

3.4.2.3 Inflorescence/plant

Number of inflorescences of observational plants was recorded and the average was worked out.

3.4.2.4 Fruit set (%)

Number of flower clusters of the same inflorescence tagged for recording days to fruit set was counted. Number of fruits per inflorescence was counted after two weeks of flowering.

$$\text{Fruit set (\%)} = \frac{\text{Number of fruits/inflorescence}}{\text{Number of flowers/inflorescence}} \times 100$$

3.4.2.5 Fruits/plant

Total number of fruits produced per plant till the last harvest were counted.

3.4.2.6 Fruit length (cm)

Ten fruits were selected at random from the observational plants. Length of the fruits was measured as the distance from pedicel attachment of the fruit to the apex using twine and scale. Average was taken and expressed in centimeters.

3.4.2.7 Fruit girth (cm)

Diameter of fruit was taken from same fruits used for recording the fruit length. Fruits were cut transversely and diameter was measured at maximum point. The average was worked out and expressed in centimeters.

3.4.2.8 Fruit weight (g)

Weight of fruits used for recording fruit length was measured and average was found out and expressed in g/plant.

3.4.2.9 Yield/plant (g)

Weight of all fruits harvested from selected plants was recorded, average worked out and expressed in grams.

3.4.3 Biochemical characters

3.4.3.1 Lycopene (mg/100g sample)

Lycopene content of fruits was determined by spectrophotometry and expressed as mg 100 g^{-1} of fresh ripe fruit.

3.4.3.2 Ascorbic acid (mg/100g sample)

Ascorbic acid content was estimated by titrimetric method (Sadasivam and Manickam,1996) and expressed as mg 100 g^{-1} of fresh ripe fruit.

3.4.4 Water Use Efficiency

Water use efficiency was found out using the formula

WUE(g L^{-1}) = Yield/Total quantity of water used

Yield was expressed in g $growbag^{-1}$ and quantity of water used was calculated by considering the quantity of water applied and receipt of rainfall.

3.4.5 Pest and disease incidence

Incidence of pest and diseases were noted at regular intervals. Drenching with copper oxychloride @ 0.3 per cent was done twice in all growbags as a prophylatic measure against wilt disease.

3.4.6 Growth media analysis

Samples of potting media were analyzed for pH, EC, organic carbon, total nitrogen, total phosphorus and total potassium using standard procedures.

Table 1: Analytical procedures followed in growth media analysis

Sl. No.	Properties	Method	References
1	Organic carbon	Walkley and Black rapid titration method	Jackson (1973)
2	Nitrogen	Wet digestion by H_2SO_4 and micro	Jackson

		kjeldahl method	(1973)
3	Phosphorus	Digestion with H_2SO_4 and phosphomolybdate yellow colour method	Jackson (1973)
4	Potassium	Digestion with H_2SO_4 and flame photometry	Jackson (1973)
5	pH	pH meter method	Jackson (1973)
6	EC	Conductivity meter method	Jackson (1973)

3.4.7 Plant analysis

Sample plants were collected at harvest, chopped, sun dried and oven dried (70^0C) to a constant weight. Samples were ground to pass through a 5 mm mesh in a Willey Mill and required quantity of samples were digested and used for nutrient analysis.

3.4.7.1 Uptake of nitrogen

Nitrogen content was estimated by the modified microkjeldahl method (Jackson, 1973). The uptake was calculated by multiplying the nitrogen content of the sample with total dry weight of the plants. The uptake values were expressed in g $plant^{-1}$.

3.4.7.2 Uptake of phosphorus

Phosphorus content in the plant sample was determined colorimetrically (Piper,1967) and the uptake was calculated by multiplying the phosphorus content of the sample with total dry weight of the plants. The uptake values were expressed in g per plant.

3.4.7.3 Uptake of potassium

Potassium content in the plant sample was estimated by flame photometer method and expressed in percentage (Piper, 1967). The uptake was calculated by multiplying the potassium content of the sample with total dry weight of the plants. The uptake values were expressed in g $plant^{-1}$.

3.4.8 Economic analysis

Economics of cultivation was worked out for the experiment by taking into account the cost of cultivation and prevailing market price of tomato.

Net income and B:C ratio were calculated as follows:

Net income = Gross income – Total expenditure

Benefit : Cost ratio = Gross income / Total expenditure

3.4.9 Statistical analysis

Data generated from the experiment were subjected to statistical analysis by applying ANOVA technique and significance was tested by 'F' test (Snedecor and Cochran, 1975). CD was calculated in cases where treatments were found to be significant, using standard procedures.

Results

4. RESULT

A pot culture experiment was conducted at College of Agriculture, Vellayani during the period 2014 – 2015 to standardize the growth media and nutrient schedule for tomato production in soilless culture and to work out the economics of different treatments. The experimental data collected were statistically analyzed and the results obtained are presented below.

4.1 PART 1- STANDARDIZATION OF DIFFERENT GROWTH MEDIA FOR SOILLESS CULTURE OF TOMATO

4.1.1 Growth characters

The major growth characters recorded are plant height, number of primary branches and crop duration.

4.1.1.1 Height of plants (cm)

Average height of plants taken at 30 days interval (30, 60 and 90 DAT) is presented in table 2. The results showed that plant height was significantly influenced by the growth media at all growth stages. At all stages M_4 (52.83, 77.66 and 103.46 on 30, 60 and 90 DAT respectively) recorded the maximum height and was on par with M_3 (49.91, 74.66 and 100.73 30, 60 and 90 DAT respectively).

4.1.1.2 Number of primary branches

Data on number of primary branches shown in table 3 revealed that different growth media failed to show any significant effect on number of primary branches.

4.1.1.3 Crop duration (Days)

The data on crop duration is presented in table 3.

The results revealed that different growth media had significant influence on the duration of crop. Shortest duration was recorded by M_4 (107.67), M_3 (109.30), M_7 (109.65) and M_8 (110.34) and they themselves were on par with each other.

4.1.2.1 Days to first flowering, days to fruit set, inflorescence/plant and fruit set (%)

Data on days to first flowering, days to fruit set, inflorescence/plant and fruit set (%) are presented in table 4.

Different growth media significantly influenced the days to first flowering, days to fruit set and fruit set percentage. It couldn't make any effect on the number of inflorescence per plant.

Early flowering was noticed in M_3 (24.00 days) and it was on par with M_6 (25.17 days). M_4 showed early fruit setting (7.17 days) and higher fruit setting percentage (55.67%). M_2 (7.33), M_3 and M_6 (7.43) each also showed earliness in fruit setting and were on par with M_4. Fruit setting percent was also higher in M_1 (54.50%) and M_8 (53.67%).

4.1.2.2 Fruits/plant, fruit length, fruit girth, fruit weight and yield/plant

Results on fruits/plant, fruit length, fruit girth, fruit weight and yield/plant are presented in table 5.

Different growth media significantly influenced the number of fruits per plant, fruit girth, weight and average yield per plant. M_4 showed significantly higher number of fruits (23.41), girth (13.08 cm), weight (35.43 g) and yield per plant (883.46g).

Among the different media tried the lowest yield was recorded by coir pith compost alone (M_5). The same media recorded the lowest number of fruits per plant, fruit length and fruit weight.

Table 2. Effect of different growth media on plant height (cm)

Media	30 DAT	60 DAT	90 DAT
M_1 - (CP + FYM 1:1)	39.94	64.66	95.70
M_2 - (CP+ FYM 1:2)	43.77	68.50	96.70
M_3 - (CPC+ FYM 1:1)	49.91	74.66	100.73
M_4 - (CPC+ FYM 2:1)	52.83	77.66	103.46
M_5 - (CPC alone)	37.50	62.00	94.22
M_6 - (Neopeat + FYM 1:1)	43.16	67.00	98.31
M_7 - (Neopeat + FYM 1:2)	48.83	73.66	97.00
M_8 - (Potting mixture)	42.08	67.08	95.76
SEm(±)	1.598	1.630	1.915
CD(0.05)	3.387	3.450	4.066

Table 3. Effect of different growth media on number of primary branches and crop duration

Media	Number of primary branches	Crop duration (days)
M_1 - (CP + FYM 1:1)	4.20	114.70
M_2 - (CP+ FYM 1:2)	4.85	112.00
M_3 - (CPC+ FYM 1:1)	5.00	109.30
M_4 - (CPC+ FYM 2:1)	5.50	107.67
M_5 - (CPC alone)	4.91	111.57
M_6 - (Neopeat + FYM 1:1)	5.25	113.00
M_7 - (Neopeat + FYM 1:2)	5.36	109.65
M_8 - (Potting mixture)	4.39	110.34
SEm(±)	0.886	1.323
CD(0.05)	NS	2.804

CP-Coir Pith
CPC-Coir Pith Compost

Table 4. Effect of different growth media on days to first flowering, days to fruit set, inflorescence per plant and fruit set

Media	Days to first flowering	Days to fruit set	Inflorescence per plant	Fruit set (%)
M_1 - (CP + FYM 1:1)	26.08	8.33	5.83	54.50
M_2 - (CP+ FYM 1:2)	27.16	7.33	5.13	51.17
M_3 - (CPC+ FYM 1:1)	24.00	7.43	4.60	50.39
M_4 - (CPC+ FYM 2:1)	26.42	7.17	6.29	55.67
M_5 - (CPC alone)	26.50	8.76	4.77	49.03
M_6 - (Neopeat + FYM 1:1)	25.17	7.43	4.97	52.33
M_7 - (Neopeat + FYM 1:2)	29.47	7.93	4.90	51.83
M_8 - (Potting mixture)	27.92	7.85	5.92	53.67
SEm(±)	0.684	0.274	0.556	1.405
CD(0.05)	1.456	0.594	NS	2.972

Table 5. Effect of different growth media on setting of fruits, fruits per plant, length, girth, weight of fruit and yield per plant

Media	Fruits per plant	Fruit length (g)	Fruit girth (cm)	Fruit weight (g)	Yield/ Plant (g)
M_1 - (CP + FYM 1:1)	19.90	5.91	11.33	31.33	623.47
M_2 - (CP+ FYM 1:2)	20.30	5.96	12.30	32.65	661.59
M_3 - (CPC+ FYM 1:1)	20.10	6.14	12.75	33.04	631.02
M_4 - (CPC+ FYM 2:1)	23.41	6.21	13.08	35.43	883.46
M_5 - (CPC alone)	19.03	5.83	10.00	30.62	583.89
M_6 - (Neopeat + FYM 1:1)	20.50	6.07	11.25	30.66	628.43
M_7 - (Neopeat + FYM 1:2)	19.62	6.17	12.26	31.25	612.70
M_8 - (Potting mixture)	22.78	6.03	13.00	35.10	795.60
SEm(±)	0.320	0.109	0.362	1.282	2.137
CD(0.05)	0.688	NS	0.769	2.710	4.530

CP-Coir Pith
CPC-Coir Pith Compost

4.2 PART -2 NUTRIENT SCHEDULING OF TOMATO FOR SOILLESS CULTURE

4.2.1 Growth characters

4.2.1.1 Height of plants (cm)

Data on height of plants (30, 60 and 90 DAT) is presented in table 6.

Both nutrient sources and levels did not exert any significant influence on plant height.

4.2.1.2 Number of primary branches

Number of primary branches recorded are shown in table 7.

Branching was significantly influenced by nutrient sources. Maximum branching was recorded by S_1 (5.58) and S_2 (5.37). They themselves were on par and were significantly higher than S_3 and S_4. Nutrient levels failed to impart any significant influence on branching. Interaction between nutrient sources and levels were non-significant in this regard.

4.2.1.3 Crop duration (Days)

The data on crop duration is presented in table 7.

Crop duration was influenced by nutrient sources, nutrient levels and their interaction. N_2 (110.56 days) recorded significantly less duration compared to N_1 and N_3. Significantly shortest duration was recorded by S_4 (109.92) and S_3 (110.75). Crop duration was significantly less in n_2s_4 (109.50), n_2s_2 (109.75), n_1s_4 (110), n_3s_4 (110.25), n_2s_3 (110.50) and n_1s_3 (110.75) when compared to other treatments.

4.2.2 Yield and yield attributes

4.2.2.1 Days to first flowering, days to fruit set, inflorescence/plant and fruit set (%)

Data on days to first flowering, days to fruit set, inflorescence/plant and fruit set (%) are presented in table 8.

Nutrient sources, nutrient levels and interaction significantly influenced days to first flowering, days to fruit set, inflorescence/plant and fruit set.

Among the nutrient levels N_3 (25.50 days) showed early flowering which is on par with N_1 (25.62 days). Early flowering was noticed in S_2 and S_4 (25.50 days) and was significantly higher than other treatments. The treatments n_1s_4 and n_3s_2 (23.50 days) showed lower days to flowering and was significantly different from other treatments.

Nutrient levels influenced earliness in fruit setting. N_1 (7.42 days) and N_3 (7.50 days) set fruits early and were on par to each other. S_4 (7.34 days) and S_2 (7.45 days) showed early fruit set and they themselves were on par to each other. The interaction effect couldn't show any effect on days to fruit setting.

Regarding the nutrient levels, N_3 (4.94) recorded maximum number of inflorescence per plant and was significantly higher than other nutrient levels. S_1 (5.17) and S_2 (4.75) recorded significantly higher number of inflorescence per plant than other treatments and they themselves were on par. Higher number of inflorescence per plant was observed in n_3s_2 (6.25) and n_3s_1 (5.75) and these were on par to each other.

Significantly higher fruit set was observed in N_1 (57.78 %) and N_3 (56.97 %) and were on par. Fruit set percentage was higher in S_1 (57.46 %) and was on par with S_2 (55.50 %). Regarding interaction effect n_1s_1 (65.37 %) recorded significantly higher fruit set percentage.

4.2.2.2 Fruits/plant, fruit length, fruit girth, fruit weight and yield per plant

Results on fruits/plant, fruit length, fruit girth, fruit weight and yield/plant are presented in table 10.

Among the nutrient levels N_3 recorded maximum number of fruits per plant (21.56), fruit length (6.43 cm), fruit girth (12.71 cm) and yield per plant (687.31g).

Table 6. Effect of nutrient sources and levels on plant height (cm)

Treatments	30 DAT	60 DAT	90 DAT
Nutrient levels			
N_1–POP	48.74	78.22	103.53
N_2 - 75 % of POP	46.64	75.71	101.01
N_3 - 125 % of POP	49.67	76.80	101.80
SEm(±)	1.395	1.636	1.580
CD (0.05)	NS	NS	NS
Nutrient sources			
S_1	47.35	76.41	101.83
S_2	49.33	76.16	101.57
S_3	48.69	78.52	103.53
S_4	48.03	76.55	101.56
SEm(±)	1.611	1.889	1.825
CD (0.05)	NS	NS	NS
Interaction			
n_1s_1	45.01	79.90	104.90
n_1s_2	48.95	77.21	103.45
n_1s_3	48.60	79.07	104.07
n_1s_4	52.40	76.72	101.72
n_2s_1	46.47	73.12	99.37
n_2s_2	46.20	76.16	101.15
n_2s_3	48.65	77.50	102.50
n_2s_4	45.25	76.05	101.05
n_3s_1	50.57	76.20	101.20
n_3s_2	52.85	75.11	100.11
n_3s_3	48.82	79.00	104.00
n_3s_4	46.45	76.90	101.90
SEm(±)	2.791	3.272	3.161
CD (0.05)	NS	NS	NS

POP - Package of practices recommendations

S_1 - Fermented groundnut cake

S_2 - Incubated groundnut cake + PGPR mix

S_3 - As chemical fertilizers in solid form

S_4 - As chemical fertilizers in liquid form

Table 7. Effect of nutrient sources and levels on number of primary branches and crop duration

Treatments	Number of primary branches	Crop duration (days)
Nutrient levels		
N_1–POP	5.25	112.43
N_2 - 75 % of POP	5.05	110.56
N_3 - 125 % of POP	5.31	113.00
SEm(±)	0.109	0.420
CD (0.05)	NS	0.736
Nutrient sources		
S_1	5.58	113.91
S_2	5.37	113.42
S_3	4.87	110.75
S_4	5.01	109.92
SEm(±)	0.126	0.420
CD (0.05)	0.255	0.849
Interaction		
n_1s_1	5.60	113.25
n_1s_2	5.40	115.75
n_1s_3	5.12	110.75
n_1s_4	4.90	110.00
n_2s_1	5.37	112.50
n_2s_2	5.22	109.75
n_2s_3	4.75	110.50
n_2s_4	4.87	109.50
n_3s_1	5.77	116.00
n_3s_2	5.50	114.75
n_3s_3	4.75	111.00
n_3s_4	5.25	110.25
SEm(±)	0.219	0.728
CD (0.05)	NS	1.471

POP- Package of practices recommendations
S_1- Fermented groundnut cake S_2- Incubated groundnut cake + PGPR mix
S_3- As chemical fertilizers in solid form S_4- As chemical fertilizers in liquid form

Table 8. Effect of nutrient sources and levels on days to first flowering, days to fruit set, inflorescence/plant and fruit set (%)

Treatments	Days to first flowering	Days to fruit set	Inflorescence per plant	Fruit set (%)
Nutrient levels				
N_1–POP	25.62	7.42	4.13	57.78
N_2 - 75 % of POP	28.31	8.35	4.13	51.31
N_3 - 125 % of POP	25.50	7.50	4.94	56.97
SEm(±)	0.204	0.129	0.197	0.808
CD (0.05)	0.412	0.262	0.398	1.633
Nutrient sources				
S_1	28.00	8.27	5.17	57.46
S_2	25.50	7.45	4.75	55.59
S_3	26.91	7.96	3.67	53.33
S_4	25.50	7.34	4.00	55.04
SEm(±)	0.235	0.149	0.227	0.933
CD (0.05)	0.412	0.262	0.398	1.633
Interaction				
n_1s_1	27.50	8.00	4.75	65.37
n_1s_2	25.50	7.25	4.50	56.25
n_1s_3	26.00	7.45	3.75	54.25
n_1s_4	23.50	7.00	3.50	55.25
n_2s_1	30.00	8.92	5.00	46.00
n_2s_2	27.50	8.12	3.50	54.00
n_2s_3	28.25	8.60	3.50	52.25
n_2s_4	27.50	7.77	4.50	53.00
n_3s_1	26.50	7.90	5.75	61.00
n_3s_2	23.50	7.00	6.25	56.54
n_3s_3	26.50	7.85	3.75	53.50
n_3s_4	25.50	7.25	4.00	56.87
SEm(±)	0.408	0.259	0.394	1.616
CD (0.05)	0.825	NS	0.796	3.267

POP - Package of practices recommendations

S_1 - Fermented groundnut cake

S_2 - Incubated groundnut cake + PGPR mix

S_3 - As chemical fertilizers in solid form

S_4 - As chemical fertilizers in liquid form

S_1 (20.60) and S_2 (20.38) recorded significantly higher number of fruits per plant than other treatments. S_2 recorded maximum fruit length (6.32 cm), fruit girth (13.35 cm), fruit weight (35.12 g) and yield per plant (723.21g) than other treatments. S_2 was followed by S_4 in fruit length (6.16 cm) and fruit girth (12.61 cm) while it was on par with S_2 in fruit weight (34.16 g). S_1 (667.32 g) followed S_2 with regard to yield per plant.

n_3s_1 (25.85), n_3s_2 (24.20) and n_1s_1 (23.70) recorded significantly higher number of fruits per plant and were on par to each other. Maximum fruit length was obtained by n_3s_1 (6.62 cm) and was on par with n_3s_2 (6.52 cm). n_3s_2 recorded maximum fruit girth (13.65 cm), fruit weight (37.30 g) and yield per plant (901.85 g). n_2s_2 (13.37 cm), n_3s_4 (13.15 cm) and n_1s_2 (13.02 cm) were on par with n_3s_2 with regard to fruit girth. n_1s_2 (36.40 g) and n_2s_4 (35.50 g) recorded fruit weight which were on par with n_3s_2.

4.2.3 Biochemical characters

Lycopene and Ascorbic acid (mg/100 g sample)

Data on biochemical characters like lycopene and ascorbic acid are presented in table 11.

Both the nutrient levels and sources couldn’t exert any significant effect on lycopene and ascorbic acid content.

4.2.4 Water use efficiency (g/L)

Data on water use efficiency is presented in table 11.

Among the different nutrient levels tried, N_3 (6.70) recorded the maximum WUE and was significantly superior to other nutrient levels.

Water use efficiency was influenced by nutrient sources, nutrient levels and their interaction. Significantly higher WUE was recorded by S_2(7.00) and S_1 (6.70) when compared to other nutrient sources and these were on par to each other.

With respect to the interaction effect of different nutrient sources and levels, n_3s_2 (8.70) obtained the highest WUE and was significantly higher than other treatments.

4.2.5 Pest and disease incidence

Observations on incidence of disease are presented in table 12.

There was no severe pest incidence. The incidence of wilt was not significantly influenced by different sources and levels of nutrients.

4.2.6 Growth media analysis

The media was analyzed for organic carbon, nitrogen, phosphorus, potassium, pH and EC before and after the experiment.

Table 9. Chemical properties of growth media before the experiment

Sl No.	**Properties**	**Growth media (M_4)**
1	Organic carbon (%)	8.17
2	Nitrogen (%)	1.37
3	Phosphorus (%)	0.43
4	Potassium (%)	0.11
5	pH	6.66
6	EC (dS/m)	0.93

4.2.6.1 Organic carbon, Nitrogen, Phosphorus and Potassium (%)

The data recorded on organic carbon, N, P and K are presented in table 13.

N_1 recorded significantly higher organic carbon (11.12), nitrogen (2.02), phosphorus (0.79) and potassium content (0.16). It was on par with N_3 with regard to organic carbon (11.10) and potassium content (0.16). Nutrient level N_2 (0.15) was on par with other nutrient levels with respect to potassium content.

Table 10. Effect of nutrient sources and levels on number, length, girth and weight of fruit and yield/plant

Treatments	Fruits/plant	Fruit length (cm)	Fruit girth (cm)	Fruit weight(g)	Yield/plant (g)
Nutrient levels					
N_1 - POP	19.71	5.93	11.78	31.42	632.26
N_2 - 75 % of POP	17.57	5.73	11.65	30.68	527.97
N_3 - 125 % of POP	21.56	6.43	12.71	31.89	687.31
SEm(±)	0.57	0.07	0.17	0.71	26.96
CD (0.05)	1.162	0.142	0.359	NS	54.494
Nutrient sources					
S_1	20.60	6.08	11.91	29.63	667.32
S_2	20.38	6.32	13.35	35.12	723.21
S_3	16.27	5.56	10.32	27.75	453.26
S_4	18.2	6.16	12.61	34.16	619.60
SEm(±)	0.66	0.08	0.20	0.82	31.13
CD (0.05)	1.342	0.164	0.415	1.663	62.925
Interaction					
n_1s_1	23.70	6.00	12.12	29.29	674.38
n_1s_2	20.12	6.25	13.02	36.40	735.80
n_1s_3	17.65	5.37	9.27	29.62	523.25
n_1s_4	17.37	6.10	12.20	34.37	595.62
n_2s_1	21.27	5.62	11.37	28.74	571.06
n_2s_2	16.82	6.20	13.37	31.65	531.97
n_2s_3	15.18	5.07	9.87	26.83	407.85
n_2s_4	17.00	6.02	12.50	35.50	601.00
n_3s_1	25.85	6.62	12.25	30.84	756.51
n_3s_2	24.20	6.52	13.65	37.30	901.85
n_3s_3	16.00	6.25	11.82	26.79	428.69
n_3s_4	20.22	6.33	13.15	32.62	662.18
SEm(±)	1.15	0.14	0.35	1.42	53.62
CD (0.05)	2.324	0.284	0.719	2.881	108.990

POP - Package of practices recommendations

S_1 - Fermented groundnut cake
S_2 - Incubated groundnut cake + PGPR mix
S_3 - As chemical fertilizers in solid form
S_4 - As chemical fertilizers in liquid form

Table 11. Effect of nutrient sources and levels on lycopene, ascorbic acid content and water use efficiency

Treatments	Lycopene (mg 100 g^{-1} sample)	Ascorbic acid (mg 100 g^{-1} sample)	WUE (g L^{-1})
Nutrient levels			
N_1 - POP	5.30	31.24	6.20
N_2 - 75 % of POP	5.32	29.96	5.30
N_3 - 125 % of POP	5.33	30.03	6.70
SEm(±)	0.077	1.101	1.500
CD (0.05)	NS	NS	3.100
Nutrient sources			
S_1	5.37	29.29	6.70
S_2	5.25	30.28	7.00
S_3	5.30	29.49	4.50
S_4	5.33	32.57	6.20
SEm(±)	0.089	1.271	1.800
CD (0.05)	NS	NS	3.600
Interaction			
n_1s_1	5.47	30.12	6.50
n_1s_2	5.20	29.48	6.90
n_1s_3	5.25	30.76	5.20
n_1s_4	5.26	34.61	6.00
n_2s_1	5.27	28.60	5.60
n_2s_2	5.23	31.52	5.40
n_2s_3	5.35	28.76	4.10
n_2s_4	5.42	30.95	6.00
n_3s_1	5.37	29.14	7.30
n_3s_2	5.33	29.85	8.70
n_3s_3	5.29	28.95	4.20
n_3s_4	5.34	32.16	6.60
SEm(±)	0.153	2.200	3.100
CD (0.05)	NS	NS	6.200

POP - Package of practices recommendations
S_1 - Fermented groundnut cake
S_2 - Incubated groundnut cake + PGPR mix
S_3 - As chemical fertilizers in solid form
S_4 - As chemical fertilizers in liquid form

Table 12. Effect of nutrient sources and levels on disease incidence

Treatments	Incidence of wilt
Nutrient levels	
N_1 – POP	8.42
N_2 - 75 % of POP	8.41
N_3 - 125 % of POP	10.12
SEm(±)	0.044
CD (0.05)	NS
Nutrient sources	
S_1	9.03
S_2	8.97
S_3	8.92
S_4	9.01
SEm(±)	0.051
CD (0.05)	NS
Interaction	
n_1s_1	9.08
n_1s_2	9.00
n_1s_3	8.87
n_1s_4	8.96
n_2s_1	9.01
n_2s_2	8.83
n_2s_3	9.00
n_2s_4	9.08
n_3s_1	8.98
n_3s_2	9.07
n_3s_3	8.90
n_3s_4	9.00
SEm(±)	0.087
CD (0.05)	NS

POP - Package of practices recommendations
S_1 - Fermented groundnut cake
S_2 - Incubated groundnut cake + PGPR mix
S_3 - As chemical fertilizers in solid form
S_4 - As chemical fertilizers in liquid form

S_1 (11.95) recorded significantly higher organic carbon content than other sources. Nitrogen (2.08) and phosphorus (0.77) content were maximum in S_2. S_1(0.75) was on par with S_2 with regard to phosphorus content, whereas nutrient sources failed to impart any significant influence in the potassium content of the media.

The interaction of nutrient sources and nutrient levels could significantly influence the chemical properties of the media. n_3s_2 recorded significantly higher organic carbon (11.78), N (2.25) and P (0.90) content than other treatments. Higher nitrogen content was observed in n_2s_4 (2.25), n_1s_2(2.14), n_3s_3 (2.05), n_1s_1 (2.05), and n_1s_4 (2.04) and they themselves were on par. n_3s_2 was on par with n_1s_2 (0.86) with respect to P content. Regarding the potassium content n_1s_4 (0.19), n_3s_1 (0.18), n_2s_4 (0.17), n_3s_3 (0.17) and n_3s_4 (0.17) obtained the highest percentage and were on par to each other.

4.2.6.1 pH and EC

The data on pH and EC are presented in table 13.

Nutrient sources, nutrient levels and their interaction significantly influenced the pH and EC. The nutrient level N_3 recorded significantly higher pH (6.60) and EC (1.15 dSm^{-1}). The lowest value of EC was recorded by N_1 (0.97dSm^{-1}).

Among the different nutrient sources S_2 (6.67) showed significantly higher pH than other treatments whereas S_3 (1.19dSm^{-1}) recorded maximum EC and was significantly superior to other treatments. Lowest EC was recorded by S_1 (0.91 dSm^{-1}).

The interaction effect was also significant. High pH (6.84) and EC (1.31 dSm^{-1}) were obtained in treatment combination n_3s_2 and was on par with n_1s_2 (6.79) regarding pH and n_3s_3 (1.29 dSm^{-1}) and n_3s_4 (1.22 dSm^{-1}) regarding EC.

Table 13. Chemical properties of growth media after the experiment

Treatments	Organic carbon (%)	N (%)	P (%)	K (%)	pH	EC (dSm^{-1})
Nutrient levels						
N_1 – POP	11.12	2.02	0.79	0.16	6.38	0.97
N_2 - 75 % of POP	8.73	1.86	0.58	0.15	6.44	1.10
N_3 - 125 % of POP	11.10	1.82	0.74	0.16	6.60	1.15
SEm(±)	0.10	0.01	0.01	0.01	0.02	0.02
CD (0.05)	0.214	0.015	0.027	0.014	0.041	0.048
Nutrient sources						
S_1	11.95	1.07	0.75	0.16	6.56	0.91
S_2	11.33	2.08	0.77	0.14	6.67	1.12
S_3	9.73	1.86	0.58	0.15	6.16	1.19
S_4	9.59	1.95	0.73	0.18	6.53	1.09
SEm(±)	0.12	0.01	0.02	0.01	0.02	0.03
CD (0.05)	0.274	0.017	0.031	NS	0.047	0.056
Interaction						
n_1s_1	11.08	2.05	0.83	0.16	6.30	0.83
n_1s_2	10.31	2.14	0.86	0.12	6.79	0.91
n_1s_3	9.07	1.85	0.82	0.16	6.07	1.15
n_1s_4	9.99	2.04	0.66	0.19	6.36	1.00
n_2s_1	10.62	1.66	0.58	0.15	6.70	1.07
n_2s_2	9.08	1.86	0.54	0.16	6.37	1.12
n_2s_3	7.52	1.68	0.43	0.13	6.19	1.13
n_2s_4	7.68	2.25	0.77	0.17	6.52	1.07
n_3s_1	11.14	1.40	0.82	0.18	6.67	0.80
n_3s_2	11.78	2.25	0.90	0.13	6.84	1.31
n_3s_3	10.39	2.05	0.48	0.17	6.20	1.29
n_3s_4	9.09	1.58	0.74	0.17	6.70	1.22
SEm(±)	0.21	0.02	0.03	0.02	0.04	0.05
CD (0.05)	0.428	0.302	0.053	0.027	0.081	0.097

POP - Package of practices recommendations
S_1 - Fermented groundnut cake
S_2 - Incubated groundnut cake + PGPR mix
S_3 - As chemical fertilizers in solid form
S_4 - As chemical fertilizers in liquid form

4.2.7 Plant analysis

Uptake of nitrogen, phosphorus and potassium (g/plant)

Data on plant uptake is presented in table 14.

Uptake of nutrients was significantly influenced by nutrient sources, levels and their interaction. Among the nutrient levels tried, N_3 recorded the maximum nitrogen (1.72), phosphorus (0.35) and potassium (1.52) uptake and it was on par with other nutrient levels regarding phosphorus and potassium uptake.

S_2 recorded the highest nitrogen (1.75) and potassium (1.63) uptake while S_1 (0.46) recorded the highest phosphorus uptake. S_2 was on par with S_1 (1.62) with respect to potassium uptake.

Regarding the interaction effect, n_3s_1 recorded the highest nitrogen uptake (1.99) and it was on par with n_3s_2 (1.88). Maximum phosphorus (0.52) uptake was recorded by n_2s_1 and was on par with n_3s_1 (0.49). Significantly higher and similar potassium uptake was noticed in n_3s_2 (2.04) and n_2s_1 (1.96).

4.2.8 Economic analysis

Net income and benefit cost ratio

Data on net income and BCR are presented in table 15.

Net income and benefit cost ratio were significantly influenced by the sources and levels of nutrients. Among the different nutrient levels tried, N_3 recorded the highest net income (Rs.4.79 grow bag^{-1}) and benefit cost ratio (1.69). It was significantly different from other nutrient levels.

Incubated groundnut cake and PGPR mix I (S_2) recorded the highest net income (Rs.5.50 grow bag^{-1}) and benefit cost ratio (1.61). S_1 was on par with S_2 with regard to benefit cost ratio (1.55).

The interaction effect was also significant. n_2s_3 recorded the highest net income (Rs.9.02grow bag^{-1}) and benefit cost ratio (2.02) and was significantly superior to other treatments.

Table 14. Effect of nutrient sources and levels on plant nutrient uptake (g/plant)

Treatments	Nitrogen	Phosphorus	Potassium
Nutrient levels			
N_1 - POP	1.53	0.33	1.48
N_2 - 75 % of POP	1.41	0.35	1.51
N_3 - 125 % of POP	1.72	0.35	1.52
SEm(±)	0.03	0.01	0.02
CD (0.05)	0.053	0.020	0.048
Nutrient sources			
S_1	1.59	0.46	1.62
S_2	1.75	0.38	1.63
S_3	1.56	0.28	1.36
S_4	1.30	0.27	1.54
SEm(±)	0.03	0.01	0.02
CD (0.05)	0.062	0.020	0.048
Interaction			
n_1s_1	1.62	0.36	1.52
n_1s_2	1.53	0.20	1.36
n_1s_3	1.53	0.47	1.38
n_1s_4	1.45	0.29	1.65
n_2s_1	1.17	0.52	1.96
n_2s_2	1.86	0.31	1.18
n_2s_3	1.56	0.33	1.45
n_2s_4	1.06	0.26	1.85
n_3s_1	1.99	0.49	1.38
n_3s_2	1.88	0.32	2.04
n_3s_3	1.57	0.34	1.25
n_3s_4	1.41	0.27	1.41
SEm(±)	0.05	0.01	0.04
CD (0.05)	0.110	0.029	0.084

POP - Package of practices recommendations

S_1 - Fermented groundnut cake

S_2 - Incubated groundnut cake + PGPR mix

S_3 - As chemical fertilizers in solid form

S_4 - As chemical fertilizers in liquid form

Table 15 Effect of nutrient sources and levels on net income and BCR

Treatments	Net income	BCR
Nutrient levels		
N_1 - POP	3.77	1.36
N_2 - 75 % of POP	1.89	1.17
N_3 - 125 % of POP	4.79	1.69
SEm(±)	0.06	0.04
CD (0.05)	0.113	0.089
Nutrient sources		
S_1	4.72	1.55
S_2	5.50	1.61
S_3	0.66	1.12
S_4	3.04	1.34
SEm(±)	0.06	0.05
CD (0.05)	0.130	0.102
Interaction		
n_1s_1	4.87	1.57
n_1s_2	5.74	1.63
n_1s_3	1.95	1.26
n_1s_4	2.52	1.29
n_2s_1	2.87	1.33
n_2s_2	1.73	1.19
n_2s_3	0.02	1.10
n_2s_4	2.93	1.33
n_3s_1	6.44	1.76
n_3s_2	9.02	2.02
n_3s_3	0.02	1.01
n_3s_4	3.67	1.40
SEm(±)	0.11	0.09
CD (0.05)	0.225	0.177

POP - Package of practices recommendations
S_1 - Fermented groundnut cake
S_2 - Incubated groundnut cake + PGPR mix
S_3 - As chemical fertilizers in solid form
S_4 - As chemical fertilizers in liquid form

Discussion

5. DISCUSSION

An experiment entitled 'Performance evaluation of tomato in soilless culture' was undertaken to standardize the media and nutrient schedule for tomato production in soilless culture and to work out the economics of different treatments. The results obtained are discussed below.

5.1 Part 1 - Standardization of different growth media for soilless culture of tomato

5.1.1 Effect of different growth media on growth characters of tomato

Results of the study indicated a significant effect of growth media on plant height and crop duration. Among the different media coir pith compost along with FYM in both ratio (M_3 and M_4) recorded the highest plant height at all growth stages and shortest crop duration. The result is in line with that of Cuckoorani (2013) who observed maximum growth characters like height, number of leaves, LAI and shortest crop duration for bhindi grown in coir pith compost + FYM (2:1 by weight).

Coir pith alone registered significantly lower growth characters that might be due to the wide C:N ratio and high content of polyphenols and phenolic acids which are inhibitive to plant growth. Combining neopeat along with FYM registered significantly higher growth characters compared to coir pith alone. Addition of FYM must have reduced C:N ratio and made more favourable to crop attributes.

5.1.2 Effect of different growth media on yield and yield attributes of tomato

Eight growth media were tested for their efficiency in promoting growth and yield of tomato in soilless culture. Perusal of the yield data showed that M_4 (coir pith compost + FYM 2:1) registered significantly higher productivity (883.46g plant^{-1}) which might be due to the favourable influence on yield attributes like higher fruit set percentage, fruits/plant, fruit girth and fruit weight. The data on the influence of different growth media on yield and yield attributes also revealed the superiority of the growth media coir pith compost along with

FYM in 2:1 ratio on yield and yield characters viz., days to fruit set, fruit set percentage, fruits/plant (Fig. 4a), fruit girth (Fig. 4b), fruit weight (Fig. 5) and yield/plant (Fig. 6). Though with respect to growth attributes M_4 (coir pith compost + FYM 2:1) and M_3 (coir pith compost + FYM 1:1) were on par, M_3 was found to be inferior to M_4 with respect to yield due to less number of fruits in plants grown in M_3 media. This might be due to better water holding capacity associated with higher nutrient content of coir pith compost which provided a supplemental effect when mixed with FYM. This is in confirmity with the findings of Cuckoorani (2013) who reported higher yield and yield attributes in bhindi with coir pith compost + FYM (2:1) as growth media.

The lower yield of tomato (Fig 6) in coir pith may be due to non-availability of essential nutrients, such as nitrogen and phosphorous and high C:N ratio. This is in line with the report of Kunchikannan *et al*. (2007), who reported that in coir pith essential nutrients are mostly organically bound and high C:N ratio might be the reason for reduced yield in coir pith media. Arenas *et al*. (2002) also reported that the reduction in yield with coir pith was due to nitrogen immobilization and wide C:N ratio.

Composts being a “warm” growing medium, would have promoted quicker root growth, subsequent canopy development and overall crop performance. Better aeration, nutrient availability and vigorous root growth allows better growth and yield attributes which might have resulted in higher yield in M_4 (coir pith compost +FYM (2:1)) media.

Instead of coir pith compost, using coir pith or neopeat along with FYM also resulted in reasonably good yield ranging from 610-660g per plant which is on an average 25 % lesser than the yield obtained from coir pith compost+FYM combination. The result of the study showed that for soilless cultivation of tomato, the growth media M_4 *i.e.,* combination of coir pith compost and FYM in 2:1 ratio by weight is the ideal growth medium for achieving higher productivity in tomato.

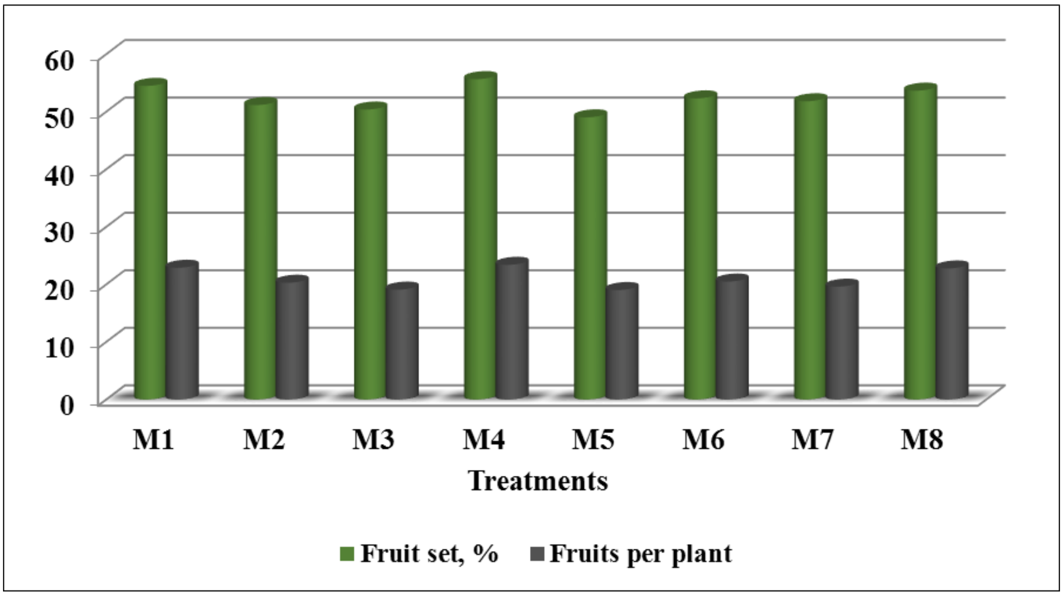

Fig 4. Effect of different growth media on days to fruit set and fruits per plant

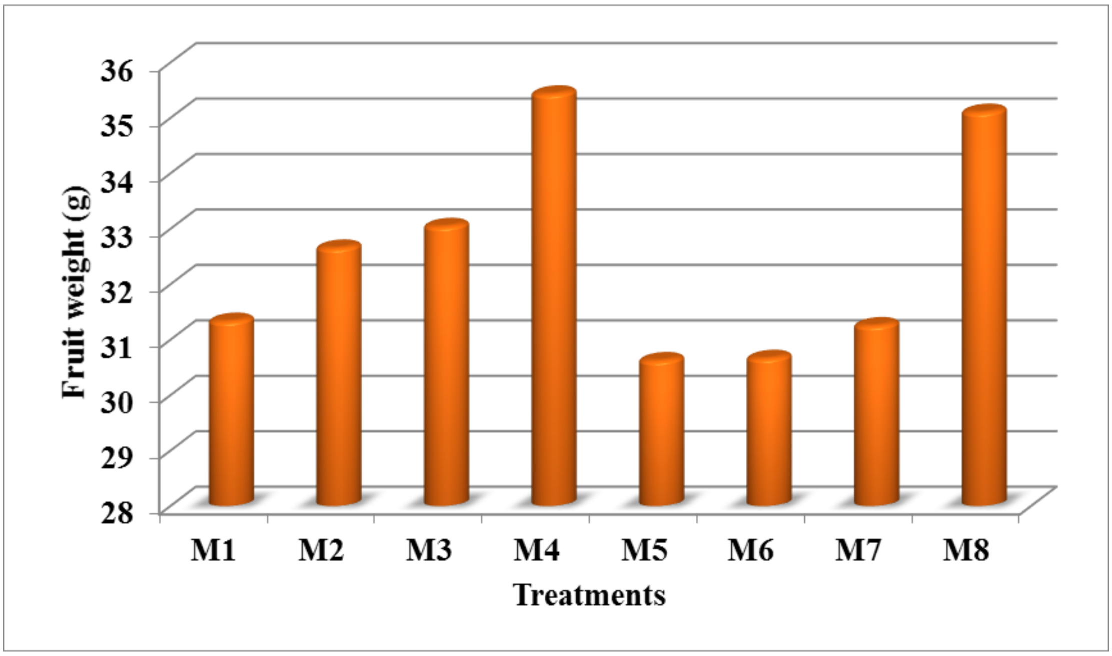

Fig 5. Effect of different growth media on fruit weight

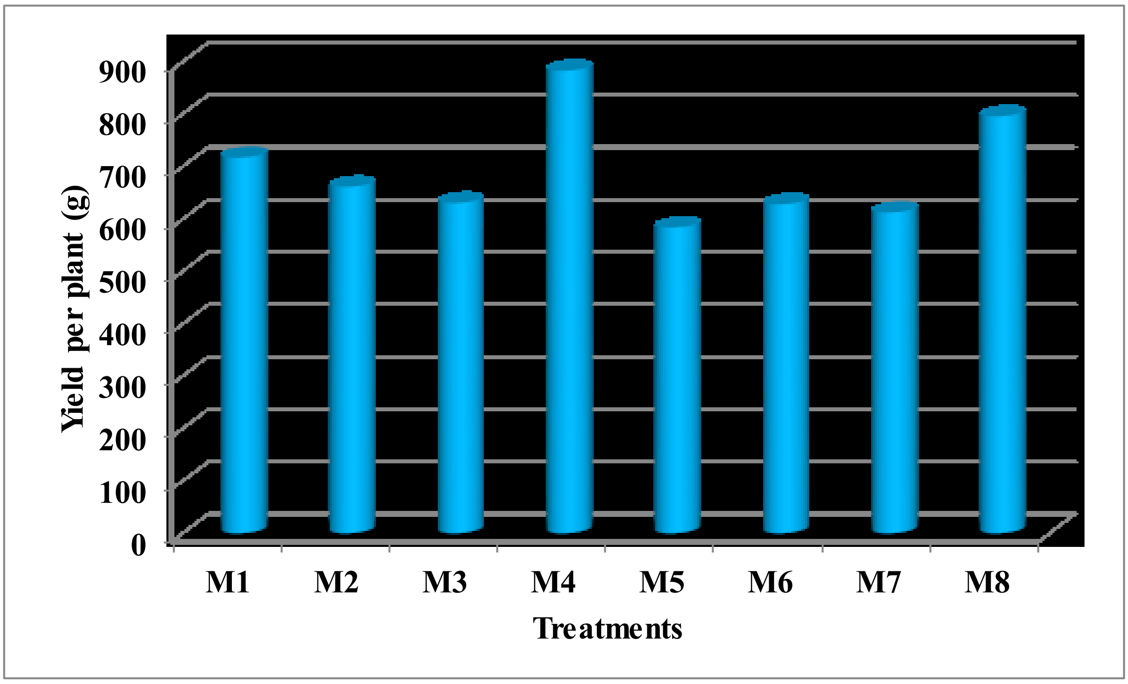

Fig 6. Effect of different growth media on yield per plant (g)

part II- Nutrient scheduling of tomato for soilless culture

5.1 Effect of nutrient levels and sources on growth characters of tomato

Effect of nutrient sources and levels on growth characters like plant height, number of primary branches and crop duration were analyzed in the study. Nutrient sources and nutrient levels significantly influenced the duration and branching in tomato but not the plant height.

Among the nutrient sources, fermented groundnut cake recorded maximum number of primary branches and crop duration and it was on par with plants that received incubated ground nut cake + PGPR mix I (n_3s_2). Chinnaswammy (1967) observed better growth in tomato plants with the application of FYM and groundnut cake. Sharu (2000) reported significant influence on the growth characters like plant height, number of primary branches and dry matter accumulation in chilli as a result of oil cake application. Amongst the rhizosphere microorganisms, plant growth promoting rhizobacteria (PGPR) has been considered important in sustainable agriculture due to their plant growth promotional ability (Mallesh, 2008). PGPR may be directly affecting root respiration which in turn leads to increase in root growth. This increase in root respiration caused a compensatory increase in carbon assimilation in the shoot, leading to an 8% increase in plant growth (Kevin, 2003). Aridoss *et al.* (2004) also reported the superiority of oilcakes in increasing the growth of plants due to the higher percentage of NPK. PGPR @ 2% seed inoculation significantly enhanced seed germination and seedling vigour of maize (Gholami *et al*., 2009).

Results revealed that increase in nutrient levels increased the crop duration. Among the nutrient levels, N_3 (125% of recommended dose of nutrients) recorded longest crop duration which is in contradictory with the findings of Cuckoorani (2013) who observed the shortest crop duration in bhindi when the highest nutrient level was tried.

Among the different nutrient sources tried , organic sources was found best for increasing the crop duration compared to inorganic sources. Application of fertilizers reduced crop duration significantly compared to organic sources. This increase in the duration may be due to slow and steady release of nutrients from organic source.

5.2 Effect of nutrient levels and sources on yield and yield attributes of tomato

Effect of nutrient sources and levels on yield and yield attributes like days to first flowering, days to fruit set, inflorescence/plant, fruit set, fruits/plant, fruit length, fruit girth and fruit weight were analyzed in the study.

Among the different nutrient sources, incubated groundnut cake + PGPR mix 1(n_3s_2) registered the highest yield. This recorded 56% higher yield than the next best treatment *i.e.,* fermented groundnut cake (S_1). Fermented groundnut cake recorded the highest number of inflorescence per plant and fruit setting percentage but it was on par with incubated groundnut cake + PGPR mix 1. This superiority of these two organic nutrient sources may be due to favourable effect on growth characters like branching. Better branching must have resulted in production of more number of leaves and better utilization of solar radiation. This tapping coupled with high nutrient content and better availability have resulted in more number of fruits per plant, fruit girth and length and resulted in higher yield in S_1 and S_2.

Superiority of oil cake has been reported by several researchers. Islam and Haque (1992) considered oil cake as good manure to be applied during land preparation of brinjal, chilli and bhindi for better yield. Yield improvement by the application of groundnut cake might be due to the higher NPK percentage in the oil cakes. Thakur *et al.* (1998) opined that nitrogen influences the growth and yield of crops. Arunkumar (2000) also reported the superiority of oilcakes in increasing the yield in amaranthus compared to fertilizers. Plant growth promotion by some PGPR has been associated with the solubilization and increased uptake of phosphate (Gyaneshwar *et al*., 2002).

Compared to organic sources, fertilizers recorded less productivity in soilless culture. This better performance of organic sources may be due to the continuous availability of nutrients in a slow and steady manner. Nutrients from fertilizers must have released immediately and due to the porous nature of growth media chances for leaching loss of nutrients is more. Similar response was seen with respect to effect on other yield parameters.

The highest nutrient level (N_3) showed earliness in flowering and fruit set, maximum number of inflorescence per plant and fruit setting percentage. This better responses on yield contributing characters resulted in a productivity of 687.31g per plant which was significantly higher the than other two nutrient levels tested.

Critical examination of the results of the study indicated that fruit girth (Fig.7), fruit weight (Fig 8) and per plant yield (Fig. 9) were the highest in treatment that received the highest level of nutrient (125%) as incubated groundnut cake + PGPR mix I (n_3s_2). Fruits per plant and fruit length were maximum for the plants that received fermented groundnut cake (125 % of POP). This was on par with incubated groundnut cake + PGPR mix I (125 % of POP).

Results revealed that incubated groundnut cake + PGPR mix I at 125 % of recommended dose (94:50:31 kg NPK ha^{-1}) was superior to other treatments. Better nutrient availability and uptake during the vegetative phase might have increased the production, translocation and assimilation of photosynthates to growing points and stimulated the plants to produce more number of fruits and better fruit characters (Cuckoorani, 2013).

It is clear that the number of inflorescence per plant and fruit setting percentage were higher in incubated groundnut cake + PGPR mix I (125 % of POP). The higher availability and uptake of nutrients might have enabled the plant to produce more number of flower buds which in turn increased the number of fruits and yield per plant. Increased fruit yield may be due to better vegetative growth, better availability of nutrients, greater synthesis of carbohydrates and their proper translocation (Dar *et al.,* 2009). Naval *et al*. (2012) observed that

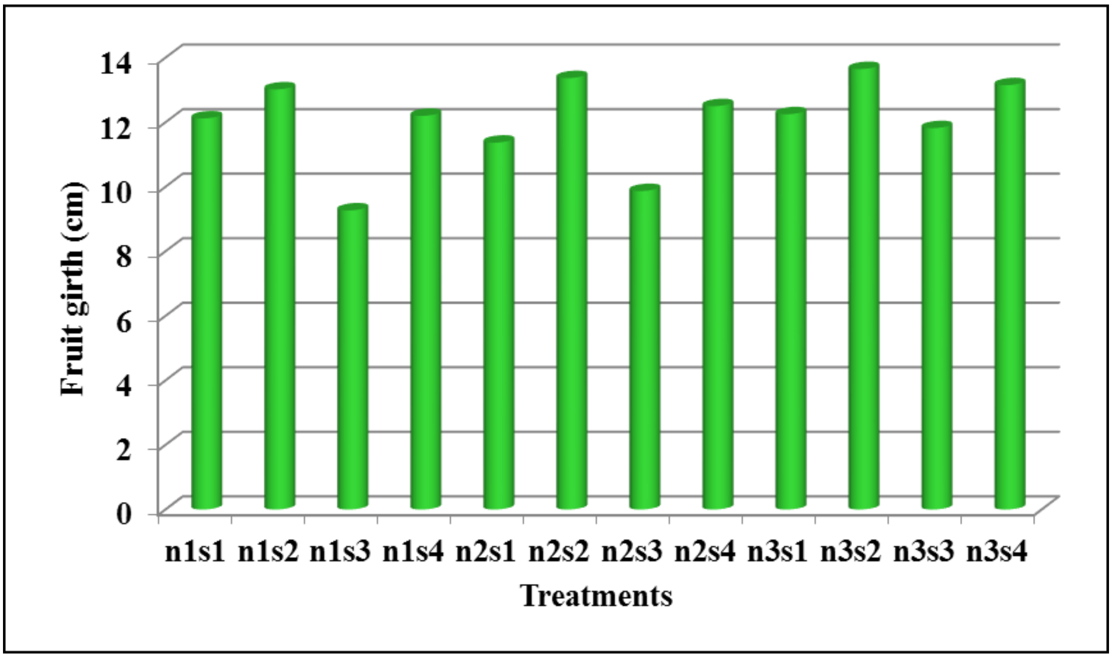

Fig 7. Effect of nutrient sources and levels on fruit girth

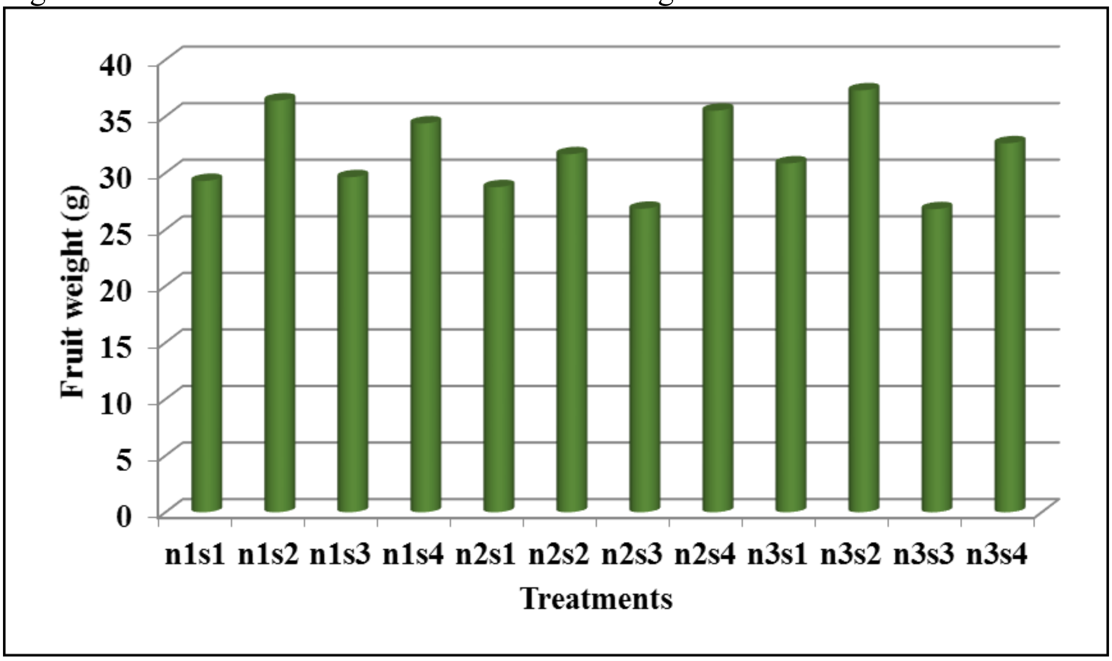

Fig 8. Effect of nutrient sources and levels on fruit weight

successive doses of fertilizer levels increased considerably the number of cluster per plant, number of fruits per cluster, size of fruit, weight of fruit and yield per plant in tomato. Cuckoorani (2013) also observed increased fruit yield in bhindi at higher levels of nutrient application.

The reason attributed for higher yield with PGPR might be due to the stimulated plant growth by the production of growth promoting substance like auxin, increased the availability of nutrients by N fixation and solubilisation of phosphorus and potassium in the media (Glick, 1995).

Supplementation of essential plant nutrients in relatively higher amount resulted in better growth and development of crop (Meena *et al*., 2007). Shukla *et al*. (2009) reported that with the increment in supply of essential nutrients, their availability, acquisition, mobilization and influx into the plant tissues increased and thus improved growth and yield components in tomato.

Beneficial effect of groundnut cake might be due to supplementation of essential nutrients in relatively higher amount which resulted in better growth and development of the crop. This is in conformity with the report of Edward and Daniel (1992). Cakmakci *et al*. (2001) reported that PGPR can stimulate growth and increase yield in sugar beet.

Facilitating plant nutrition could be the mechanism by which PGPR enhance crop yield and fruit size, since the nutritional plants status is enhanced by increasing the availability of nutrients in the rhizosphere (Bar-Ness *et al*., 1992; Richardson, 2001).

5.3 Effect of nutrient levels and sources on water use efficiency and chemical properties of media

An appraisal of the data presented in Table 11, it was seen that nutrient levels and sources had significant influence on WUE. Among the nutrient sources organic sources recorded higher WUE. Incubated groundnut cake + PGPR mix I (n_3s_2) recorded the highest WUE (7.00 g L^{-1}) closely followed by fermented groundnut cake (6.70 g L^{-1}). Organic sources, on an average recorded 21% higher

WUE. Water use efficiency being a function of total quantity of water used and productivity, organic manures applied plots recorded higher WUE due to the higher productivity. It was observed that organic nutrient sources registered 23% higher productivity than chemical fertilizers. Among the nutrient levels, 125% recommended dose of nutrients resulted in higher yield and thereby higher WUE. It was 4.5% higher than the immediately lower dose (100 % of recommended dose *i.e.* 75:40:25 kg NPK ha^{-1}). The results of the study revealed that significantly higher value of WUE by the treatment which received the highest nutrient level (N_3) as incubated groundnut cake + PGPR mix I (Fig. 10). This might be due to cumulative effect of the individual best treatments. Higher availability of nutrients in the N_3 treated media would have helped in the development of healthy root system, growth and yield attributes which in turn reflected in higher yield and WUE. The higher value of nutrients in the treatment N_3 might be due to the higher level of nutrients given to the crop. It can also be due to higher degree of decomposition of coir pith compost in the media.

The growth media was analyzed for organic carbon, N, P, K, pH and EC. N_1 and N_3 recorded significantly similar organic carbon and potassium content. This better status of organic carbon and potassium may be due to better availability of C and K. N and P status were not in line with that of K. K being a constituent which exists in free state in plants, the status increased with increased level of application. The availability of N and P is determined by rate of mineralization which again depends on a variety of factors like soil properties, microbial activities etc. So in this study, compared to 125% recommended dose of nutrients, 100% resulted in higher N status after experiment. So this reduction in N status even by application of higher level of N, may be due to better uptake of N at the highest level. In the case of P, lower two levels recorded higher P status compared to the highest level. This may be due to the complexity in mineralization process and due to the better uptake. Compared to the initial organic carbon content and primary nutrient status, an increase was observed resulting in a sustainable nature for the treatments.

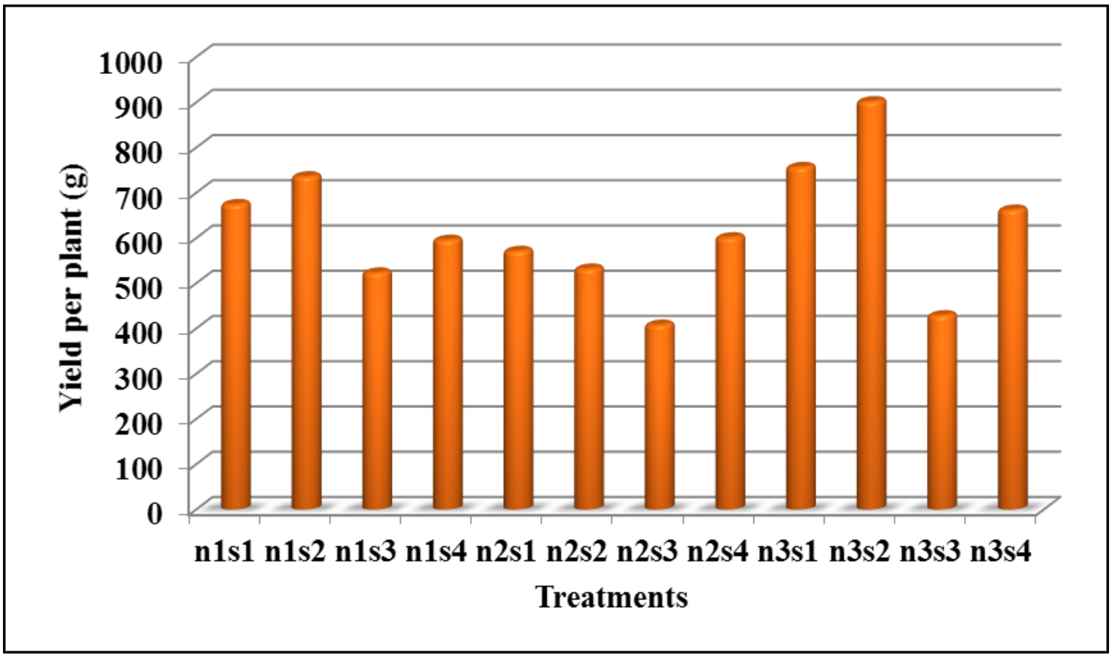

Fig 9. Effect of nutrient sources and levels on yield per plant

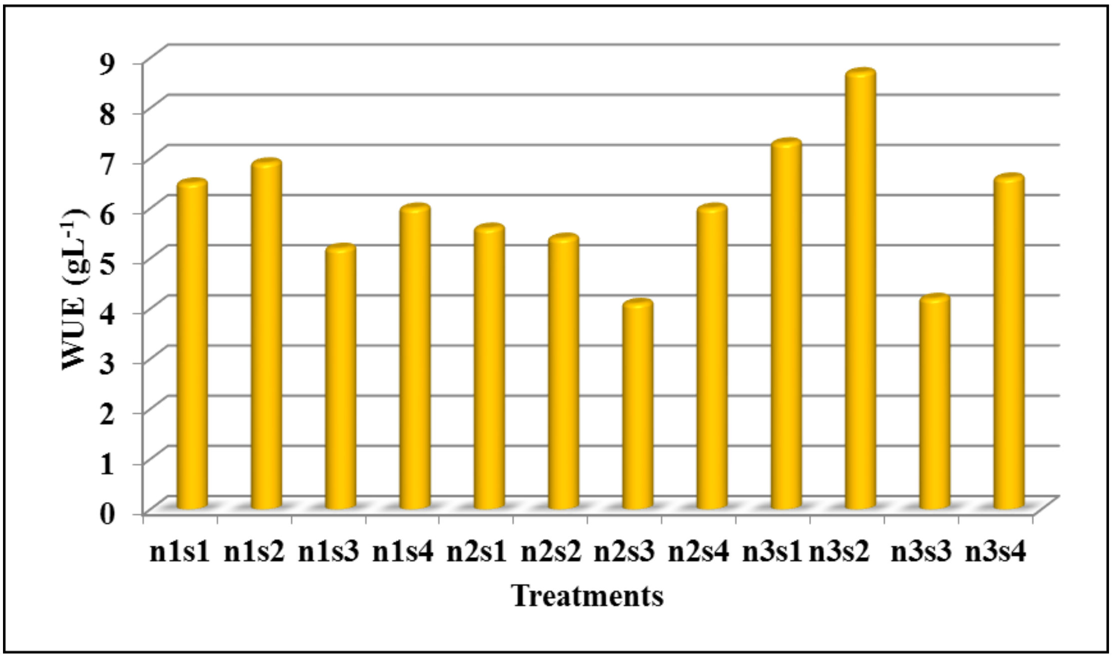

Fig 10. Effect of nutrient sources and levels on water use efficiency

Among the nutrient sources, application of fertilizers registered a slightly lower pH compared to the initial status whereas organic nutrient sources resulted in more or less static pH. This may be due to better buffering action. The EC value before and after the experiment was in safe level. Fertilizers recorded a higher EC compared to organic sources that may be due to their chemical nature.

The solubilization of P in the rhizosphere is the most common mode of action implicated in PGPR that increase nutrient availability to host plants (Richardson, 2001). The suitability of groundnut cake for preparing quality organic manure was earlier reported by Vipitha (2011). The beneficial microbes in PGPR might have favoured *in vitro* N fixation leading to enhanced N content (Vipitha, 2011 and Asha, 2012). The beneficial microorganisms present in the microbial consortium might have enhanced the mineralization process and resulted in further improvement in nutrient content by the addition of PGPR. Similar results were reported by Asha (2012).

5.4 Effect of nutrient levels and sources on nutrient uptake

Observations on the nutrient uptake revealed that the maximum NPK uptake was recorded by the highest nutrient level N_3 (125%). The higher value of nutrient uptake in N_3 might be due to the higher level of nutrients given to the crop. Cuckoorani (2013) reported similar results. Higher uptake of nitrogen due to higher rate of nutrient application is a proven fact. A stimulated growth under higher levels of nutrient application might have resulted in better proliferation of root system and increased intake efficiency of plants (Cuckoorani, 2013).

Higher uptake at maximum fertility levels might be due to more nutrient content and yields which removed more nutrients from the media. Similar increase in nutrient uptake was also observed by Edward and Daniel (1992) and Singh and Singh (2006). Better vegetative growth under higher levels of nutrients might have resulted in increased uptake efficiency of plants. Meena *et al*. (2007) observed that total nutrient uptake increased significantly in organic treatments compared to control. Better nutrient content resulted in better nutrient uptake. In amarathus, application of organic manures favoured crop growth conditions by producing more number of leaves and maximum dry weight. Total yield and N uptake were higher in treatment with coir pith compost, groundnut cake and rock dust (Vipitha, 2011).

Among the nutrient sources organic sources registered higher NPK uptake compared to inorganic sources. Incubated groundnut cake + PGPR mix I (n_3s_2) recorded the highest N and K uptake whereas fermented groundnut recorded the highest P uptake. The application of FYM increases the availability of phosphorus from the native and applied sources (Krishnaswamy *et al.*, 1984). Singaravel *et al.* (1998) also noticed that higher levels of nitrogen can increase the uptake of P and K. The positive effect of coir pith compost and FYM in moisture retention in the media would have accelerated K^+ diffusion to roots. IAA-producing PGPR are believed to increase root growth and root length, resulting in greater root surface area which enables the plant to access more nutrients. Plant growth promotion by some PGPR has been associated with the solubilization and increased uptake of phosphate (Gyaneshwar, 2002). PGPR have also been reported to affect nitrate uptake by plants (Mantelin and Touraine, 2004; Adesemoye *et al*., 2008).

The PGPR promote the growth of the plant and increase the root surface area or the general root architecture (Biswas *et al.,* 2000; Lucy *et al.*, 2004). Plants growing better in turn release higher amounts of C in root exudates. The release of more C prompts increase in microbial activity, and this process continues in a cycle. The whole process makes more N available from the soil pool, influencing N flux into plant roots, and the plant is able to take up more available N (Adesemoye, 2009). Raj *et al.,* (2011) reported that PGPR was effective in reducing the use of chemical fertilizers, improving the availability and uptake of nutrients and maintaining sustainability.

5.5 Effect of nutrient levels and sources on economic analysis

A perusal of data presented in table 15 on economic analysis revealed that there is a marked increase in the net income and BCR with the progressive

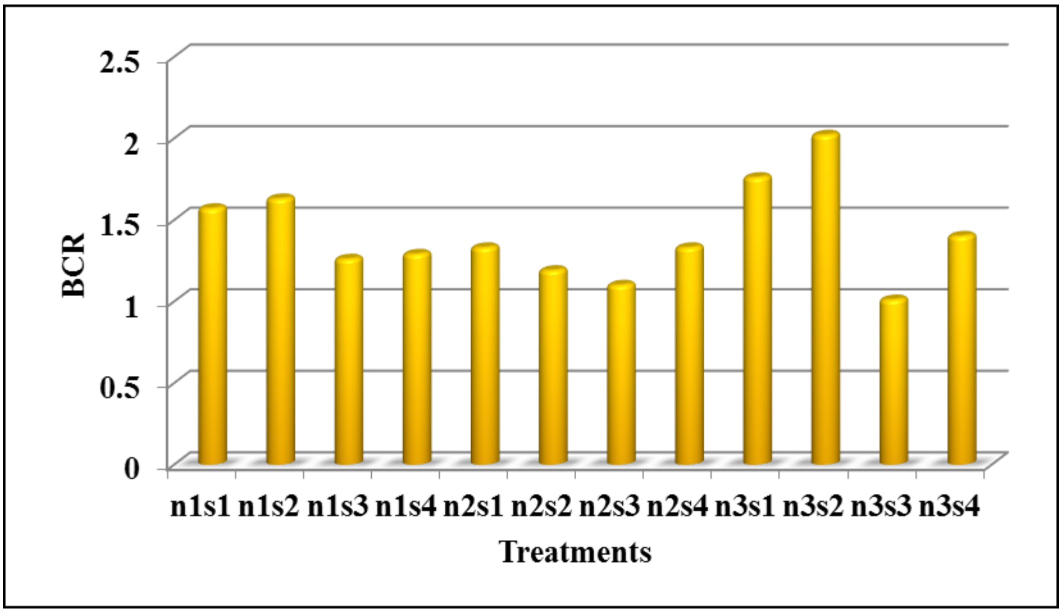

Fig 11. Effect of nutrient sources and levels on BCR

increase in levels of the nutrients. Among the nutrient levels tried, the highest level (N_3) recorded the highest cost of cultivation of about Rs. 8.95 grow bag^{-1}. The same nutrient level registered the highest gross returns of Rs. 13.75 grow bag^{-1}. Among the nutrient sources, organic sources performed better than chemical fertilizers. Organic sources were found economically superior to chemical fertilizers. Between the two organic sources, incubated ground nut cake + PGPR mix I(S_2) recorded the highest net income (Rs. 5.50 grow bag^{-1}) and this was due to the highest gross return resulted from higher productivity and low cost of cultivation. Interaction effect of different sources and levels of nutrients revealed that incubated ground nut cake + PGPR mix I applied at 125% of POP (n_3s_2) recorded the highest net income (Rs. 9.02 grow bag^{-1}) and BCR (2.02)(Fig. 11) indicating the economic feasibility organic nutrition in soilless culture. Edward and Daniel (1992) and Cuckoorani (2013) also noticed an increase in net income and BCR with increase in nutrient levels. These results have got practical significance in urban agriculture.

Summary

6. SUMMARY

A study entitled 'Performance evaluation of tomato in soilless culture' was carried out at College of Agriculture, Vellayani during August 2014- December 2014 with the objectives of standardizing the growth media, scheduling of nutrients and to work out economics of different treatments. Bacterial wilt resistant variety Manulakshmi was used for the study and the experiment comprised of two pot culture experiments laid out in CRD.

PART 1- Standardization of different growth media for soilless culture of tomato

First experiment was to standardize the growth media for soilless culture. The experiment consisted of eight growth media namely, Coir pith + FYM (1:1), Coir pith + FYM (1:2), Coir pith compost + FYM (1:1), Coir pith compost + FYM (2:1), Coir pith compost alone, Neopeat + FYM (1:1), Neopeat + FYM (1:2) and Potting mixture (1:1:1 soil, sand and FYM), replicated thrice.

At all stages of growth, plants grown in coir pith compost + FYM (2:1) media registered maximum height. The same media recorded the shortest crop duration. Number of primary branches and number of inflorescences per plant didn't show any variation due to different treatments.

Plants grown in coir pith compost + FYM (1:1) media flowered early while early fruit setting and higher fruit setting percentage were recorded by coir pith compost + FYM (2:1).

Fruit characters like girth and weight varied significantly with various growth media. Coir pith compost + FYM (2:1) recorded maximum girth and weight. The same media recorded the highest number of fruits per plant and yield per plant. Hence this media was selected for Part II study.

PART -2. Nutrient scheduling of tomato for soilless culture

Second experiment was to standardize nutrient schedule for soilless culture of tomato. The experiment with twelve treatments replicated four times consisted of four nutrient sources - fermented groundnut cake (S_1), incubated groundnut cake + PGPR mix 1 (S_2), as chemical fertilizers in solid form (S_3) and as chemical fertilizers in liquid form (S_4) and three nutrient levels - Package of practices recommendations (POP) (N_1), 75 % of POP (N_2) and 125 % of POP (N_3).

Both nutrient sources and levels did not exert any significant influence on plant height. Maximum branching was recorded by fermented groundnut cake. Shortest crop duration was recorded by plants that were given 75 % of POP recommendations of nutrients as chemical fertilizers in solid form.

Treatments which received nutrients in liquid form (100%of POP) showed earliness in flowering. Higher number of inflorescence per plant was observed in treatments where 125 % of POP recommendations of nutrients were given as incubated ground nut cake +PGPR mix I. Higher fruit set percentage was observed where 100% of POP recommendations of nutrients are supplied as liquid fertilizer while fermented groundnut cake (125% of POP) recorded significantly higher number of fruits per plant.

Fruit length was maximum in plants that were given fermented groundnut cake (125% of POP). Incubated ground nut cake +PGPR mix I (125% of POP) recorded maximum fruit girth, fruit weight and yield per plant.

Levels of nutrients and sources didn’t exert any significant influence on biochemical characters like lycopene and ascorbic acid content and pest and disease incidence. Incubated ground nut cake +PGPR mix I (125% of POP) showed maximum WUE.

Organic carbon, N, P and pH were higher in incubated ground nut cake + PGPR mix I (125% of POP) while K content was maximum in treatments which received nutrients in liquid form (100% of POP) and lowest EC was recorded by fermented groundnut cake (125% of POP). N and K uptake by plants were significantly improved by incubated groundnut cake +PGPR mix I (125% of POP) but P uptake was maximum in plants that received fermented groundnut cake (75% of POP).

Incubated ground nut cake +PGPR mix I (125% of POP) recorded the highest net income and benefit cost ratio and was significantly superior to other treatments.

The results of the study indicated that incubated groundnut cake + PGPR mix 1 at 125 % of POP was the best nutrient source which recorded maximum fruit girth (13.65cm), fruit weight (37.30g) and yield per plant (901.85g). The highest BCR was recorded by incubated groundnut cake + PGPR mix 1 at 125 % of POP and resulted in a net income of Rs. 9.02 per grow bag.

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PERFORMANCE EVALUATION OF TOMATO IN SOILLESS CULTURE

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(2013-11-126)

Abstract of the Thesis
submitted in partial fulfillment of the
requirement for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture
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2015

ABSTRACT

A study entitled 'Performance evaluation of tomato in soilless culture' was carried out at College of Agriculture, Vellayani during August 2014- December 2014 with the objectives of standardizing the growth media, scheduling of nutrients and to work out economics of different treatments. Manulakshmi was the variety used in the study and the experiment comprised of two pot culture experiments, laid out in CRD.

First experiment was to standardize the growth media for soilless culture. The experiment consisted of eight treatments, namely, Coir pith + FYM (1:1), Coir pith + FYM (1:2), Coir pith compost + FYM (1:1), Coir pith compost + FYM (2:1), Coir pith compost alone, Neopeat + FYM (1:1), Neopeat + FYM (1:2) and Potting mixture (1:1:1 soil, sand and FYM), replicated thrice. The results showed that Coir pith compost + FYM (2:1) was the best media which recorded maximum fruits per plant (23.41), fruit weight (35.43g) and yield per plant (883.46g) and hence was selected for the Part II study.

Second experiment was to standardize nutrient schedule for soilless culture of tomato. The experiment with twelve treatments replicated four times consisted of four nutrient sources - fermented groundnut cake (S_1), incubated groundnut cake + PGPR mix 1(S_2), as chemical fertilizers in solid form(S_3) and as chemical fertilizers in liquid form(S_4) and three nutrient levels - Package of practices recommendations (POP)(N_1-75:40:25 kg NPK ha^{-1}), 75 % of POP(N_2-56:30:19 kg NPK ha^{-1}) and 125 % of POP(N_3-94:50:31 kg NPK ha^{-1}).

The results of the study indicated that incubated groundnut cake + PGPR mix 1(S_2) was the best nutrient source which recorded early flowering (25.50 days), maximum fruit length (6.32cm), fruit girth (13.35cm), fruit weight (35.12g), yield per plant (723.21g), water use efficiency (7.00 gL^{-1}), highest net income (4.79 Rs bag^{-1}) and BCR (1.69) .

Among the different nutrient levels tried, 125 % of POP (N_3) recorded early flowering (25.50 days), early fruit set (7.50 days) maximum number of inflorescence per plant (4.94), fruits per plant (21.56), fruit length (6.43cm), fruit girth (12.71cm), yield per plant (687.31g), water use efficiency (6.70gL^{-1}), highest net income (5.50 Rs bag^{-1}) and BCR (1.61).

The results revealed that combined effect (n_3s_2) of incubated groundnut cake + PGPR mix 1(S_2) at 125 % of POP (N_3) gave a fruit set percentage of 57.46 % with 20.60 fruits per plant. n_3s_2 recorded early flowering (25.50 days), maximum number of inflorescence per plant (6.25), fruit girth (13.65cm), fruit weight (37.30g), yield per plant (901.85g), water use efficiency (8.70 gL^{-1}), highest net income (9.02 Rs bag^{-1}) and BCR (2.02).

Both the nutrient levels and nutrient sources failed to show any significant effect on biochemical properties like lycopene and ascorbic acid content and pest and disease incidence.

Coir pith compost +FYM (2:1) was found to be the best soilless media for tomato cultivation in grow bags. Incubated groundnut cake at 125 % of Package of Practices nutrient recommendations (94:50:31 kg NPK ha^{-1}) + PGPR mix 1(2%) was found to be the most economic nutrient schedule for soilless tomato cultivation in grow bags.

Appendix

Appendix I

Weather data for the cropping period

(6th August to 31st December)- Weekly averages

Standard week	Temperature (^oC)		Relative humidity (%)	Rain fall (mm)
	Maximum	Minimum		
32	29.4	23.5	88.6	22.2
33	29.7	24.0	89.7	2.0
34	29.8	24.0	94.0	73.0
35	29.9	23.9	87.6	34.4
36	29.2	23.9	96.1	16.0
37	30.1	24.5	89.3	1.5
38	30.5	24.6	85.0	0
39	31.1	24.1	93.3	18.6
40	30.7	23.9	95.4	3.0
41	30.7	24.2	73.6	6.9
42	30.3	23.7	82.4	23.3
43	30.2	23.5	80.9	7.1
44	30.5	23.5	86.1	4.8
45	30.7	23.1	93.1	1.0
46	31.2	23.7	90.4	4.4
47	29.4	23.4	95.9	9.4
48	29.1	23.1	96.3	8.6
49	30.6	22.6	90.1	5.1
50	29.9	23.3	89.6	24.3
51	30.6	23.4	93.6	4.9
52	29.9	23.8	90.9	6.0

Appendix II

Varietal characters of tomato var. Manulakshmi

First bacterial wilt resistant tomato variety with high fruit size.

Plant height	80.00 cm
Plant characters	Semi determinate, with attractive oval shaped fruits light green when immature turning to uniform dark red on ripening.
Days to flowering	55 days
Days to first harvest	96 days
Potential yield	35 t ha^{-1}
Average fruit weight	55 g
Fruit length	3.88 cm
Fruit girth	4.69 cm
Average TSS	3.95^{0} brix